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IN THE UNITED STATES COURT OF APPEALS FOR  
THE DISTRICT OF COLUMBIA CIRCUIT

RECEIVED

CENTER FOR BIOLOGICAL )  
DIVERSITY, CLEAN AIR COUNCIL, and )  
NATIONAL PARKS CONSERVATION )  
ASSOCIATION, )

*Petitioners,* )

v. )

LISA P. JACKSON, Administrator, )  
United States Environmental )  
Protection Agency, and )  
UNITED STATES ENVIRONMENTAL )  
PROTECTION AGENCY, )

*Respondents.* )

No. 12-1238

**PETITION FOR REVIEW**

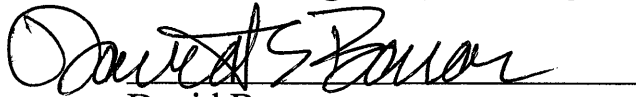
Pursuant to Clean Air Act § 307(b)(1), 42 U.S.C. § 7607(b)(1), Rule 15 of the Federal Rules of Appellate Procedure, and Circuit Rule 15, Center for Biological Diversity, Clean Air Council, and National Parks Conservation Association hereby petition this Court for review of the final action taken by Respondents at 77 Fed. Reg. 20,218 (April 3, 2012) and titled "Secondary National Ambient Air Quality Standards for Oxides of Nitrogen and Sulfur."

DATED: June 1, 2012

Respectfully submitted,



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UNITED STATES ENVIRONMENTAL )  
PROTECTION AGENCY, )

*Respondents.*

**RULE 26.1 DISCLOSURE STATEMENT**

**Center for Biological Diversity:** Center for Biological Diversity has no parent companies, and there are no publicly held companies that have a 10 percent or greater ownership interest in Center for Biological Diversity.

Center for Biological Diversity, a corporation organized and existing under the laws of the State of New Mexico, is a not-for-profit organization focused on the preservation, protection, and restoration of biodiversity, native species, ecosystems, public lands and waters, and public health.

**Clean Air Council:** Clean Air Council has no parent companies, and there are no publicly held companies that have a 10 percent or greater ownership interest in Clean Air Council.

Clean Air Council, a corporation organized and existing under the laws of the Commonwealth of Pennsylvania, is a not-for-profit organization focused on the protection of public health and the environment.

**National Parks Conservation Association:** National Parks Conservation Association has no parent companies, and there are no publicly held companies that have a 10 percent or greater ownership interest in the National Parks Conservation Association.

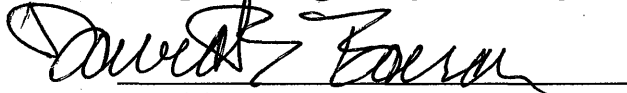
National Parks Conservation Association, a corporation organized and existing under the laws of the District of Columbia, is a national nonprofit organization dedicated to protecting and enhancing America's National Parks for present and future generations.

DATED: June 1, 2012

Respectfully submitted,



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## CERTIFICATE OF SERVICE

I hereby certify that I have served the foregoing **Petition for Review and Rule 26.1 Disclosure Statement**, on respondents by sending a copy via First Class Mail to each of the following addresses on the   /   day of June, 2012.

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\_\_\_\_\_  
David T. Woodsmall

**ENVIRONMENTAL PROTECTION AGENCY**

**40 CFR Part 50**

[EPA-HQ-OAR-2007-1145; FRL-9654-4]

RIN 2060-A072

**Secondary National Ambient Air Quality Standards for Oxides of Nitrogen and Sulfur**

**AGENCY:** Environmental Protection Agency (EPA).

**ACTION:** Final rule.

**SUMMARY:** This final rule is being issued as required by a consent decree governing the schedule for completion of this review of the air quality criteria and the secondary national ambient air quality standards (NAAQS) for oxides of nitrogen and oxides of sulfur. Based on its review, the EPA is retaining the current nitrogen dioxide (NO<sub>2</sub>) and sulfur dioxide (SO<sub>2</sub>) secondary standards to address the direct effects on vegetation of exposure to gaseous oxides of nitrogen and sulfur and, for reasons described in detail in this final preamble, is not adding new standards at this time to address effects associated with the deposition of oxides of nitrogen and sulfur on sensitive aquatic and terrestrial ecosystems. In addition, in this rule the EPA describes a field pilot program being developed to enhance our understanding of the degree of protectiveness that would likely be afforded by a multi-pollutant standard to address deposition-related acidification of sensitive aquatic ecosystems.

**DATES:** This final rule is effective on June 4, 2012.

**ADDRESSES:** The EPA has established a docket for this action under Docket ID No. EPA-HQ-OAR-2007-1145. All documents in the docket are listed in the [www.regulations.gov](http://www.regulations.gov) index. Although listed in the index, some information is not publicly available, e.g., confidential business information (CBI) or other information whose disclosure is restricted by statute. Certain other material, such as copyrighted material, will be publicly available only in hard copy. Publicly available docket materials are available either electronically in [www.regulations.gov](http://www.regulations.gov) or in hard copy at the Air and Radiation Docket and Information Center, EPA/DC, EPA West, Room 3334, 1301 Constitution Ave. NW., Washington, DC. The Public Reading Room is open from 8:30 a.m. to 4:30 p.m., Monday through Friday, excluding legal holidays. The telephone number for the Public Reading Room is

(202) 566-1744 and the telephone number for the Air and Radiation Docket and Information Center is (202) 566-1742.

**FOR FURTHER INFORMATION CONTACT:** Mrs. Ginger Tennant, Office of Air Quality Planning and Standards (OAQPS), U.S. Environmental Protection Agency, Mail Code C504-06, Research Triangle Park, NC 27711; telephone: 919-541-4072; fax: 919-541-0237; email: [tennant.ginger@epa.gov](mailto:tennant.ginger@epa.gov).

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## I. Background

### A. Legislative Requirements

Two sections of the Clean Air Act (CAA) govern the establishment and revision of the NAAQS. Section 108 (42 U.S.C. Section 7408) directs the Administrator to identify and list certain air pollutants and then to issue air quality criteria for those pollutants. The Administrator is to list those air pollutants that in her “judgment, cause or contribute to air pollution which may reasonably be anticipated to endanger public health or welfare;” “the presence of which in the ambient air results from numerous or diverse mobile or stationary sources;” and “for which \* \* \* [the Administrator] plans to issue air quality criteria \* \* \*” Air quality criteria are intended to “accurately reflect the latest scientific knowledge useful in indicating the kind and extent of all identifiable effects on public health or welfare which may be expected from the presence of [a] pollutant in the ambient air \* \* \*” 42 U.S.C. Section 7408(b). Section 109 (42 U.S.C. 7409) directs the Administrator to propose and promulgate “primary” and “secondary” NAAQS for pollutants for which air quality criteria are issued. Section 109(b)(1) defines a primary standard as one “the attainment and maintenance of which in the judgment of the Administrator, based on such criteria and allowing an adequate margin of safety, are requisite to protect the public health.”<sup>1</sup> A secondary standard, as defined in Section 109(b)(2), must “specify a level of air quality the attainment and maintenance of which, in the judgment of the Administrator, based on such criteria, is requisite to protect the public welfare from any known or anticipated adverse effects associated with the presence of [the] pollutant in the ambient air.” Welfare effects as defined in Section 302(h) (42 U.S.C. Section 7602(h)) include, but are not limited to, “effects on soils, water, crops, vegetation, man-made materials, animals, wildlife, weather, visibility and climate, damage to and deterioration of property, and hazards to transportation, as well as effects on economic values and on personal comfort and well-being.”

In setting standards that are “requisite” to protect public health and

<sup>1</sup> The legislative history of Section 109 of the CAA indicates that a primary standard is to be set at “the maximum permissible ambient air level \* \* \* which will protect the health of any [sensitive] group of the population,” and that for this purpose “reference should be made to a representative sample of persons comprising the sensitive group rather than to a single person in such a group” S. Rep. No. 91–1196, 91st Cong., 2d Sess. 10 (1970).

welfare, as provided in Section 109(b), the EPA’s task is to establish standards that are neither more nor less stringent than necessary for these purposes. In so doing, the EPA may not consider the costs of implementing the standards. See generally, *Whitman v. American Trucking Associations*, 531 U.S. 457, 465–472, 475–76 (2001). Likewise, “[a]ttainability and technological feasibility are not relevant considerations in the promulgation of national ambient air quality standards” (*American Petroleum Institute v. Costle*, 665 F. 2d at 1185). Section 109(d)(1) requires that “not later than December 31, 1980, and at 5-year intervals thereafter, the Administrator shall complete a thorough review of the criteria published under Section 108 and the national ambient air quality standards \* \* \* and shall make such revisions in such criteria and standards and promulgate such new standards as may be appropriate \* \* \*” Section 109(d)(2) requires that an independent scientific review committee “shall complete a review of the criteria \* \* \* and the national primary and secondary ambient air quality standards \* \* \* and shall recommend to the Administrator any new \* \* \* standards and revisions of existing criteria and standards as may be appropriate \* \* \*” Since the early 1980’s, this independent review function has been performed by the Clean Air Scientific Advisory Committee (CASAC).

### B. History of Reviews of NAAQS for Nitrogen Oxides and Sulfur Oxides

#### 1. NAAQS for Oxides of Nitrogen

After reviewing the relevant science on the public health and welfare effects associated with oxides of nitrogen, the EPA promulgated identical primary and secondary NAAQS for NO<sub>2</sub> in April 1971. These standards were set at a level of 0.053 parts per million (ppm) as an annual average (36 FR 8186). In 1982, the EPA published Air Quality Criteria Document for Oxides of Nitrogen (U.S. EPA, 1982), which updated the scientific criteria upon which the initial standards were based. In February 1984, the EPA proposed to retain the standards set in 1971 (49 FR 6866). After taking into account public comments, the EPA published the final decision to retain these standards in June 1985 (50 FR 25532).

The EPA began the most recent previous review of the oxides of nitrogen secondary standards in 1987. In November 1991, the EPA released an updated draft air quality criteria document (AQCD) for CASAC and public review and comment (56 FR

59285), which provided a comprehensive assessment of the available scientific and technical information on health and welfare effects associated with NO<sub>2</sub> and other oxides of nitrogen. The CASAC reviewed the draft document at a meeting held on July 1, 1993, and concluded in a closure letter to the Administrator that the document “provides a scientifically balanced and defensible summary of current knowledge of the effects of this pollutant and provides an adequate basis for the EPA to make a decision as to the appropriate NAAQS for NO<sub>2</sub>” (Wolff, 1993). The AQCD for Oxides of Nitrogen was then finalized (U.S. EPA, 1995a). The EPA also prepared a Staff Paper that summarized and integrated the key studies and scientific evidence contained in the revised AQCD for oxides of nitrogen and identified the critical elements to be considered in the review of the NO<sub>2</sub> NAAQS. The CASAC reviewed two drafts of the Staff Paper and concluded in a closure letter to the Administrator that the document provided a “scientifically adequate basis for regulatory decisions on nitrogen dioxide” (Wolff, 1995).

In October 1995, the Administrator announced her proposed decision not to revise either the primary or secondary NAAQS for NO<sub>2</sub> (60 FR 52874; October 11, 1995). A year later, the Administrator made a final determination not to revise the NAAQS for NO<sub>2</sub> after careful evaluation of the comments received on the proposal (61 FR 52852; October 8, 1996). While the primary NO<sub>2</sub> standard was revised in January 2010, by supplementing the existing annual standard with the establishment of a new 1-hour standard, set at a level of 100 parts per billion (ppb) (75 FR 6474), the secondary NAAQS for NO<sub>2</sub> remains 0.053 ppm (100 micrograms per cubic meter [ $\mu\text{g}/\text{m}^3$ ] of air), annual arithmetic average, calculated as the arithmetic mean of the 1-hour NO<sub>2</sub> concentrations.

#### 2. NAAQS for Oxides of Sulfur

The EPA promulgated primary and secondary NAAQS for SO<sub>2</sub> in April 1971 (36 FR 8186). The secondary standards included a standard set at 0.02 ppm, annual arithmetic mean, and a 3-hour average standard set at 0.5 ppm, not to be exceeded more than once per year. These secondary standards were established solely on the basis of evidence of adverse effects on vegetation. In 1973, revisions made to Chapter 5 (“Effects of Sulfur Oxide in the Atmosphere on Vegetation”) of the AQCD for Sulfur Oxides (U.S. EPA, 1973) indicated that it could not



properly be concluded that the vegetation injury reported resulted from the average SO<sub>2</sub> exposure over the growing season, rather than from short-term peak concentrations. Therefore, the EPA proposed (38 FR 11355) and then finalized (38 FR 25678) a revocation of the annual mean secondary standard. At that time, the EPA was aware that then-current concentrations of oxides of sulfur in the ambient air had other public welfare effects, including effects on materials, visibility, soils, and water. However, the available data were considered insufficient to establish a quantitative relationship between specific ambient concentrations of oxides of sulfur and such public welfare effects (38 FR 25679).

In 1979, the EPA announced that it was revising the AQCD for oxides of sulfur concurrently with that for particulate matter (PM) and would produce a combined PM and oxides of sulfur criteria document. Following its review of a draft revised criteria document in August 1980, CASAC concluded that acid deposition was a topic of extreme scientific complexity because of the difficulty in establishing firm quantitative relationships among (1) Emissions of relevant pollutants (e.g., SO<sub>2</sub> and oxides of nitrogen), (2) formation of acidic wet and dry deposition products, and (3) effects on terrestrial and aquatic ecosystems. The CASAC also noted that acid deposition involves, at a minimum, several different criteria pollutants: oxides of sulfur, oxides of nitrogen, and the fine particulate fraction of suspended particles. The CASAC felt that any document on this subject should address both wet and dry deposition, since dry deposition was believed to account for a substantial portion of the total acid deposition problem.

For these reasons, CASAC recommended that a separate, comprehensive document on acid deposition be prepared prior to any consideration of using the NAAQS as a regulatory mechanism for the control of acid deposition. The CASAC also suggested that a discussion of acid deposition be included in the AQCDs for oxides of nitrogen and PM and oxides of sulfur. Following CASAC closure on the AQCD for oxides of sulfur in December 1981, the EPA published a Staff Paper in November 1982, although the paper did not directly assess the issue of acid deposition. Instead, the EPA subsequently prepared the following documents to address acid deposition: The Acidic Deposition Phenomenon and Its Effects: Critical Assessment Review Papers, Volumes I and II (U.S.

EPA, 1984a, b) and The Acidic Deposition Phenomenon and Its Effects: Critical Assessment Document (U.S. EPA, 1985) (53 FR 14935–14936). These documents, though they were not considered criteria documents and did not undergo CASAC review, represented the most comprehensive summary of scientific information relevant to acid deposition completed by the EPA at that point.

In April 1988 (53 FR 14926), the EPA proposed not to revise the existing primary and secondary standards for SO<sub>2</sub>. This proposed decision with regard to the secondary SO<sub>2</sub> NAAQS was due to the Administrator's conclusions that: (1) Based upon the then-current scientific understanding of the acid deposition problem, it would be premature and unwise to prescribe any regulatory control program at that time; and (2) when the fundamental scientific uncertainties had been decreased through ongoing research efforts, the EPA would draft and support an appropriate set of control measures. Although the EPA revised the primary SO<sub>2</sub> standard in June 2010 by establishing a new 1-hour standard at a level of 75 ppb and revoking the existing 24-hour and annual standards (75 FR 35520), no further decision on the secondary SO<sub>2</sub> standard has been published.

### *C. History of Related Assessments and Agency Actions*

In 1980, the Congress created the National Acid Precipitation Assessment Program (NAPAP) in response to growing concern about acidic deposition. The NAPAP was given a broad 10-year mandate to examine the causes and effects of acidic deposition and to explore alternative control options to alleviate acidic deposition and its effects. During the course of the program, the NAPAP issued a series of publicly available interim reports prior to the completion of a final report in 1990 (NAPAP, 1990).

In spite of the complexities and significant remaining uncertainties associated with the acid deposition problem, it soon became clear that a program to address acid deposition was needed. The CAA Amendments of 1990 included numerous separate provisions related to the acid deposition problem. The primary and most important of the provisions, the amendments to Title IV of the Act, established the Acid Rain Program to reduce emissions of SO<sub>2</sub> by 10 million tons and emissions of nitrogen oxides by 2 million tons from 1980 emission levels in order to achieve reductions over broad geographic regions. In this provision, Congress

included a statement of findings that led them to take action, concluding that (1) The presence of acid compounds and their precursors in the atmosphere and in deposition from the atmosphere represents a threat to natural resources, ecosystems, materials, visibility, and public health; (2) the problem of acid deposition is of national and international significance; and (3) current and future generations of Americans will be adversely affected by delaying measures to remedy the problem.

Second, Congress authorized the continuation of the NAPAP in order to assure that the research and monitoring efforts already undertaken would continue to be coordinated and would provide the basis for an impartial assessment of the effectiveness of the Title IV program.

Third, Congress considered that further action might be necessary in the long-term to address any problems remaining after implementation of the Title IV program and, reserving judgment on the form that action could take, included Section 404 of the 1990 Amendments (CAA Amendments of 1990, Pub. L. 101–549, Section 404) requiring the EPA to conduct a study on the feasibility and effectiveness of an acid deposition standard or standards to protect “sensitive and critically sensitive aquatic and terrestrial resources.” At the conclusion of the study, the EPA was to submit a report to Congress. Five years later, the EPA submitted its report, entitled Acid Deposition Standard Feasibility Study: Report to Congress (U.S. EPA, 1995b) in fulfillment of this requirement. That report concluded that establishing acid deposition standards for sulfur and nitrogen deposition may at some point in the future be technically feasible, although appropriate deposition loads for these acidifying chemicals could not be defined with reasonable certainty at that time.

Fourth, the 1990 Amendments also added new language to sections of the CAA pertaining to the scope and application of the secondary NAAQS designed to protect the public welfare. Specifically, the definition of “effects on welfare” in Section 302(h) was expanded to state that the welfare effects include effects “\* \* \* whether caused by transformation, conversion, or combination with other air pollutants.”

In 1999, seven Northeastern states cited this amended language in Section 302(h) in a petition asking the EPA to use its authority under the NAAQS program to promulgate secondary NAAQS for the criteria pollutants

associated with the formation of acid rain. The petition stated that this language “clearly references the transformation of pollutants resulting in the inevitable formation of sulfate and nitrate aerosols and/or their ultimate environmental impacts as wet and dry deposition, clearly signaling Congressional intent that the welfare damage occasioned by sulfur and nitrogen oxides be addressed through the secondary standard provisions of Section 109 of the Act.” The petition further stated that “recent federal studies, including the NAPAP Biennial Report to Congress: An Integrated Assessment, document the continued and increasing damage being inflicted by acid deposition to the lakes and forests of New York, New England and other parts of our nation, demonstrating that the Title IV program had proven insufficient.” The petition also listed other adverse welfare effects associated with the transformation of these criteria pollutants, including impaired visibility, eutrophication of coastal estuaries, global warming, and tropospheric ozone and stratospheric ozone depletion.

In a related matter, the Office of the Secretary of the U.S. Department of Interior (DOI) requested in 2000, that the EPA initiate a rulemaking proceeding to enhance the air quality in national parks and wilderness areas in order to protect resources and values that are being adversely affected by air pollution. Included among the effects of concern identified in the request were the acidification of streams, surface waters, and/or soils; eutrophication of coastal waters; visibility impairment; and foliar injury from ozone.

In a **Federal Register** notice in 2001 (65 FR 48699), the EPA announced receipt of these requests and asked for comment on the issues raised in them. The EPA stated that it would consider any relevant comments and information submitted, along with the information provided by the petitioners and DOI, before making any decision concerning a response to these requests for rulemaking.

The 2005 NAPAP report states that “\* \* \* scientific studies indicate that the emission reductions achieved by Title IV are not sufficient to allow recovery of acid-sensitive ecosystems. Estimates from the literature of the scope of additional emission reductions that are necessary in order to protect acid-sensitive ecosystems range from approximately 40–80 percent beyond full implementation of Title IV \* \* \*.” The results of the modeling presented in this Report to Congress indicate that broader recovery is not predicted

without additional emission reductions (NAPAP, 2005).

Given the state of the science as described in the Integrated Science Assessment (ISA), Risk and Exposure Assessment (REA), and in other recent reports, such as the NAPAP reports noted above, the EPA has decided, in the context of evaluating the adequacy of the current NO<sub>2</sub> and SO<sub>2</sub> secondary standards in this review, to revisit the question of the appropriateness of setting secondary NAAQS to address remaining known or anticipated adverse public welfare effects resulting from the acidic and nutrient deposition of these criteria pollutants.

#### *D. History of the Current Review*

The EPA initiated this current review in December 2005, with a call for information (70 FR 73236) for the development of a revised ISA. An Integrated Review Plan (IRP) was developed to provide the framework and schedule as well as the scope of the review and to identify policy-relevant questions to be addressed in the components of the review. The IRP was released in 2007 (U.S. EPA, 2007) for CASAC and public review. The EPA held a workshop in July 2007 on the ISA to obtain broad input from the relevant scientific communities. This workshop helped to inform the preparation of the first draft ISA, which was released for CASAC and public review in December 2007; a CASAC meeting was held on April 2–3, 2008, to review the first draft ISA. A second draft ISA was released for CASAC and public review in August 2008, and was discussed at a CASAC meeting held on October 1–2, 2008. The final ISA (U.S. EPA, 2008) was released in December 2008.

Based on the science presented in the ISA, the EPA developed the REA to further assess the national impact of the effects documented in the ISA. The Draft Scope and Methods Plan for Risk/Exposure Assessment: Secondary NAAQS Review for Oxides of Nitrogen and Oxides of Sulfur outlining the scope and design of the future REA was prepared for CASAC consultation and public review in March 2008. A first draft REA was presented to CASAC and the public for review in August 2008, and a second draft was presented for review in June 2009. The final REA (U.S. EPA, 2009) was released in September 2009. A first draft Policy Assessment (PA) was released in March 2010, and reviewed by CASAC on April 1–2, 2010. In a June 22, 2010, letter to the Administrator, CASAC provided advice and recommendations to the Agency concerning the first draft PA (Russell and Samet, 2010a). A second

draft PA was released to CASAC and the public in September 2010, and reviewed by CASAC on October 6–7, 2010. The CASAC provided advice and recommendations to the Agency regarding the second draft PA in a December 9, 2010 letter (Russell and Samet 2010b). The CASAC and public comments on the second draft PA were considered by the EPA staff in developing a final PA (U.S. EPA, 2011). CASAC requested an additional meeting to provide additional advice to the Administrator based on the final PA on February 15–16, 2011. On January 14, 2011 the EPA released a version of the final PA prior to final document production, to provide sufficient time for CASAC review of the document in advance of this meeting. The final PA, incorporating final reference checks and document formatting, was released in February 2011. In a May 17, 2011, letter (Russell and Samet, 2011a), CASAC offered additional advice and recommendations to the Administrator with regard to the review of the secondary NAAQS for oxides of nitrogen and oxides of sulfur.

In 2005, the Center for Biological Diversity and four other plaintiffs filed a complaint alleging that the EPA had failed to complete the current review within the period provided by statute.<sup>2</sup> The schedule for completion of this review is governed by a consent decree resolving that lawsuit and the subsequent extension agreed to by the parties. The schedule presented in the original consent decree that governs this review, entered by the court on November 19, 2007, was revised on October 22, 2009 to allow for a 17-month extension of the schedule. The current decree provides that the EPA sign for publication notices of proposed and final rulemaking concerning its review of the oxides of nitrogen and oxides of sulfur NAAQS no later than July 12, 2011 and March 20, 2012, respectively.

This action presents the Administrator’s final decisions on the review of the current secondary oxides of nitrogen and oxides of sulfur standards. Throughout this preamble a number of conclusions, findings, and determinations by the Administrator are noted.

#### *E. Scope of the Current Review*

##### *1. Scope Presented in the Proposal*

In conducting this periodic review of the secondary NAAQS for oxides of nitrogen and oxides of sulfur, as discussed in the IRP and REA, the EPA

<sup>2</sup> *Center for Biological Diversity, et al. v. Johnson*, No. 05–1814 (D.D.C.).

decided to assess the scientific information, associated risks, and standards relevant to protecting the public welfare from adverse effects associated jointly with oxides of nitrogen and sulfur. Although the EPA has historically adopted separate secondary standards for oxides of nitrogen and oxides of sulfur, the EPA is conducting a joint review of these standards because oxides of nitrogen and sulfur, and their associated transformation products are linked from an atmospheric chemistry perspective, as well as from an environmental effects perspective. The National Research Council (NRC) has recommended that the EPA consider multiple pollutants, as appropriate, in forming the scientific basis for the NAAQS (NRC, 2004). As discussed in the ISA and REA, there is a strong basis for considering these pollutants together, building upon the EPA's past recognition of the interactions of these pollutants and on the growing body of scientific information that is now available related to these interactions and associated ecological effects.

In defining the scope of this review, it must be considered that the EPA has set secondary standards for two other criteria pollutants related to oxides of nitrogen and sulfur: ozone (O<sub>3</sub>) and PM. Oxides of nitrogen are precursors to the formation of ozone in the atmosphere, and under certain conditions, can combine with atmospheric ammonia to form ammonium nitrate, a component of fine PM. Oxides of sulfur are precursors to the formation of particulate sulfate, which is a significant component of fine PM in many parts of the United States. There are a number of welfare effects directly associated with ozone and fine PM, including ozone-related damage to vegetation and PM-related visibility impairment. Protection against those effects is provided by the ozone and fine PM secondary standards. This review focuses on evaluation of the protection provided by secondary standards for oxides of nitrogen and sulfur for two general types of effects: (1) direct effects on vegetation associated with exposure to gaseous oxides of nitrogen and sulfur in the ambient air, which are the effects that the current NO<sub>2</sub> and SO<sub>2</sub> secondary standards protect against; and (2) effects associated with the deposition of oxides of nitrogen and sulfur to sensitive aquatic and terrestrial ecosystems, including deposition in the form of particulate nitrate and particulate sulfate.

The ISA focuses on the ecological effects associated with deposition of ambient oxides of nitrogen and sulfur to natural sensitive ecosystems, as

distinguished from commercially managed forests and agricultural lands. This focus reflects the fact that the majority of the scientific evidence regarding acidification and nutrient enrichment is based on studies in unmanaged ecosystems. Non-managed terrestrial ecosystems tend to have a higher fraction of nitrogen deposition resulting from atmospheric nitrogen (U.S. EPA, 2008, section 3.3.2.5). In addition, the ISA notes that agricultural and commercial forest lands are routinely fertilized with amounts of nitrogen that exceed air pollutant inputs even in the most polluted areas (U.S. EPA, 2008, section 3.3.9). This review recognizes that the effects of nitrogen deposition in managed areas are viewed differently from a public welfare perspective than are the effects of nitrogen deposition in natural, unmanaged ecosystems, largely due to the more homogeneous, controlled nature of species composition and development in managed ecosystems and the potential for benefits of increased productivity in those ecosystems.

In focusing on natural sensitive ecosystems, the PA primarily considers the effects of ambient oxides of nitrogen and sulfur via deposition on multiple ecological receptors. The ISA highlights effects including those associated with acidification and nitrogen nutrient enrichment. With a focus on these deposition-related effects the EPA's objective is to develop a framework for oxides of nitrogen and sulfur standards that incorporates ecologically relevant factors and that recognizes the interactions between the two pollutants as they deposit to sensitive ecosystems. The overarching policy objective is to develop a secondary standard(s) based on the ecological criteria described in the ISA and the results of the assessments in the REA, and consistent with the requirement of the CAA to set secondary standards that are requisite to protect the public welfare from any known or anticipated adverse effects associated with the presence of these air pollutants in the ambient air. Consistent with the CAA, this policy objective includes consideration of "variable factors \* \* \* which of themselves or in combination with other factors may alter the effects on public welfare" of the criteria air pollutants included in this review.

In addition, we have chosen to focus on the effects of ambient oxides of nitrogen and sulfur on ecological impacts on sensitive aquatic ecosystems associated with acidifying deposition of nitrogen and sulfur, which is a transformation product of ambient

oxides of nitrogen and sulfur. Based on the information in the ISA, the assessments presented in the REA, and advice from CASAC on earlier drafts of this PA (Russell and Samet, 2010a, 2010b), and as discussed in detail in the PA, we have the greatest confidence in the causal linkages between oxides of nitrogen and sulfur and aquatic acidification effects relative to other deposition-related effects, including terrestrial acidification and aquatic and terrestrial nutrient enrichment.

## 2. Comments on the Scope of the Review

Comments received regarding the scope of the review were primarily those that questioned the EPA's legal authority under Section 109 of the CAA to set NAAQS that address deposition-related effects, focusing in particular on effects resulting from acidifying deposition to ecosystems.

While environmental organizations and some other commenters urged the EPA to establish a NAAQS that would protect against the impacts on sensitive ecosystems associated with the acidifying deposition of nitrogen and sulfur, several industry commenters argued that the enactment of Title IV of the CAA in 1990 displaced the EPA's authority to address acidification through the setting of NAAQS. These commenters contend that the existence of a specific regulatory program to address the acidification effects of oxides of nitrogen and sulfur supplants the EPA's general authority under the CAA. According to industry comments, this is demonstrated by a close reading of Section 404 which required the EPA to report to Congress on the feasibility of developing an acid deposition standard and the actions that would be required to integrate such a program into the CAA. The required study described in Section 404, commenters argue, demonstrates that Congress had concluded that the EPA lacked the authority under Section 109 of the CAA to establish a secondary NAAQS to address acid deposition.

Although the EPA is not adopting a secondary standard designed to protect the public welfare from the effects associated with the acidifying deposition of nitrogen and sulfur, the EPA does not agree that the enactment of Title IV displaced the EPA's authority under Section 109 of the CAA to set such a NAAQS. We note that the purpose of Title IV "is to reduce the adverse effects of acid deposition," CAA Section 401(b), while Section 109 directs the Administrator to go beyond this to set a standard that is "requisite to protect public welfare from any known or

anticipated adverse effects,” CAA Section 109(b)(2). These provisions are not accordingly in conflict, but represent the often typical interlinked approach of Congress to address the frequently complex problems of air pollution.

Nothing in the text or the legislative history of Title IV of the Act indicates a clear intention by Congress to foreclose the EPA’s authority to address acid deposition through the NAAQS process. The requirement in Section 404 of the 1990 CAA Amendments that the EPA send to Congress “a report on the feasibility and effectiveness of an acid deposition standard or standards” does not indicate that Congress had concluded that an amendment to the CAA would be necessary to give the EPA the authority to issue regulations addressing acidification. The significance of the report required by Section 404 cannot be understood clearly in isolation, but should be considered in the overall context of the history of Congress’ and the EPA’s attempts to understand and to address the causes and effects of acid deposition and the EPA’s conclusion in 1988 that the scientific uncertainties associated with acid deposition were too great to allow the Agency to establish a secondary NAAQS at that time. In the proposed rule, we noted that it was clear at the time of the 1990 CAA Amendments that a program to address acid deposition was needed and that the primary and most important of these provisions is Title IV of the Act, establishing the Acid Rain Program. In assessing the import of Section 404 in this overall context, the EPA has noted in the past and in section I.C above that “Congress reserved judgment as to whether further action might be necessary or appropriate in the longer term” to address any problems remaining after implementation of the Title IV program, and “if so, what form it should take” (58 FR 21351, 21356 (April 21, 1993)). Such reservation of judgment does not indicate that Congress viewed the EPA as lacking authority under Section 109 to establish a secondary NAAQS to address acid deposition but a recognition that the uncertainties associated with such a standard may be too significant to allow the Administrator to reach a reasoned conclusion as to the appropriate standard.

Having carefully considered the public comments, the EPA finds that the conclusions reached in the proposed rule with regard to the scope of the current review continue to be valid. The EPA concludes that the Agency has the authority under Section 109 of the CAA

to consider deposition-related to ambient air concentrations of oxides of nitrogen and sulfur and the resulting effects on ecosystems and that the focus of the current review of the NAAQS for oxides of nitrogen and sulfur on aquatic acidification is appropriate. This issue is discussed in more detail in the EPA’s Response to Comments document.

## **II. Rationale for Final Decisions on the Adequacy of the Current Secondary Standards**

This section presents the rationale for the Administrator’s final conclusions with regard to the adequacy of protection and ecological relevance of the current secondary standards for oxides of nitrogen and sulfur. As discussed more fully below, this rationale considered the latest scientific information on ecological effects associated with the presence of oxides of nitrogen and oxides of sulfur in the ambient air. This rationale also takes into account: (1) Staff assessments of the most policy-relevant information in the ISA and staff analyses of air quality, exposure, and ecological risks, presented more fully in the REA and in the PA, upon which staff conclusions on revisions to the secondary oxides of nitrogen and oxides of sulfur standards are based; (2) CASAC advice and recommendations, as reflected in discussions of drafts of the ISA, REA, and PA at public meetings, in separate written comments, and in CASAC’s letters to the Administrator; and (3) public comments received during the development of these documents, either in connection with CASAC meetings or separately as well as comments received on the proposal notice.

In developing this rationale, the EPA has drawn upon an integrative synthesis of the entire body of evidence, published through early 2008, on ecological effects associated with the deposition of oxides of nitrogen and oxides of sulfur in the ambient air (U.S. EPA, 2008). As discussed below, this body of evidence addresses a broad range of ecological endpoints associated with ambient levels of oxides of nitrogen and oxides of sulfur. In considering this evidence, the EPA focuses on those ecological endpoints, such as aquatic acidification, for which the ISA judges associations with oxides of nitrogen and oxides of sulfur to be causal, likely causal, or for which the evidence is suggestive that oxides of nitrogen and/or sulfur contribute to the reported effects. The categories of causality determinations have been developed in the ISA (U.S. EPA, 2008) and are discussed in section 1.6 of the ISA.

Decisions on retaining or revising the current secondary standards for oxides of nitrogen and sulfur are largely public welfare policy judgments based on the Administrator’s informed assessment of what constitutes requisite protection against adverse effects to public welfare. A public welfare policy decision should draw upon scientific information and analyses about welfare effects, exposure and risks, as well as judgments about the appropriate response to the range of uncertainties that are inherent in the scientific evidence and analyses. The ultimate determination as to what level of damage to ecosystems and the services provided by those ecosystems is adverse to public welfare is not wholly a scientific question, although it is informed by scientific studies linking ecosystem damage to losses in ecosystem services, and information on the value of those losses of ecosystem services. In reaching such decisions, the Administrator seeks to establish standards that are neither more nor less stringent than necessary for this purpose.

Drawing from information in sections II.A–C of the proposal, section II.A below provides overviews of the public welfare effects considered in this review, the risk and exposure assessments, and the adversity of effects on public welfare. Section II.B presents conclusions in the ISA, REA, and PA on the adequacy of the current secondary standards for oxides of nitrogen and oxides of sulfur. Consideration is given to the adequacy of protection afforded by the current standards for both direct and deposition-related effects, as well as to the appropriateness of the fundamental structure and the basic elements of the current standards for providing protection from deposition-related effects. The views of CASAC and a summary of the Administrator’s proposed conclusions are also included. Section II. C presents a discussion of the comments received on the proposal with regard to the adequacy of the current standards. Section II. D presents the Administrator’s final decisions with regard to the adequacy of the current standards for both direct and deposition-related effects on public welfare.

### *A. Introduction*

A discussion of the effects associated with oxides of nitrogen and sulfur in the ambient air is presented below in section II.A.1. The discussion is organized around the types of effects being considered, including direct effects of gaseous oxides of nitrogen and sulfur, deposition-related effects related to acidification and nutrient

enrichment, and other effects such as materials damage, climate-related effects and mercury methylation.

Section II.A.2 presents a summary and discussion of the risk and exposure assessment performed for each of the four major effects categories. The REA uses case studies representing the broad geographic variability of the impacts from oxides of nitrogen and sulfur to conclude that there are ongoing adverse effects in many ecosystems from deposition of oxides of nitrogen and sulfur and that under current emissions scenarios these effects are likely to continue.

Section II.A.3 presents a discussion of adversity linking ecological effects to measures that can be used to characterize the extent to which such effects are reasonably considered to be adverse to public welfare. This involves consideration of how to characterize adversity from a public welfare perspective. In so doing, consideration is given to the concept of ecosystem services, the evidence of effects on ecosystem services, and how ecosystem services can be linked to ecological indicators.

#### 1. Overview of Effects

This section discusses the known or anticipated ecological effects associated with oxides of nitrogen and sulfur, including the direct effects of gas-phase exposure to oxides of nitrogen and sulfur (section II.A.1.a) and effects associated with deposition-related exposure (section II.A.1.b). These sections also address questions about the nature and magnitude of ecosystem responses to reactive nitrogen and sulfur deposition, including responses related to acidification, nutrient depletion, and the mobilization of toxic metals in sensitive aquatic and terrestrial ecosystems. The uncertainties and limitations associated with the evidence of such effects are also discussed throughout this section.

##### a. Effects Associated With Gas-Phase Oxides of Nitrogen and Sulfur

Ecological effects on vegetation as discussed in earlier reviews as well as the ISA can be attributed to gas-phase oxides of nitrogen and sulfur. Acute and chronic exposures to gaseous pollutants such as SO<sub>2</sub>, NO<sub>2</sub>, nitric oxide (NO), nitric acid (HNO<sub>3</sub>) and peroxyacetyl nitrite (PAN) are associated with negative impacts to vegetation. The current secondary NAAQS were set to protect against direct damage to vegetation by exposure to gas-phase oxides of nitrogen and sulfur, such as foliar injury, decreased photosynthesis, and decreased growth. The following

summary is a concise overview of the known or anticipated effects to vegetation caused by gas phase nitrogen and sulfur. Most phototoxic effects associated with gas phase oxides of nitrogen and sulfur occur at levels well above ambient concentrations observed in the United States (U.S. EPA, 2008, section 3.4.2.4).

The 2008 ISA found that gas phase nitrogen and sulfur are associated with direct phytotoxic effects (U.S. EPA, 2008, section 4.4). The evidence is sufficient to infer a causal relationship between exposure to SO<sub>2</sub> and injury to vegetation (U.S. EPA, 2008, section 4.4.1 and 3.4.2.1). Acute foliar injury to vegetation from SO<sub>2</sub> may occur at levels above the current secondary standard (3-h average of 0.50 ppm). Effects on growth, reduced photosynthesis and decreased yield of vegetation are also associated with increased SO<sub>2</sub> exposure concentration and time of exposure.

The evidence is sufficient to infer a causal relationship between exposure to NO, NO<sub>2</sub> and PAN and injury to vegetation (U.S. EPA, 2008, section 4.4.2 and 3.4.2.2). At sufficient concentrations, NO, NO<sub>2</sub> and PAN can decrease photosynthesis and induce visible foliar injury to plants. Evidence is also sufficient to infer a causal relationship between exposure to HNO<sub>3</sub> and changes to vegetation (U.S. EPA, 2008, section 4.4.3 and 3.4.2.3). Phytotoxic effects of this pollutant include damage to the leaf cuticle in vascular plants and disappearance of some sensitive lichen species.

Vegetation in ecosystems near sources of gaseous oxides of nitrogen and sulfur or where SO<sub>2</sub>, NO, NO<sub>2</sub>, PAN and HNO<sub>3</sub> are most concentrated are more likely to be impacted by these pollutants. Uptake of these pollutants in a plant canopy is a complex process involving adsorption to surfaces (leaves, stems and soil) and absorption into leaves (U.S. EPA, 2008, section 3.4.2). The functional relationship between ambient concentrations of gas phase oxides of nitrogen and sulfur and specific plant response are impacted by internal factors such as rate of stomatal conductance and plant detoxification mechanisms, and external factors including plant water status, light, temperature, humidity, and pollutant exposure regime (U.S. EPA, 2008, section 3.4.2).

Entry of gases into a leaf is dependent upon physical and chemical processes of gas phase as well as to stomatal aperture. The aperture of the stomata is controlled largely by the prevailing environmental conditions, such as water availability, humidity, temperature, and light intensity. When the stomata are

closed, resistance to gas uptake is high and the plant has a very low degree of susceptibility to injury. Mosses and lichens do not have a protective cuticle barrier to gaseous pollutants or stomata and are generally more sensitive to gaseous sulfur and nitrogen than vascular plants (U.S. EPA, 2008, section 3.4.2).

The appearance of foliar injury can vary significantly across species and growth conditions affecting stomatal conductance in vascular plants (U.S. EPA, 2009, section 6.4.1). For example, damage to lichens from SO<sub>2</sub> exposure includes decreased photosynthesis and respiration, damage to the algal component of the lichen, leakage of electrolytes, inhibition of nitrogen fixation, decreased potassium (K<sup>+</sup>) absorption, and structural changes.

The phytotoxic effects of gas phase oxides of nitrogen and sulfur are dependent on the exposure concentration and duration and species sensitivity to these pollutants. Effects to vegetation associated with oxides of nitrogen and sulfur are therefore variable across the United States and tend to be higher near sources of photochemical smog. For example, SO<sub>2</sub> is considered to be the primary factor contributing to the death of lichens in many urban and industrial areas.

The ISA states there is very limited new research on phytotoxic effects of NO, NO<sub>2</sub>, PAN and HNO<sub>3</sub> at concentrations currently observed in the United States with the exception of some lichen species (U.S. EPA, 2008, section 4.4). Past and current HNO<sub>3</sub> concentrations may be contributing to the decline in lichen species in the Los Angeles basin. Most phytotoxic effects associated with gas phase oxides of nitrogen and sulfur occur at levels well above ambient concentrations observed in the United States (U.S. EPA, 2008, section 3.4.2.4).

##### b. Effects Associated With Deposition of Oxides of Nitrogen and Sulfur

Ecological effects associated with the deposition of oxides of nitrogen and oxides of sulfur can be divided into endpoints related to the type of ecosystem affected and the type of effect. As more fully discussed in section II.A of the proposal and chapter 3 of the PA, this section provides a brief summary of effects on ecosystems related to acidification, nutrient enrichment, and metal toxicity.

##### i. Acidification Effects on Aquatic and Terrestrial Ecosystems

Sulfur oxides and nitrogen oxides in the atmosphere undergo a complex mix of reactions in gaseous, liquid, and solid

phases to form various acidic compounds. These acidic compounds are removed from the atmosphere through deposition: either wet (e.g., rain, snow), fog or cloud, or dry (e.g., gases, particles). Deposition of these acidic compounds to aquatic and terrestrial ecosystems can lead to effects on ecosystem structure and function. Following deposition, these compounds can, in some instances, unless retained by soil or biota, leach out of the soils in the form of sulfate ( $\text{SO}_4^{2-}$ ) and nitrate ( $\text{NO}_3^-$ ), leading to the acidification of surface waters. The effects on ecosystems depend on the magnitude and rate of deposition, as well as a host of biogeochemical processes occurring in the soils and water bodies (U.S. EPA, 2009, section 2.1). The chemical forms of nitrogen that may contribute to acidifying deposition include both oxidized and reduced chemical species, including reduced forms of nitrogen ( $\text{NH}_x$ ).

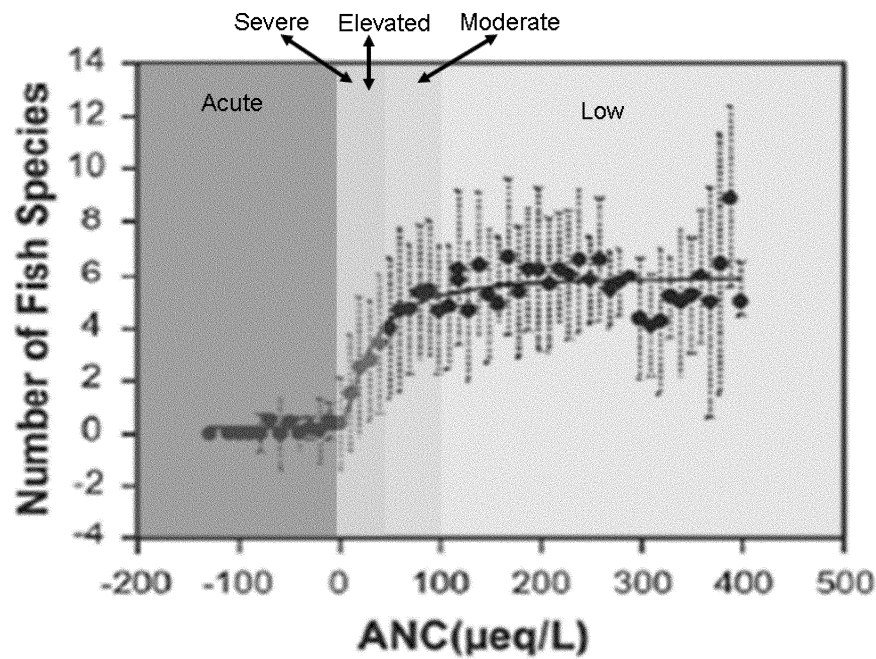
The ISA concluded that deposition of oxides of nitrogen and sulfur and  $\text{NH}_x$  leads to the varying degrees of acidification of ecosystems (U.S. EPA, 2008). In the process of acidification, biogeochemical components of terrestrial and freshwater aquatic ecosystems are altered in a way that leads to effects on biological organisms. Deposition to terrestrial ecosystems often moves through the soil and eventually leaches into adjacent water bodies. Principal factors governing the sensitivity of terrestrial and aquatic ecosystems to acidification from sulfur and nitrogen deposition include geology, plant uptake of nitrogen, soil depth, and elevation. Geologic formations having low base cation supply generally underlie the watersheds of acid-sensitive lakes and

streams. Other factors that contribute to the sensitivity of soils and surface waters to acidifying deposition include topography, soil chemistry, land use, and hydrologic flowpath. Chronic as well as episodic acidification tends to occur primarily at relatively high elevations in areas that have base-poor bedrock, high relief, and shallow soils.

With regard to aquatic acidification, the ISA concluded that the scientific evidence is sufficient to infer a causal relationship between acidifying deposition and effects on biogeochemistry and biota in aquatic ecosystems (U.S. EPA, 2008, section 4.2.2). The strongest evidence comes from studies of surface water chemistry in which acidic deposition is observed to alter sulfate and nitrate concentrations in surface waters, the sum of base cations, acid neutralizing capacity (ANC), dissolved inorganic aluminum (Al) and pH (U.S. EPA, 2008, section 3.2.3.2). The ANC is a key indicator of acidification with relevance to both terrestrial and aquatic ecosystems. The ANC is useful because it integrates the overall acid-base status of a lake or stream and reflects how aquatic ecosystems respond to acidic deposition over time. There is also a relationship between ANC and the surface water constituents that directly contribute to or ameliorate acidity-related stress, in particular, concentrations of hydrogen ion (as pH), calcium ( $\text{Ca}^{2+}$ ) and Al. Moreover, low pH surface waters leach aluminum from soils, which is quite lethal to fish and other aquatic organisms. In aquatic systems, there is a direct relationship between ANC and fish and phytoplankton diversity and abundance. Acidification in terrestrial ecosystems has been shown to cause decreased

growth and increased susceptibility to disease and injury in sensitive tree species, including red spruce and sugar maple.

Based on analyses of surface water data from freshwater ecosystem surveys and monitoring, the most sensitive lakes and streams are contained in New England, the Adirondack Mountains, the Appalachian Mountains (northern Appalachian Plateau and Ridge/Blue Ridge region), the mountainous West, and the Upper Midwest. ANC is the most widely used indicator of acid sensitivity and has been found in various studies to be the best single indicator of the biological response and health of aquatic communities in acid sensitive systems. Annual or multi-year average ANC is a good overall indicator of sensitivity, capturing the ability of an ecosystem to withstand chronic acidification as well as episodic events such as spring melting that can lower ANC over shorter time spans. Biota are generally not harmed when annual average ANC levels are  $>100$  microequivalents per liter ( $\mu\text{eq/L}$ ). At annual average ANC levels between 100 and  $50 \mu\text{eq/L}$ , the fitness of sensitive species (e.g., brook trout, zooplankton) begins to decline. When annual average ANC is  $<50 \mu\text{eq/L}$ , negative effects on aquatic biota are observed, including large reductions in diversity of fish species, and declines in health of fish populations, affecting reproductive ability and fitness. Annual average ANC levels below  $0 \mu\text{eq/L}$  are generally associated with complete loss of fish species and other biota that are sensitive to acidification. An example of the relationship between ANC level and aquatic effects based on lakes in the Adirondacks is illustrated in the following figure:



Recent studies indicate that acidification of lakes and streams can result in significant loss in economic value, which is one indicator of adversity associated with loss of ecosystem services. A 2006 study of New York residents found that they are willing to pay between \$300 and \$800 million annually for the equivalent of improving lakes in the Adirondacks region to an ANC level of 50 µeq/L. Several states have set goals for improving the acid status of lakes and streams, generally targeting ANC in the range of 50 to 60 µeq/L, and have engaged in costly activities to decrease acidification.

With regard to terrestrial ecosystems, the evidence is sufficient to infer a causal relationship between acidifying deposition and changes in biogeochemistry (U.S. EPA, 2008, section 4.2.1.1). The strongest evidence comes from studies of forested ecosystems, with supportive information on other plant taxa, including shrubs and lichens (U.S. EPA, 2008, section 3.2.2.1.). Three useful indicators of chemical changes and acidification effects on terrestrial ecosystems, showing consistency among multiple studies are: soil base saturation, Al concentrations in soil water, and soil carbon to nitrogen (C:N) ratio (U.S. EPA, 2008, section 3.2.2.2).

Forests of the Adirondack Mountains of New York, Green Mountains of Vermont, White Mountains of New Hampshire, the Allegheny Plateau of Pennsylvania, and high-elevation forest ecosystems in the southern Appalachians and mountainous regions

in the West are the regions most sensitive to acidifying deposition. The health of at least a portion of the sugar maple and red spruce growing in the United States may have been compromised by acidifying total nitrogen and sulfur deposition in recent years. Soil acidification caused by acidic deposition has been shown to cause decreased growth and increased susceptibility to disease and injury in sensitive tree species. Red spruce dieback or decline has been observed across high elevation areas in the Adirondack, Green and White mountains. The frequency of freezing injury to red spruce needles has increased over the past 40 years, a period that coincided with increased emissions of sulfur and nitrogen oxides and increased acidifying deposition. Acidifying deposition can contribute to dieback in sugar maple through depletion of cations from soil with low levels of available calcium. Grasslands are likely less sensitive to acidification than forests due to grassland soils being generally rich in base cations.

A commonly used indicator of terrestrial acidification is the base cation-to-aluminum ratio, Bc/Al. Many locations in sensitive areas of the United States have Bc/Al levels below benchmark levels we have classified as providing low to intermediate levels of protection to tree health. At a Bc/Al ratio of 1.2 (intermediate level of protection), red spruce growth can be reduced by 20 percent. At a Bc/Al ratio of 0.6 (low level of protection), sugar maple growth can be reduced by 20 percent. While not defining whether a

20 percent reduction in growth can be considered significant, existing economic studies suggest that avoiding significant declines in the health of spruce and sugar maple forests may be worth billions of dollars to residents of the Eastern United States.

ii. Nutrient Enrichment Effects in Terrestrial and Aquatic Ecosystems

The ISA found that deposition of nitrogen, including oxides of nitrogen and NH<sub>x</sub>, leads to the nitrogen enrichment of terrestrial, freshwater and estuarine ecosystems (U.S. EPA 2008). In the process of nitrogen enrichment, biogeochemical components of terrestrial and freshwater aquatic ecosystems are altered in a way that leads to effects on biological organisms. Nitrogen deposition is a major source of anthropogenic nitrogen. For many terrestrial and freshwater ecosystems other sources of nitrogen including fertilizer and waste treatment are greater than deposition. Nitrogen deposition often contributes to nitrogen-enrichment effects in estuaries, but does not drive the effects since other sources of nitrogen greatly exceed nitrogen deposition. Both oxides of nitrogen and NH<sub>x</sub> contribute to nitrogen deposition. For the most part, nitrogen effects on ecosystems do not depend on whether the nitrogen is in oxidized or reduced form. Thus, this summary focuses on the effects of nitrogen deposition in total.

The numerous ecosystem types that occur across the United States have a broad range of sensitivity to nitrogen deposition. Organisms in their natural

environment are commonly adapted to a specific regime of nutrient availability. Change in the availability of one important nutrient, such as nitrogen, may result in imbalances in ecosystems, with effects on ecosystem processes, structure and function. In certain nitrogen-limited ecosystems, including many ecosystems managed for commercial production, nitrogen deposition can result in beneficial increases in productivity. Nutrient enrichment effects from deposition of oxides of nitrogen are difficult to disentangle from overall effects of nitrogen enrichment. This is caused by two factors: the inputs of reduced nitrogen from deposition and, in estuarine ecosystems, a large fraction of nitrogen inputs from non-atmospheric sources.

The numerous ecosystem types that occur across the United States have a broad range of sensitivity to nitrogen deposition (U.S. EPA, 2008, Table 4–4). Increased deposition to nitrogen-limited ecosystems can lead to production increases that may be either beneficial or adverse depending on the system and management goals. Organisms in their natural environment are commonly adapted to a specific regime of nutrient availability. Change in the availability of one important nutrient, such as nitrogen, may result in an imbalance in ecological stoichiometry, with effects on ecosystem processes, structure and function.

With regard to terrestrial ecosystems, the ISA concluded that the evidence is sufficient to infer a causal relationship between nitrogen deposition and the alteration of biogeochemical cycling in terrestrial ecosystems (U.S. EPA, 2008, section 4.3.1.1 and 3.3.2.1). Due to the complexity of interactions between the nitrogen and carbon cycling, the effects of nitrogen on carbon budgets (quantified input and output of carbon to the ecosystem) are variable. Regional trends in net ecosystem productivity (NEP) of forests (not managed for silviculture) have been estimated through models based on gradient studies and meta-analysis. Atmospheric nitrogen deposition has been shown to cause increased litter accumulation and carbon storage in above-ground woody biomass. In the West, this has led to increased susceptibility to more severe fires. Less is known regarding the effects of nitrogen deposition on carbon budgets of non-forest ecosystems. The ISA also concludes that the evidence is sufficient to infer a causal relationship between nitrogen deposition on the alteration of species richness, species composition and biodiversity in

terrestrial ecosystems (U.S. EPA, 2008, section 4.3.1.2).

Little is known about the full extent and distribution of the terrestrial ecosystems in the United States that are most sensitive to impacts caused by nutrient enrichment from atmospheric nitrogen deposition. Effects are most likely to occur where areas of relatively high atmospheric N deposition intersect with nitrogen-limited plant communities. The alpine ecosystems of the Colorado Front Range, chaparral watersheds of the Sierra Nevada, lichen and vascular plant communities in the San Bernardino Mountains and the Pacific Northwest, and the southern California coastal sage scrub (CSS) community are among the most sensitive terrestrial ecosystems. There is growing evidence (U.S. EPA, 2008, section 4.3.1.2) that existing grassland ecosystems in the western United States are being altered by elevated levels of N inputs, including inputs from atmospheric deposition.

More is known about the sensitivity of particular plant communities. Based largely on results obtained in more extensive studies conducted in Europe, it is expected that the more sensitive terrestrial ecosystems include hardwood forests, alpine meadows, arid and semi-arid lands, and grassland ecosystems (U.S. EPA, 2008, section 3.3.5). The REA used published research results (U.S. EPA, 2009, section 5.3.1 and U.S. EPA, 2008, Table 4.4) to identify meaningful ecological benchmarks associated with different levels of atmospheric nitrogen deposition. These are illustrated in Figure 3–4 of the PA. The sensitive areas and ecological indicators identified by the ISA were analyzed further in the REA to create a national map that illustrates effects observed from ambient and experimental atmospheric nitrogen deposition loads in relation to Community Multi-scale Air Quality (CMAQ) 2002 modeling results and National Atmospheric Deposition Program (NADP) monitoring data. This map, reproduced in Figure 3–5 of the PA, depicts the sites where empirical effects of terrestrial nutrient enrichment have been observed and site proximity to elevated atmospheric nitrogen deposition.

With regard to freshwater ecosystems, the ISA concluded that the evidence is sufficient to infer a causal relationship between nitrogen deposition and the alteration of biogeochemical cycling in freshwater aquatic ecosystems (U.S. EPA, 2008, section 3.3.2.3). Nitrogen deposition is the main source of nitrogen enrichment to headwater streams, lower order streams and high elevation lakes. The ISA also concludes

that the evidence is sufficient to infer a causal relationship between nitrogen deposition and the alteration of species richness, species composition and biodiversity in freshwater aquatic ecosystems (U.S. EPA, 2008, section 3.3.5.3).

There are many examples of fresh waters that are nitrogen-limited or nitrogen and phosphorous (P) co-limited (U.S. EPA, 2008, section 3.3.3.2). Less is known about the extent and distribution of the terrestrial ecosystems in the United States that are most sensitive to the effects of nutrient enrichment from atmospheric nitrogen deposition compared to acidification. Grasslands in the western United States are typically nitrogen-limited ecosystems dominated by a diverse mix of perennial forbs and grass species. A meta-analysis discussed in the ISA (U.S. EPA, 2008, section 3.3.3), indicated that nitrogen fertilization increased aboveground growth in all non-forest ecosystems except for deserts. Because the productivity of estuarine and near shore marine ecosystems is generally limited by the availability of nitrogen, they are also susceptible to the eutrophication effect of nitrogen deposition (U.S. EPA, 2008, section 4.3.4.1).

The magnitude of ecosystem response to nutrient enrichment may be thought of on two time scales, current conditions and how ecosystems have been altered since the onset of anthropogenic nitrogen deposition. As noted previously, studies found that nitrogen-limitation occurs as frequently as phosphorous-limitation in freshwater ecosystems (U.S. EPA, 2008, section 3.3.3.2). Recently, a comprehensive study of available data from the northern hemisphere surveys of lakes along gradients of nitrogen deposition show increased inorganic nitrogen concentration and productivity to be correlated with atmospheric nitrogen deposition. The results are unequivocal evidence of nitrogen limitation in lakes with low ambient inputs of nitrogen, and increased nitrogen concentrations in lakes receiving nitrogen solely from atmospheric nitrogen deposition. It has been suggested that most lakes in the northern hemisphere may have originally been nitrogen-limited, and that atmospheric nitrogen deposition has changed the balance of nitrogen and phosphorous in lakes.

Eutrophication effects from nitrogen deposition are most likely to be manifested in undisturbed, low nutrient surface waters such as those found in the higher elevation areas of the western United States. The most severe eutrophication from nitrogen deposition effects is expected downwind of major



urban and agricultural centers. High concentrations of lake or streamwater  $\text{NO}_3^-$ , indicative of ecosystem saturation, have been found at a variety of locations throughout the United States, including the San Bernardino and San Gabriel Mountains within the Los Angeles Air Basin, the Front Range of Colorado, the Allegheny mountains of West Virginia, the Catskill Mountains of New York, the Adirondack Mountains of New York, and the Great Smoky Mountains in Tennessee (U.S. EPA, 2008, section 3.3.8).

With regard to estuaries, the ISA concludes that the evidence is sufficient to infer a causal relationship between nitrogen deposition and the biogeochemical cycling of nitrogen and carbon in estuaries (U.S. EPA, 2008, section 4.3.4.1 and 3.3.2.3). In general, estuaries tend to be nitrogen-limited, and many currently receive high levels of nitrogen input from human activities (U.S. EPA, 2009, section 5.1.1). It is unknown if atmospheric deposition alone is sufficient to cause eutrophication; however, the contribution of atmospheric nitrogen deposition to total nitrogen load is calculated for some estuaries and can be >40 percent (U.S. EPA, 2009, section 5.1.1). The evidence is also sufficient to infer a causal relationship between nitrogen deposition and the alteration of species richness, species composition and biodiversity in estuarine ecosystems (U.S. EPA, 2008, section 4.3.4.2 and 3.3.5.4). Atmospheric and non-atmospheric sources of nitrogen contribute to increased phytoplankton and algal productivity, leading to eutrophication. Shifts in community composition, reduced hypolimnetic dissolved oxygen (DO), decreases in biodiversity, and mortality of submerged aquatic vegetation are associated with increased N deposition in estuarine systems.

In contrast to terrestrial and freshwater systems, atmospheric nitrogen load to estuaries contributes to the total load but does not necessarily drive the effects since other combined sources of nitrogen often greatly exceed nitrogen deposition. In estuaries, nitrogen-loading from multiple anthropogenic and non-anthropogenic pathways leads to water quality deterioration, resulting in numerous effects including hypoxic zones, species mortality, changes in community composition and harmful algal blooms that are indicative of eutrophication.

A recent national assessment of eutrophic conditions in estuaries found that 65 percent of the assessed systems had moderate to high overall eutrophic conditions. Most eutrophic estuaries

occurred in the mid-Atlantic region and the estuaries with the lowest degree of eutrophication were in the North Atlantic. Other regions had mixtures of low, moderate, and high degrees of eutrophication (U.S. EPA, 2008, section 4.3.4.3). The mid-Atlantic region is the most heavily impacted area in terms of moderate or high loss of submerged aquatic vegetation due to eutrophication (U.S. EPA, 2008, section 4.3.4.2). Submerged aquatic vegetation is important to the quality of estuarine ecosystem habitats because it provides habitat for a variety of aquatic organisms, absorbs excess nutrients, and traps sediments (U.S. EPA, 2008, section 4.3.4.2). It is partly because many estuaries and near-coastal marine waters are degraded by nutrient enrichment that they are highly sensitive to potential negative impacts from nitrogen addition from atmospheric deposition.

### iii. Effects on Metal Toxicity

As discussed in the ISA (U.S. EPA, 2008, section 3.4.1 and 4.5), mercury is a highly neurotoxic contaminant that enters the food web as a methylated compound, methylmercury (MeHg). Mercury is principally methylated by sulfur-reducing bacteria and can be taken up by microorganisms, zooplankton and macroinvertebrates. The contaminant is concentrated in higher trophic levels, including fish eaten by humans. Experimental evidence has established that only inconsequential amounts of MeHg can be produced in the absence of sulfate. Once MeHg is present, other variables influence how much accumulates in fish, but elevated mercury levels in fish can only occur where substantial amounts of MeHg are present. Current evidence indicates that in watersheds where mercury is present, increased oxides of sulfur deposition very likely results in additional production of MeHg which leads to greater accumulation of MeHg concentrations in fish. With respect to sulfur deposition and mercury methylation, the final ISA determined that “[t]he evidence is sufficient to infer a causal relationship between sulfur deposition and increased mercury methylation in wetlands and aquatic environments.”

The production of meaningful amounts of MeHg requires the presence of  $\text{SO}_4^{2-}$  and mercury, and where mercury is present, increased availability of  $\text{SO}_4^{2-}$  results in increased production of MeHg. There is increasing evidence on the relationship between sulfur deposition and increased methylation of mercury in aquatic environments; this effect occurs only where other factors are present at levels

within a range to allow methylation. The production of MeHg requires the presence of  $\text{SO}_4^{2-}$  and mercury, but the amount of MeHg produced varies with oxygen content, temperature, pH, and supply of labile organic carbon (U.S. EPA, 2008, section 3.4). In watersheds where changes in sulfate deposition did not produce an effect, one or several of those interacting factors were not in the range required for meaningful methylation to occur (U.S. EPA, 2008, section 3.4). Watersheds with conditions known to be conducive to mercury methylation can be found in the northeastern United States and southeastern Canada.

While the ISA concluded that the evidence was sufficient to infer a causal relationship between sulfur deposition and increased MeHg production in wetlands and aquatic ecosystems, the REA concluded that there was insufficient evidence to quantify the relationship between sulfur deposition and MeHg production. Therefore, only a qualitative assessment was included in chapter 6 of the REA. As a result, the PA could not reach a conclusion as to the adequacy of the existing  $\text{SO}_2$  standards in protecting against welfare effects associated with increased mercury methylation.

## 2. Overview of Risk and Exposure Assessment

The risk and exposure assessment conducted for the current review was developed to describe potential risk from current and future deposition of oxides of nitrogen and sulfur to sensitive ecosystems. The case study analyses in the REA show that there is confidence that known or anticipated adverse ecological effects are occurring under current ambient loadings of nitrogen and sulfur in sensitive ecosystems across the United States. An overview of the analytic approaches used in the REA, a summary of the key findings from the air quality analyses and acidification and nutrient enrichment case studies, and general conclusions regarding other welfare effects are presented below.

### a. Approach to REA Analyses

The REA evaluates the relationships between atmospheric concentrations, deposition, biologically relevant exposures, targeted ecosystem effects, and ecosystem services. To evaluate the nature and magnitude of adverse effects associated with deposition, the REA also examines various ways to quantify the relationships between air quality indicators, deposition of biologically available forms of nitrogen and sulfur, ecologically relevant indicators relating

to deposition, exposure and effects on sensitive receptors, and related effects resulting in changes in ecosystem structure and services. The intent is to determine the exposure metrics that incorporate the temporal considerations (i.e., biologically relevant timescales), pathways, and ecologically relevant indicators necessary to determine the effects on these ecosystems. To the extent feasible, the REA evaluates the overall load to the system for nitrogen and sulfur, as well as the variability in ecosystem responses to these pollutants. It also evaluates the contributions of atmospherically deposited nitrogen and sulfur individually relative to the combined atmospheric loadings of both elements together. Since oxidized nitrogen is the listed criteria pollutant (currently measured by the ambient air quality indicator  $\text{NO}_2$ ) for the atmospheric contribution to total nitrogen, the REA examines the contribution of nitrogen oxides to total reactive nitrogen in the atmosphere, relative to the contributions of reduced forms of nitrogen (e.g., ammonia, ammonium), to ultimately assess how a meaningful secondary NAAQS might be structured.

The REA focuses on ecosystem welfare effects that result from the deposition of total reactive nitrogen and sulfur. Because ecosystems are diverse in biota, climate, geochemistry, and hydrology, response to pollutant exposures can vary greatly between ecosystems. In addition, these diverse ecosystems are not distributed evenly across the United States. To target nitrogen and sulfur acidification and nitrogen and sulfur enrichment, the REA addresses four main targeted ecosystem effects on terrestrial and aquatic systems identified by the ISA (U.S. EPA, 2008): Aquatic acidification due to nitrogen and sulfur; terrestrial acidification due to nitrogen and sulfur; aquatic nutrient enrichment, including eutrophication; and terrestrial nutrient enrichment. In addition to these four targeted ecosystem effects, the REA also qualitatively addresses the influence of sulfur oxides deposition on MeHg production; nitrous oxide ( $\text{N}_2\text{O}$ ) effects on climate; nitrogen effects on primary productivity and biogenic greenhouse gas (GHG) fluxes; and phytotoxic effects on plants.

Because the targeted ecosystem effects outlined above are not evenly distributed across the United States, the REA identified case studies for each targeted effects based on ecosystems identified as sensitive to nitrogen and/or sulfur deposition effects. Eight case study areas and two supplemental study areas (Rocky Mountain National Park

and Little Rock Lake, Wisconsin) are summarized in the REA based on ecosystem characteristics, indicators, and ecosystem service information. Case studies selected for aquatic acidification effects were the Adirondack Mountains and Shenandoah National Park. Kane Experimental Forest in Pennsylvania and Hubbard Brook Experimental Forest in New Hampshire were selected as case studies for terrestrial acidification. Aquatic nutrient enrichment case study locations were selected in the Potomac River Basin upstream of Chesapeake Bay and the Neuse River Basin upstream of the Pamlico Sound in North Carolina. The CSS communities in southern California and the mixed conifer forest (MCF) communities in the San Bernardino and Sierra Nevada Mountains of California were selected as case studies for terrestrial nutrient enrichment. Two supplemental areas were also chosen, one in Rocky Mountain National Park for terrestrial nutrient enrichment and one in Little Rock Lake, Wisconsin for aquatic nutrient enrichment.

For aquatic and terrestrial acidification effects, a similar conceptual approach was used (critical loads) to evaluate the impacts of multiple pollutants on an ecological endpoint, whereas the approaches used for aquatic and terrestrial nutrient enrichment were fundamentally distinct. Although the ecological indicators for aquatic and terrestrial acidification (i.e., ANC and BC/Al) are very different, both ecological indicators are well-correlated with effects such as reduced biodiversity and growth. While aquatic acidification is clearly the targeted effect area with the highest level of confidence, the relationship between atmospheric deposition and an ecological indicator is also quite strong for terrestrial acidification. The main drawback with the understanding of terrestrial acidification is that the data are based on laboratory responses rather than field measurements. Other stressors that are present in the field but that are not present in the laboratory may confound this relationship.

For nutrient enrichment effects, the REA utilized different types of indicators for aquatic and terrestrial effects to assess both the likelihood of adverse effects to ecosystems and the relationship between adverse effects and atmospheric sources of oxides of nitrogen. The ecological indicator chosen for aquatic nutrient enrichment, the Assessment of Estuarine Trophic Status Eutrophication Index (ASSETS EI), seems to be inadequate to relate atmospheric deposition to the targeted ecological effect, likely due to the many

other confounding factors. Further, there is far less confidence associated with the understanding of aquatic nutrient enrichment because of the large contributions from non-atmospheric sources of nitrogen and the influence of both oxidized and reduced forms of nitrogen, particularly in large watersheds and coastal areas. However, a strong relationship exists between atmospheric deposition of nitrogen and ecological effects in high alpine lakes in the Rocky Mountains because atmospheric deposition is the only source of nitrogen to these systems. There is also a strong weight-of-evidence regarding the relationships between ecological effects attributable to terrestrial nitrogen nutrient enrichment; however, ozone and climate change may be confounding factors. In addition, the response for other species or species in other regions of the United States has not been quantified.

#### b. Key Findings

In summary, based on case study analyses, the REA concludes that known or anticipated adverse ecological effects are occurring under current conditions and further concludes that these adverse effects continue into the future. Key findings from the air quality analyses, acidification and nutrient enrichment case studies, as well as general conclusions from evaluating additional welfare effects, are summarized below.

##### i. Air Quality Analyses

The air quality analyses in the REA encompass the current emissions sources of nitrogen and sulfur, as well as atmospheric concentrations, estimates of deposition of total nitrogen, policy-relevant background, and non-atmospheric loadings of nitrogen and sulfur to ecosystems, both nationwide and in the case study areas. Spatial fields of deposition were created using wet deposition measurements from the NADP National Trends Network and dry deposition predictions from the 2002 CMAQ model simulation. Some key conclusions from this analysis are:

(1) Total reactive nitrogen deposition and sulfur deposition are much greater in the East compared to most areas of the West.

(2) These regional differences in deposition correspond to the regional differences in oxides of nitrogen and  $\text{SO}_2$  concentrations and emissions, which are also higher in the East. Oxides of nitrogen emissions are much greater and generally more widespread than ammonia ( $\text{NH}_3$ ) emissions nationwide; high  $\text{NH}_3$  emissions tend to be more local (e.g., eastern North Carolina) or sub-regional (e.g., the upper

Midwest and Plains states). The relative amounts of oxidized versus reduced nitrogen deposition are consistent with the relative amounts of oxides of nitrogen and NH<sub>3</sub> emissions. Oxidized nitrogen deposition exceeds reduced nitrogen deposition in most of the case study areas; the major exception being the Neuse River/Neuse River Estuary Case Study Area.

(3) Reduced nitrogen deposition exceeds oxidized nitrogen deposition in the vicinity of local sources of NH<sub>3</sub>.

(4) There can be relatively large spatial variations in both total reactive nitrogen deposition and sulfur deposition within a case study area; this occurs particularly in those areas that contain or are near a high emissions source of oxides of nitrogen, NH<sub>3</sub> and/or SO<sub>2</sub>.

(5) The seasonal patterns in deposition differ between the case study areas. For the case study areas in the East, the season with the greatest amounts of total reactive nitrogen deposition correspond to the season with the greatest amounts of sulfur deposition. Deposition peaks in spring in the Adirondack, Hubbard Brook Experimental Forest, and Kane Experimental Forest case study areas, and it peaks in summer in the Potomac River/Potomac Estuary, Shenandoah, and Neuse River/Neuse River Estuary case study areas. For the case study areas in the West, there is less consistency in the seasons with greatest total reactive nitrogen and sulfur deposition in a given area. In general, both nitrogen and/or sulfur deposition peaks in spring or summer. The exception to this is the Sierra Nevada Range portion of the MCF Case Study Area, in which sulfur deposition is greatest in winter.

#### ii. Aquatic Acidification Case Studies

The role of aquatic acidification in two eastern United States areas—northeastern New York's Adirondack area and the Shenandoah area in Virginia—was analyzed in the REA to assess surface water trends in SO<sub>4</sub><sup>2-</sup> and NO<sub>3</sub><sup>-</sup> concentrations and ANC levels and to affirm the understanding that reductions in deposition could influence the risk of acidification. Monitoring data from the EPA-administered Temporally Integrated Monitoring of Ecosystems/Long-Term Monitoring (TIME/LTM) programs and the Environmental Monitoring and Assessment Program (EMAP) were assessed for the years 1990 to 2006, and past, present and future water quality levels were estimated using both steady-state and dynamic biogeochemical models.

Although wet deposition rates for SO<sub>2</sub> and oxides of nitrogen in the Adirondack Case Study Area have reduced since the mid-1990s, current concentrations are still well above pre-acidification (1860) conditions. For a discussion of the uncertainties of pre-acidification, see U.S. EPA, 2011, Appendix F. The Model of Acidification of Groundwater in Catchments (MAGIC) modeling predicts NO<sub>3</sub><sup>-</sup> and SO<sub>4</sub><sup>2-</sup> are 17- and 5-fold higher today, respectively. The estimated average ANC for 44 lakes in the Adirondack Case Study Area is 62.1 µeq/L (±15.7 µeq/L); 78 percent of all monitored lakes in the Adirondack Case Study Area have a current risk of Elevated, Severe, or Acute. Of the 78 percent, 31 percent experience episodic acidification, and 18 percent are chronically acidic today.

(1) Based on the steady-state critical load model for the year 2002, 18 percent, 28 percent, 44 percent, and 58 percent of 169 modeled lakes received combined total sulfur and nitrogen deposition that exceeded critical loads corresponding to ANC limits of 0, 20, 50, and 100 µeq/L respectively.

(2) Based on a deposition scenario that maintains current emission levels to 2020 and 2050, the simulation forecast indicates no improvement in water quality in the Adirondack Case Study Area. The percentage of lakes within the Elevated to Acute Concern classes remains the same in 2020 and 2050.

(3) Since the mid-1990s, streams in the Shenandoah Case Study Area have shown slight declines in NO<sub>3</sub> and SO<sub>4</sub><sup>2-</sup> concentrations in surface waters. The ANC levels increased from about 50 µeq/L in the early 1990s to >75 µeq/L until 2002, when ANC levels declined back to 1991–1992 levels. Current concentrations are still above pre-acidification (1860) conditions. The MAGIC modeling predicts surface water concentrations of NO<sub>3</sub> and SO<sub>4</sub><sup>2-</sup> are 10- and 32-fold higher today, respectively. The estimated average ANC for 60 streams in the Shenandoah Case Study Area is 57.9 µeq/L (±4.5 µeq/L). Fifty-five percent of all monitored streams in the Shenandoah Case Study Area have a current risk of Elevated, Severe, or Acute. Of the 55 percent, 18 percent experience episodic acidification, and 18 percent are chronically acidic today.

(4) Based on the steady-state critical load model for the year 2002, 52 percent, 72 percent, 85 percent and 93 percent of 60 modeled streams received combined total sulfur and nitrogen deposition that exceeded critical loads corresponding to ANC limits of 0, 20, 50, and 100 µeq/L respectively.

(5) Based on a deposition scenario that maintains current emission levels to 2020 and 2050, the simulation forecast indicates that a large number of streams would still have Elevated to Acute problems with acidity.

#### iii. Terrestrial Acidification Case Studies

The role of terrestrial acidification was examined in the REA using a critical load analysis for sugar maple and red spruce forests in the eastern United States by using the BC/Al ratio in acidified forest soils as an indicator to assess the impact of nitrogen and sulfur deposition on tree health. These are the two most commonly studied species in North America for impacts of acidification. At a BC/Al ratio of 1.2, red spruce growth can be reduced by 20 percent. Sugar maple growth can be reduced by 20 percent at a BC/Al ratio of 0.6. Key findings of the case study are summarized below.

(1) Case study results suggest that the health of at least a portion of the sugar maple and red spruce growing in the United States may have been compromised with acidifying total nitrogen and sulfur deposition in 2002. The 2002 CMAQ/NADP total nitrogen and sulfur deposition levels exceeded three selected critical loads in 3 percent to 75 percent of all sugar maple plots across 24 states. The three critical loads ranged from 6,008 to 107 eq/ha/yr for the BC/Al ratios of 0.6, 1.2, and 10.0 (increasing levels of tree protection). The 2002 CMAQ/NADP total nitrogen and sulfur deposition levels exceeded three selected critical loads in 3 percent to 36 percent of all red spruce plots across eight states. The three critical loads ranged from 4,278 to 180 eq/ha/yr for the BC/Al ratios of 0.6, 1.2, and 10.0 (increasing levels of tree protection).

(2) The SMB model assumptions made for base cation weathering (Bcw) and forest soil ANC input parameters are the main sources of uncertainty since these parameters are rarely measured and require researchers to use default values.

(3) The pattern of case study results suggests that nitrogen and sulfur acidifying deposition in the sugar maple and red spruce forest areas studied were similar in magnitude to the critical loads for those areas and both ecosystems are likely to be sensitive to any future changes in the levels of deposition.

#### iv. Aquatic Nutrient Enrichment Case Studies

The role of nitrogen deposition in two main stem rivers feeding their respective estuaries was analyzed in the REA to determine if decreases in deposition could influence the risk of eutrophication as predicted using the ASSETS EI scoring system in tandem with SPARROW (SPATIally Referenced Regression on Watershed Attributes) modeling. This modeling approach provides a transferrable, intermediate-level analysis of the linkages between atmospheric deposition and receiving waters, while providing results on which conclusions could be drawn. A summary of findings follows:

(1) The 2002 CMAQ/NADP results showed that an estimated 40,770,000 kilograms (kg) of total nitrogen was deposited in the Potomac River watershed. The SPARROW modeling predicted that 7,380,000 kg N/yr of the deposited nitrogen reached the estuary (20 percent of the total load to the estuary). The overall ASSETS EI for the Potomac River and Potomac Estuary was Bad (based on all sources of N).

(2) To improve the Potomac River and Potomac Estuary ASSETS EI score from Bad to Poor, a decrease of at least 78 percent in the 2002 total nitrogen atmospheric deposition load to the watershed would be required.

(3) The 2002 CMAQ/NADP results showed that an estimated 18,340,000 kg of total nitrogen was deposited in the Neuse River watershed. The SPARROW modeling predicted that 1,150,000 kg N/yr of the deposited nitrogen reached the estuary (26 percent of the total load to the estuary). The overall ASSETS EI for the Neuse River/Neuse River Estuary was Bad.

(4) It was found that the Neuse River/Neuse River Estuary ASSETS EI score could not be improved from Bad to Poor with decreases only in the 2002 atmospheric deposition load to the watershed. Additional reductions would be required from other nitrogen sources within the watershed.

The small effect of decreasing atmospheric deposition in the Neuse River watershed is because the other nitrogen sources within the watershed are more influential than atmospheric deposition in affecting the total nitrogen loadings to the Neuse River Estuary, as estimated with the SPARROW model. A water body's response to nutrient loading depends on the magnitude (e.g., agricultural sources have a higher influence in the Neuse than in the Potomac), spatial distribution, and other characteristics of the sources within the watershed; therefore a reduction in

nitrogen deposition does not always produce a linear response in reduced load to the estuary, as demonstrated by these two case studies.

#### v. Terrestrial Nutrient Enrichment Case Studies

California CSS and MCF communities were the focus of the Terrestrial Nutrient Enrichment Case Studies of the REA. Geographic information systems analysis supported a qualitative review of past field research to identify ecological benchmarks associated with CSS and mycorrhizal communities, as well as MCF's nutrient-sensitive acidophyte lichen communities, fine-root biomass in Ponderosa pine and leached nitrate in receiving waters. These benchmarks, ranging from 3.1 to 17 kg N/ha/yr, were compared to 2002 CMAQ/NADP data to discern any associations between atmospheric deposition and changing communities. Evidence supports the finding that nitrogen alters CSS and MCF. Key findings include the following:

(1) The 2002 CMAQ/NADP nitrogen deposition data show that the 3.3 kg N/ha/yr benchmark has been exceeded in more than 93 percent of CSS areas (654,048 ha). This suggests that such deposition is a driving force in the degradation of CSS communities. One potentially confounding factor is the role of fire. Although CSS decline has been observed in the absence of fire, the contributions of deposition and fire to the CSS decline require further research. The CSS is fragmented into many small parcels, and the 2002 CMAQ/NADP 12-km grid data are not fine enough to fully validate the relationship between CSS distribution, nitrogen deposition, and fire.

(2) The 2002 CMAQ/NADP nitrogen deposition data exceeds the 3.1 kg N/ha/yr benchmark in more than 38 percent (1,099,133 ha) of MCF areas, and nitrate leaching has been observed in surface waters. Ozone effects confound nitrogen effects on MCF acidophyte lichen, and the interrelationship between fire and nitrogen cycling requires additional research.

#### c. Other Welfare Effects

Ecological effects have also been documented across the United States where elevated nitrogen deposition has been observed, including the eastern slope of the Rocky Mountains where shifts in dominant algal species in alpine lakes have occurred where wet nitrogen deposition was only about 1.5 kg N/ha/yr. High alpine terrestrial communities have a low capacity to sequester nitrogen deposition, and monitored deposition exceeding 3 to 4

kg N/ha/yr could lead to community-level changes in plant species, lichens and mycorrhizae.

Additional welfare effects are documented, but examined less extensively, in the REA. These effects include qualitative discussions related to visibility and materials damage, such as corrosion, erosion, and soiling of paint and buildings which are being addressed in the PM NAAQS review currently underway. A discussion of the causal relationship between sulfur deposition (as sulfate,  $\text{SO}_4^{2-}$ ) and increased mercury methylation in wetlands and aquatic environments is also included in the REA. On this subject the REA concludes that decreases in  $\text{SO}_4^{2-}$  deposition will likely result in decreases in MeHg concentration; however, spatial and biogeochemical variations nationally hinder establishing large scale dose-response relationships.

Several additional issues concerning oxides of nitrogen were addressed in the REA. Consideration was also given to  $\text{N}_2\text{O}$ , a potent GHG. The REA concluded that it is most appropriate to analyze the role of  $\text{N}_2\text{O}$  in the context of all of the GHGs rather than as part of the REA for this review. The REA considered nitrogen deposition and its correlation with the rate of photosynthesis and net primary productivity. Nitrogen addition ranging from 15.4 to 300 kg N/ha/yr is documented as increasing wetland  $\text{N}_2\text{O}$  production by an average of 207 percent across all ecosystems. Nitrogen addition ranging from 30 to 240 kg N/ha/yr increased methane ( $\text{CH}_4$ ) emissions by 115 percent, averaged across all ecosystems, and methane uptake was reduced by 38 percent averaged across all ecosystems when nitrogen addition ranged from 10 to 560 kg N/ha/yr, but reductions were only significant for coniferous and deciduous forests. The heterogeneity of ecosystems across the United States, however, introduces variations into dose-response relationships.

The phytotoxic effects of oxides of nitrogen and sulfur on vegetation were also briefly discussed in the REA which concluded that since a unique secondary NAAQS exists for  $\text{SO}_2$ , and concentrations of nitric oxide (NO),  $\text{NO}_2$  and PAN are rarely high enough to have phytotoxic effects on vegetation, further assessment was not warranted at this time.

#### 3. Overview of Adversity of Effects to Public Welfare

Characterizing a known or anticipated adverse effect to public welfare is an important component of developing any secondary NAAQS. According to the

CAA, welfare effects include: “effects on soils, water, crops, vegetation, manmade materials, animals, wildlife, weather, visibility, and climate, damage to and deterioration of property, and hazards to transportation, as well as effect on economic values and on personal comfort and well-being, whether caused by transformation, conversion, or combination with other air pollutants” (CAA, Section 302(h)). While the text above lists a number of welfare effects, these effects do not define public welfare in and of themselves.

Although there is no specific definition of adversity to public welfare, the paradigm of linking adversity to public welfare to disruptions in ecosystem structure and function has been used broadly by the EPA to categorize effects of pollutants from the cellular to the ecosystem level. An evaluation of adversity to public welfare might consider the likelihood, type, magnitude, and spatial scale of the effect as well as the potential for recovery and any uncertainties relating to these considerations.

Similar concepts were used in past reviews of secondary NAAQS for ozone and PM (relating to visibility), as well as in initial reviews of effects from lead deposition. Because oxides of nitrogen and sulfur are deposited from ambient sources into ecosystems where they affect changes to organisms, populations and ecosystems, the concept of adversity to public welfare as a result of alterations in structure and function of ecosystems is an appropriate consideration for this review.

Based on information provided in the PA, the following section discusses how ecological effects from deposition of oxides of nitrogen and sulfur relate to adversity to public welfare. In the PA, public welfare was discussed in terms of loss of ecosystem services (defined below), which in some cases can be monetized. Each of the four main effect areas (aquatic and terrestrial acidification and aquatic and terrestrial nutrient over-enrichment) are discussed including current ecological effects and associated ecosystem services.

#### a. Ecosystem Services

The PA defines ecosystem services as the benefits individuals and organizations obtain from ecosystems. Ecosystem services can be classified as provisioning (food and water), regulating (control of climate and disease), cultural (recreational, existence, spiritual, educational), and supporting (nutrient cycling). Conceptually, changes in ecosystem services may be used to aid in characterizing a known or anticipated

adverse effect to public welfare. In the REA and PA ecosystem services are discussed as a method of assessing the magnitude and significance to the public of resources affected by ambient concentrations of oxides of nitrogen and sulfur and deposition in sensitive ecosystems.

The EPA has in previous NAAQS reviews defined ecological goods and services for the purposes of a Regulatory Impact Analysis (RIA) as the “outputs of ecological functions or processes that directly or indirectly contribute to social welfare or have the potential to do so in the future. Some outputs may be bought and sold, but most are not marketed.” It is especially important to acknowledge that it is difficult to measure and/or monetize the goods and services supplied by ecosystems. It can be informative in characterizing adversity to public welfare to attempt to place an economic valuation on the set of goods and services that have been identified with respect to a change in policy however it must be noted that this valuation will be incomplete and illustrative only.

Knowledge about the relationships linking ambient concentrations and ecosystem services is considered in the PA as one method by which to inform a policy judgment on a known or anticipated adverse public welfare effect. For example, a change in an ecosystem structure and process, such as foliar injury, would be classified as an ecological effect, with the associated changes in ecosystem services, such as primary productivity, food availability, forest products, and aesthetics (e.g., scenic viewing), classified as public welfare effects. Additionally, changes in biodiversity would be classified as an ecological effect, and the associated changes in ecosystem services—productivity, existence (nonuse) value, recreational viewing and aesthetics—would also be classified as public welfare effects.

As described in chapters 4 and 5 of the REA, case study analyses were performed that link deposition in sensitive ecosystems to changes in a given ecological indicator (e.g., for aquatic acidification, to changes in ANC) and then to changes in ecosystems. Appendix 8 of the REA links the changes in ecosystems to the services they provide (e.g., fish species richness and its influence on recreational fishing). To the extent possible for each targeted effect area, the REA linked ambient concentrations of nitrogen and sulfur (i.e., ambient air quality indicators) to deposition in sensitive ecosystems (i.e., exposure pathways), and then to system response

as measured by a given ecological indicator (e.g., lake and stream acidification as measured by ANC). The ecological effect (e.g., changes in fish species richness) was then, where possible, associated with changes in ecosystem services and the corresponding public welfare effects (e.g., recreational fishing).

#### b. Effects on Ecosystem Services

The process used to link ecological indicators to ecosystem services is discussed extensively in appendix 8 of the REA. In brief, for each case study area assessed, the ecological indicators are linked to an ecological response that is subsequently linked to associated services to the extent possible. For example, in the case study for aquatic acidification the chosen ecological indicator is ANC which can be linked to the ecosystem service of recreational fishing. Although recreational fishing losses are the only service effects that can be independently quantified or monetized at this time, there are numerous other ecosystem services that may be related to the ecological effects of acidification.

While aquatic acidification is the focus of this proposed standard, the other effect areas were also analyzed in the REA and these ecosystems are being harmed by nitrogen and sulfur deposition and will obtain some measure of protection with any decrease in that deposition regardless of the reason for the decrease. The following summarizes the current levels of specific ecosystem services for aquatic and terrestrial acidification and aquatic and terrestrial nutrient over-enrichment and attempts to quantify and when possible monetize the harm to public welfare, as represented by ecosystem services, due to nitrogen and sulfur deposition.

##### i. Aquatic Acidification

Acidification of aquatic ecosystems primarily affects the ecosystem services that are derived from the fish and other aquatic life found in surface waters. In the northeastern United States, the surface waters affected by acidification are not a major source of commercially raised or caught fish; however, they are a source of food for some recreational and subsistence fishers and for other consumers. Although data and models are available for examining the effects on recreational fishing, relatively little data are available for measuring the effects on subsistence and other consumers. Inland waters also provide aesthetic and educational services along with non-use services, such as existence value (protection and preservation with

no expectation of direct use). In general, inland surface waters such as lakes, rivers, and streams also provide a number of regulating services, playing a role in hydrological regimes and climate regulation. There is little evidence that acidification of freshwaters in the northeastern United States has significantly degraded these specific services; however, freshwater ecosystems also provide biological control services by providing environments that sustain delicate aquatic food chains. The toxic effects of acidification on fish and other aquatic life impair these services by disrupting the trophic structure of surface waters. Although it is difficult to quantify these services and how they are affected by acidification, it is worth noting that some of these services may be captured through measures of provisioning and cultural services. For example, these biological control services may serve as “intermediate” inputs that support the production of “final” recreational fishing and other cultural services.

As summarized in Chapter 4 of the PA, recent studies indicate that acidification of lakes and streams can result in significant loss in economic value. Embedded in these numbers is a degree of harm to recreational fishing services due to acidification that has occurred over time. These harms have not been quantified on a regional scale; however, a case study was conducted in the Adirondacks area (U.S. EPA, 2011, section 4.4.2).

In the Adirondacks case study, estimates of changes in recreational fishing services were determined, as well as changes more broadly in “cultural” ecosystem services (including recreational, aesthetic, and nonuse services). First, the MAGIC model (U.S. EPA, 2009, Appendix 8 and section 2.2) was applied to 44 lakes to predict what ANC levels would be under both “business as usual” conditions (i.e., allowing for some decline in deposition due to existing regulations) and pre-emission (i.e., background) conditions. Second, to estimate the recreational fishing impacts of aquatic acidification in these lakes, an existing model of recreational fishing demand and site choice was applied. This model predicts how recreational fishing patterns in the Adirondacks would differ and how much higher the average annual value of recreational fishing services would be for New York residents if lake ANC levels corresponded to background (rather than business as usual) conditions. To estimate impacts on a broader category of cultural (and some provisioning) ecosystem services, results from the

Banzhaf et al (2006) valuation survey of New York residents were adapted and applied to this context. The focus of the survey was on impacts on aquatic resources. Pretesting of the survey indicated that respondents nonetheless tended to assume that benefits would occur in the condition of birds and forests as well as in recreational fishing.

The REA estimated 44 percent of the Adirondack lakes currently fall below an ANC of 50  $\mu\text{eq/L}$ . Several states have set goals for improving the acid status of lakes and streams, generally targeting ANC in the range of 50 to 60  $\mu\text{eq/L}$ , and have engaged in costly activities to decrease acidification.

These results imply significant value to the public in addition to those derived from recreational fishing services. Note that the results are only applicable to improvements in the Adirondacks valued by residents of New York. If similar benefits exist in other acid-impacted areas, benefits for the nation as a whole could be substantial. The analysis provides results on only a subset of the impacts of acidification on ecosystem services and suggests that the overall impact on these services could be substantial.

#### ii. Terrestrial Acidification

Chapters 4.4.3 and 4.4.4 of the PA review several economic studies of areas sensitive to terrestrial acidification. Forests in the northeastern United States provide several important and valuable provisioning ecosystem services, which are reflected in the production and sales of tree products. Sugar maples are a particularly important commercial hardwood tree species in the United States, producing timber and maple syrup that provide hundreds of millions of dollars in economic value annually. Red spruce is also used in a variety of wood products and provides up to \$100 million in economic value annually. Although the data do not exist to directly link acidification damages to economic values of lost recreational ecosystem services in forests, these resources are valuable to the public. The EPA is not able to quantify at this time the specific effects on these values of acid deposition, or of any specific reductions in deposition, relative to the effects of many other factors that may affect them.

#### iii. Nutrient Enrichment

Chapters 4.4.5 and 4.4.6 of the PA summarize economic studies of east coast estuaries affected by nutrient over-enrichment or eutrophication. Estuaries in the eastern United States are important for fish and shellfish production. The estuaries are capable of

supporting large stocks of resident commercial species, and they serve as the breeding grounds and interim habitat for several migratory species. To provide an indication of the magnitude of provisioning services associated with coastal fisheries, from 2005 to 2007, the average value of total catch was \$1.5 billion per year in 15 East Coast states. Estuaries also provide an important and substantial variety of cultural ecosystem services, including water-based recreational and aesthetic services. For example, data indicate that 4.8 percent of the population in coastal states from North Carolina to Massachusetts participated in saltwater fishing, with a total of 26 million saltwater fishing days in 2006. Recreational participation estimates for 1999–2000 showed almost 6 million individuals participated in motor boating in coastal states from North Carolina to Massachusetts. The EPA is not able to quantify at this time the specific effects on these values of nitrogen deposition, or of any specific reductions in deposition, relative to the effects of many other factors that may affect them.

Terrestrial ecosystems can also suffer from nutrient over-enrichment. Each ecosystem is different in its composition of species and nutrient requirements. Changes to individual ecosystems from changes in nitrogen deposition can be hard to assess economically. Relative recreational values are often determined by public use information. Chapter 4.4.7 of the PA reviewed studies related to park use in California. Data from California State Parks indicate that in 2002, 68.7 percent of surveyed individuals participated in trail hiking for an average of 24.1 days per year. The EPA is not able to quantify at this time the specific effects on these values of nitrogen deposition, or of any specific reductions in deposition, relative to the effects of many other factors that may affect them.

The PA also identified fire regulation as a service that could be affected by nutrient over-enrichment of the CSS and MCF ecosystems by encouraging growth of more flammable grasses, increasing fuel loads, and altering the fire cycle. Over the 5-year period from 2004 to 2008, Southern California experienced, on average, over 4,000 fires per year, burning, on average, over 400,000 acres per year. It is not possible at this time to quantify the contribution of nitrogen deposition, among many other factors, to increased fire risk.

#### c. Summary

Adversity to public welfare can be understood by looking at how deposition of oxides of nitrogen and

sulfur affect the ecological functions of an ecosystem (see II.A.), and then understanding the ecosystem services that are degraded. The monetized value of the ecosystem services provided by ecosystems that are sensitive to deposition of oxides of nitrogen and sulfur are in the billions of dollars each year, though it is not possible to quantify or monetize at this time the effects on these values of nitrogen and sulfur deposition or of any changes in deposition that may result from new secondary standards. Many lakes and streams are known to be degraded by acidic deposition which affects recreational fishing and tourism. Forest growth is likely suffering from acidic deposition in sensitive areas affecting red spruce and sugar maple timber production, sugar maple syrup production, hiking, aesthetic enjoyment and tourism. Nitrogen deposition contributes significantly to eutrophication in many estuaries affecting fish production, swimming, boating, aesthetic enjoyment and tourism. Ecosystem services are likely affected by nutrient enrichment in many natural and scenic terrestrial areas, affecting biodiversity, including habitat for rare and endangered species, fire control, hiking, aesthetic enjoyment and tourism.

**B. Adequacy of the Current Standards**

An important issue to be addressed in this review of the secondary standards for oxides of nitrogen and sulfur is whether, in view of the scientific evidence reflected in the ISA, additional information on exposure and risk discussed in the REA, and conclusions drawn from the PA, the current standards provide adequate protection of public welfare. In this review, consideration is given to the adequacy of the current standards with regard to both the direct effects of exposure to gaseous oxides of nitrogen and sulfur on vegetation and on potentially adverse deposition-related effects on sensitive aquatic and terrestrial ecosystems. This section is drawn from section II.D of the proposal. The following discussion summarizes the considerations related to the adequacy of the standards as discussed in the PA (section II.B.1), CASAC's views on adequacy (section II.B.2), and the Administrator's proposed conclusions on the adequacy of the current standards.

**1. Adequacy Considerations**

This discussion is based on the information presented in the PA and includes considerations related to the adequacy of the current NO<sub>2</sub> and SO<sub>2</sub> secondary standards with regard to

direct effects (section II.B.1.a), as well as considerations related to both the appropriateness and the adequacy of protection of the current standards with regard to deposition-related effects (section II.B.1.b).

**a. Adequacy of the Current Standards for Direct Effects**

For oxides of nitrogen, the current secondary standard was set identical to the primary standard,<sup>3</sup> i.e., an annual standard set for NO<sub>2</sub> to protect against adverse effects on vegetation from direct exposure to ambient oxides of nitrogen. For oxides of sulfur, the current secondary standard is a 3-hour standard intended to provide protection for plants from the direct foliar damage associated with atmospheric concentrations of SO<sub>2</sub>. In considering the adequacy of these standards, it is appropriate to consider whether they are adequate to protect against the direct effects on vegetation resulting from exposure to ambient oxides of nitrogen and sulfur, which was the basis for initially setting the standards in 1971. The ISA concludes that there was sufficient evidence to infer a causal relationship between exposure to SO<sub>2</sub>, NO, NO<sub>2</sub> and PAN and injury to vegetation. Additional research on acute foliar injury has been limited and there is no evidence to suggest foliar injury below the levels of the current secondary standards. Based on information in the ISA, the PA concludes that there is sufficient evidence to suggest that the levels of the current standards are likely adequate to protect against phytotoxic effects caused by direct gas-phase exposure.

**b. Appropriateness and Adequacy of the Current Standards for Deposition-related Effects**

This section addresses two concepts necessary to evaluate the current standards in the context of deposition-related effects. First, appropriateness of the current standards is considered with regard to indicator, form, level and averaging time. This discussion includes particular emphasis on the indicators and forms of the current standards and the degree to which they are ecologically relevant with regard to deposition-related effects that vary spatially and temporally. Second, this section considers the current standards in terms of adequacy of protection.

<sup>3</sup> The current primary NO<sub>2</sub> standard has recently been changed to the 3-year average of the 98th percentile of the annual distribution of the 1 hour daily maximum of the concentration of NO<sub>2</sub>. The current secondary standard remains as it was set in 1971.

**i. Appropriateness**

The ISA has established that the major effects of concern for this review are associated with deposition of nitrogen and sulfur caused by atmospheric concentrations of oxides of nitrogen and sulfur. As discussed below, the current standards are not directed toward depositional effects, and none of the elements of the current NAAQS—indicator, form, averaging time, and level—are suited for addressing the effects of nitrogen and sulfur deposition.

Four issues arise that call into question the ecological relevance of the structure of the current secondary standards for oxides of nitrogen and sulfur.

(1) The current SO<sub>2</sub> secondary standard (0.5 ppm SO<sub>2</sub> over a 3-hour average) does not utilize an averaging time that relates to an exposure period that is relevant for ecosystem impacts. The majority of deposition-related impacts are associated with depositional loads that occur over periods of months to years. This differs significantly from exposures associated with hourly concentrations of SO<sub>2</sub> as measured by the current secondary standard. By addressing short-term concentrations, the current SO<sub>2</sub> secondary standard, while protective against direct foliar effects from gaseous oxides of sulfur, does not take into account the findings of effects in the ISA, which notes the relationship between annual deposition of sulfur and acidification effects which are likely to be more severe and widespread than phytotoxic effects under current ambient conditions, and include effects from long-term and short-term deposition. Acidification is a process that occurs over time because the ability of an aquatic system to counteract acidic inputs is reduced as natural buffers are used more rapidly than they can be replaced through geologic weathering. The relevant period of exposure for ecosystems is, therefore, not the exposures captured in the short averaging time of the current SO<sub>2</sub> secondary standard. The current secondary standard for oxides of nitrogen is an annual standard (0.053 ppm averaged over 1 year) and as such the averaging time of the standard is more ecologically relevant.

(2) Current standards do not utilize appropriate atmospheric indicators. Nitrogen dioxide and SO<sub>2</sub> are used as the species of oxides of nitrogen and sulfur that are measured to determine compliance with the standards, but they do not capture all relevant chemical species of oxides of nitrogen and sulfur that contribute to deposition-related

effects. The ISA provides evidence that deposition-related effects are associated with *total* nitrogen and *total* sulfur deposition, and thus all chemical species of oxidized nitrogen and oxidized sulfur that are deposited will contribute to effects on ecosystems. Thus, by using atmospheric NO<sub>2</sub> and SO<sub>2</sub> concentrations as indicators, the current standards address only a fraction of total atmospheric oxides of nitrogen and sulfur, and do not take into account the effects from deposition of total atmospheric oxides of nitrogen and sulfur. This suggests that more comprehensive atmospheric indicators should be considered in designing ecologically relevant standards.

(3) Current standards reflect separate assessments of the two individual pollutants, NO<sub>2</sub> and SO<sub>2</sub>, rather than assessing the joint impacts of deposition of nitrogen and sulfur to ecosystems. Recognizing the role that each pollutant plays in jointly affecting ecosystem indicators, functions, and services is vital to developing a meaningful standard. The clearest example of this interaction is in assessment of the impacts of acidifying deposition on aquatic ecosystems. Acidification in an aquatic ecosystem depends on the total acidifying potential of the nitrogen and sulfur deposition resulting from oxides of nitrogen and sulfur as well as the inputs from other sources of nitrogen and sulfur such as reduced nitrogen and non-atmospheric sources. It is the joint impact of the two pollutants that determines the ultimate effect on organisms within the ecosystem, and critical ecosystem functions such as habitat provision and biodiversity. Standards that are set independently are less able to account for the contribution of the other pollutant. This suggests that interactions between oxides of nitrogen and oxides of sulfur should be a critical element of the conceptual framework for ecologically relevant standards. There are also important interactions between oxides of nitrogen and sulfur and reduced forms of nitrogen, which also contribute to acidification and nutrient enrichment. It is important that the structure of the standards address the role of reduced nitrogen in determining the ecological effects resulting from deposition of atmospheric oxides of nitrogen and sulfur. Consideration will also have to be given to total loadings as ecosystems respond to all sources of nitrogen and sulfur.

(4) Current standards do not take into account variability in ecosystem sensitivity. Ecosystems are not uniformly distributed either spatially or temporally in their sensitivity to oxides of nitrogen and sulfur. Therefore, failure

to account for the major determinants of variability, including geological and soil characteristics related to the sensitivity to acidification or nutrient enrichment, as well as atmospheric and landscape characteristics that govern rates of deposition, may lead to standards that do not provide requisite levels of protection across ecosystems. The current structures of the standards do not address the complexities in the responses of ecosystems to deposition of oxides of nitrogen and sulfur. Ecosystems contain complex groupings of organisms that respond in various ways to the alterations of soil and water that result from deposition of nitrogen and sulfur compounds. Different ecosystems therefore respond depending on a multitude of factors that control how deposition is integrated into the system. For example, the same levels of deposition falling on limestone dominated soils have a very different effect from those falling on shallow glaciated soils underlain with granite. One system may over time display no obvious detriment while the other may experience a catastrophic loss in fish communities. This degree of sensitivity is a function of many atmospheric factors that control rates of deposition as well as ecological factors that control how an ecosystem responds to that deposition. The current standards do not take into account spatial and seasonal variations, not only in depositional loadings, but also in sensitivity of ecosystems exposed to those loadings. Based on the discussion summarized above, the PA concludes that the current secondary standards for oxides of nitrogen and oxides of sulfur are not ecologically relevant in terms of averaging time, form, level or indicator.

#### ii. Adequacy of Protection

As described in the PA, ambient conditions in 2005 indicate that the current SO<sub>2</sub> and NO<sub>2</sub> secondary standards were not exceeded at that time (U.S. EPA, 2011, Figures 6–1 and 6–2) in locations where negative ecological effects have been observed. In many locations, SO<sub>2</sub> and NO<sub>2</sub> concentrations are substantially below the levels of the secondary standards. This pattern suggests that levels of deposition and any negative effects on ecosystems due to deposition of oxides of nitrogen and sulfur under recent conditions are occurring even though areas meet or are below current standards. In addition, based on conclusions in the REA, these levels will not decline in the future to levels below which it is reasonable to anticipate effects.

In determining the adequacy of the current secondary standards for oxides of nitrogen and sulfur the PA considered the extent to which ambient deposition contributes to loadings in ecosystems. Since the last review of the secondary standard for oxides of nitrogen, a great deal of information on the contribution of atmospheric deposition associated with ambient oxides of nitrogen has become available. The REA presents a thorough assessment of the contribution of oxidized nitrogen relative to total nitrogen deposition throughout the United States, and the relative contributions of ambient oxidized and reduced forms of nitrogen. The REA concludes that based on that analysis, ambient oxides of nitrogen are a significant component of atmospheric nitrogen deposition, even in areas with relatively high rates of reduced nitrogen deposition. In addition, atmospheric deposition of oxidized nitrogen contributes significantly to total nitrogen loadings in nitrogen sensitive ecosystems.

The ISA summarizes the available studies of relative nitrogen contribution and finds that in much of the United States, oxides of nitrogen contribute from 50 to 75 percent of total atmospheric deposition relative to total reactive nitrogen, which includes oxidized and reduced nitrogen species (U.S. EPA, 2008, section 2.8.4). Although the proportion of total nitrogen loadings associated with atmospheric deposition of nitrogen varies across locations, the ISA indicates that atmospheric nitrogen deposition is the main source of new anthropogenic nitrogen to most headwater streams, high elevation lakes, and low-order streams. Atmospheric nitrogen deposition contributes to the total nitrogen load in terrestrial, wetland, freshwater and estuarine ecosystems that receive nitrogen through multiple pathways. In several large estuarine systems, including the Chesapeake Bay, atmospheric deposition accounts for between 10 and 40 percent of total nitrogen loadings (U.S. EPA, 2008).

Atmospheric concentrations of oxides of sulfur account for nearly all sulfur deposition in the U.S. For the period 2004–2006, mean sulfur deposition in the United States was greatest east of the Mississippi River with the highest deposition amount, 21.3 kg S/ha-yr, in the Ohio River Valley where most recording stations reported 3-year averages >10 kg S/ha-yr. Numerous other stations in the East reported S deposition >5 kg S/ha-yr. Total sulfur deposition in the United States west of



the 100th meridian was relatively low, with all recording stations reporting <2 kg S/ha-yr and many reporting <1 kg S/ha-yr. Sulfur was primarily deposited in the form of wet  $\text{SO}_4^{2-}$  followed in decreasing order by a smaller proportion of dry  $\text{SO}_2$  and a much smaller proportion of deposition as dry  $\text{SO}_4^{2-}$ .

As discussed throughout the REA (U.S. EPA, 2009 and section II.B above), there are several key areas of risk that are associated with ambient concentrations of oxides of nitrogen and sulfur. As noted earlier, in previous reviews of the secondary standards for oxides of nitrogen and sulfur, the standards were designed to protect against direct exposure of plants to ambient concentrations of the pollutants. A significant shift in understanding of the effects of oxides of nitrogen and sulfur has occurred since the last reviews, reflecting the large amount of research that has been conducted on the effects of deposition of nitrogen and sulfur to ecosystems. The most significant current risks of adverse effects to public welfare are those related to deposition of oxides of nitrogen and sulfur to both terrestrial and aquatic ecosystems. These risks fall into two categories, acidification and nutrient enrichment, which were emphasized in the REA as most relevant to evaluating the adequacy of the existing standards in protecting public welfare from adverse ecological effects.

#### (a) Aquatic Acidification

The focus of the REA case studies was to determine whether deposition of sulfur and oxidized nitrogen in locations where ambient oxides of nitrogen and sulfur were at or below the current standards resulted in acidification and related effects, including episodic acidification and mercury methylation. Based on the case studies conducted for lakes in the Adirondacks and streams in Shenandoah National Park (case studies are discussed more fully in section II.B and U.S. EPA, 2009), there is significant risk to acid sensitive aquatic ecosystems at atmospheric concentrations of oxides of nitrogen and sulfur at or below the current standards. The REA also strongly supports a relationship between atmospheric deposition of oxides of nitrogen and sulfur and loss of ANC in sensitive ecosystems and indicates that ANC is an excellent indicator of aquatic acidification. The REA also concludes that at levels of deposition associated with oxides of nitrogen and sulfur concentrations at or below the current standards, ANC levels are expected to be below benchmark values that are associated with

significant losses in fish species richness.

Significant portions of the United States are acid sensitive, and current deposition levels exceed those that would allow recovery of the most acid sensitive lakes in the Adirondacks (U.S. EPA, 2008, Executive Summary). In addition, because of past loadings, areas of the Shenandoah are sensitive to current deposition levels (U.S. EPA, 2008, Executive Summary). Parts of the West are naturally less sensitive to acidification and subjected to lower deposition (particularly oxides of sulfur) levels relative to the eastern United States, and as such, less focus in the ISA is placed on the adequacy of the existing standards in these areas, with the exception of the mountainous areas of the West, which experience episodic acidification due to deposition.

In describing the effects of acidification in the two case study areas the REA uses the approach of describing benchmarks in terms of ANC values. Many locations in sensitive areas of the United States have ANC levels below benchmark levels for ANC classified as severe, elevated, or moderate concern (U.S. EPA, 2011, Figure 2-1). The average current ANC levels across 44 lakes in the Adirondack case study area is 62.1  $\mu\text{eq/L}$  (moderate concern). However, 44 percent of lakes had deposition levels exceeding the critical load for an ANC of 50  $\mu\text{eq/L}$  (elevated), and 28 percent of lakes had deposition levels exceeding the (higher) critical load for an ANC of 20  $\mu\text{eq/L}$  (severe) (U.S. EPA, 2009, section 4.2.4.2). This information indicates that almost half of the 44 lakes in the Adirondacks case study area are at an elevated concern level, and almost a third are at a severe concern level. These levels are associated with greatly diminished fish species diversity, and losses in the health and reproductive capacity of remaining populations. Based on assessments of the relationship between number of fish species and ANC level in both the Adirondacks and Shenandoah areas, the number of fish species is decreased by over half at an ANC level of 20  $\mu\text{eq/L}$  relative to an ANC level at 100  $\mu\text{eq/L}$  (U.S. EPA, 2009, Figure 4.2-1). When extrapolated to the full population of lakes in the Adirondacks area using weights based on the EMAP probability survey (U.S. EPA, 2009, section 4.2.6.1), 36 percent of lakes exceeded the critical load for an ANC of 50  $\mu\text{eq/L}$  and 13 percent of lakes exceeded the critical load for an ANC of 20  $\mu\text{eq/L}$ .

Many streams in the Shenandoah case study area also have levels of deposition that are associated with ANC levels

classified as severe, elevated, or moderate concern. The average ANC under recent conditions for the 60 streams evaluated in the Shenandoah case study area is 57.9  $\mu\text{eq/L}$ , indicating moderate concern. However, 85 percent of these streams had recent deposition exceeding the critical load for an ANC of 50  $\mu\text{eq/L}$ , and 72 percent exceeded the critical load for an ANC of 20  $\mu\text{eq/L}$ . As with the Adirondacks area, this information suggests that ANC levels may decline in the future and significant numbers of sensitive streams in the Shenandoah area are at risk of adverse impacts on fish populations if recent conditions persist. Many other streams in the Shenandoah area are also likely to experience conditions of elevated to severe concern based on the prevalence in the area of bedrock geology associated with increased sensitivity to acidification suggesting that effects due to stream acidification could be widespread in the Shenandoah area (U.S. EPA, 2009, section 4.2.6.2).

In addition to these chronic acidification effects, the ISA notes that "consideration of episodic acidification greatly increases the extent and degree of estimated effects for acidifying deposition on surface waters" (U.S. EPA, 2008, section 3.2.1.6). Some studies show that the number of lakes that could be classified as acid-impacted based on episodic acidification is 2 to 3 times the number of lakes classified as acid-impacted based on chronic ANC. These episodic acidification events can have long-term effects on fish populations (U.S. EPA, 2008, section 3.2.1.6). Under recent conditions, episodic acidification has been observed in locations in the eastern United States and in the mountainous western United States (U.S. EPA, 2008, section 3.2.1.6).

The ISA, REA and PA all conclude that the current standards are not adequate to protect against the adverse impacts of aquatic acidification on sensitive ecosystems. A recent survey, as reported in the ISA, found sensitive streams in many locations in the United States, including the Appalachian Mountains, the Coastal Plain, and the Mountainous West (U.S. EPA, 2008, section 4.2.2.3). In these sensitive areas, between 1 and 6 percent of stream kilometers are chronically acidified. The REA further concludes that both the Adirondack and Shenandoah case study areas are currently receiving deposition from ambient oxides of nitrogen and sulfur in excess of their ability to neutralize such inputs. In addition, based on the current emission scenarios, forecast modeling out to the year 2020 as well as 2050 indicates a large number of streams in these areas will still be

adversely impacted (section II.B). Based on these considerations, the PA concludes that the current secondary NAAQS for oxides of nitrogen and sulfur do not provide adequate protection of sensitive ecosystems with regard to aquatic acidification.

#### (b) Terrestrial Acidification

Based on the terrestrial acidification case studies, Kane Experimental Forest in Pennsylvania and Hubbard Brook Experimental Forest described in section II.B of sugar maple and red spruce habitat, the REA concludes that there is significant risk to sensitive terrestrial ecosystems from acidification at atmospheric concentrations of  $\text{NO}_2$  and  $\text{SO}_2$  at or below the current standards. The ecological indicator selected for terrestrial acidification is the BC/Al, which has been linked to tree health and growth. The results of the REA strongly support a relationship between atmospheric deposition of oxides of nitrogen and sulfur and BC/Al, and that BC/Al is a good indicator of terrestrial acidification. At levels of deposition associated with oxides of nitrogen and sulfur concentrations at or below the current standards, BC/Al levels are expected to be below benchmark values that are associated with significant effects on tree health and growth. Such degradation of terrestrial ecosystems could affect ecosystem services such as habitat provisioning, endangered species, goods production (timber, syrup, etc.) among others.

Many locations in sensitive areas of the United States have BC/Al levels below benchmark levels classified as providing low to intermediate levels of protection to tree health. At a BC/Al ratio of 1.2 (intermediate level of protection), red spruce growth can be reduced by 20 percent. At a BC/Al ratio of 0.6 (low level of protection), sugar maple growth can be decreased by 20 percent. The REA did not evaluate broad sensitive regions. However, in the sugar maple case study area (Kane Experimental Forest), recent deposition levels are associated with a BC/Al ratio below 1.2, indicating between intermediate and low level of protection, which would indicate the potential for a greater than 20 percent reduction in growth. In the red spruce case study area (Hubbard Brook Experimental Forest), recent deposition levels are associated with a BC/Al ratio slightly above 1.2, indicating slightly better than an intermediate level of protection (U.S. EPA, 2009, section 4.3.5.1).

Over the full range of sugar maple, 12 percent of evaluated forest plots

exceeded the critical loads for a BC/Al ratio of 1.2, and 3 percent exceeded the critical load for a BC/Al ratio of 0.6. However, there was large variability across states. In New Jersey, 67 percent of plots exceeded the critical load for a BC/Al ratio of 1.2, while in several states on the outskirts of the range for sugar maple (e.g. Arkansas, Illinois) no plots exceeded the critical load for a BC/Al ratio of 1.2. For red spruce, overall 5 percent of plots exceeded the critical load for a BC/Al ratio of 1.2, and 3 percent exceeded the critical load for a BC/Al ratio of 0.6. In the major red spruce producing states (Maine, New Hampshire, and Vermont), critical loads for a BC/Al ratio of 1.2 were exceeded in 0.5, 38, and 6 percent of plots, respectively.

The ISA, REA and PA all conclude that the current standards are not adequate to protect against the adverse impacts of terrestrial acidification on sensitive ecosystems. As stated in the REA and PA, the main drawback, with the understanding of terrestrial acidification lies in the sparseness of available data by which we can predict critical loads and that the data are based on laboratory responses rather than field measurements. Other stressors that are present in the field but that are not present in the laboratory may confound this relationship. The REA does however, conclude that the case study results, when extended to a 27 state region, show that nitrogen and sulfur acidifying deposition in the sugar maple and red spruce forest areas caused the calculated Bc/Al ratio to fall below 1.2 (the intermediate level of protection) in 12 percent of the sugar maple plots and 5 percent of the red spruce plots; however, results from individual states ranged from 0 to 67 percent of the plots for sugar maple and 0 to 100 percent of the plots for red spruce.

#### (c) Terrestrial Nutrient Enrichment

Nutrient enrichment effects are due to nitrogen loadings from both atmospheric and non-atmospheric sources. Evaluation of nutrient enrichment effects requires an understanding that nutrient inputs are essential to ecosystem health and that specific long-term levels of nutrients in a system affect the types of species that occur over long periods of time. Short-term additions of nutrients can affect species competition, and even small additions of nitrogen in areas that are traditionally nutrient poor can have significant impacts on productivity as well as species composition. Most ecosystems in the United States are nitrogen-limited, so regional decreases in emissions and deposition of airborne

nitrogen compounds could lead to some decrease in growth of the vegetation that surrounds the targeted aquatic system but as discussed below evidence for this is mixed. Whether these changes in plant growth are seen as beneficial or adverse will depend on the nature of the ecosystem being assessed.

Information on the effects of changes in nitrogen deposition on forestlands and other terrestrial ecosystems is very limited. The multiplicity of factors affecting forests, including other potential stressors such as ozone, and limiting factors such as moisture and other nutrients, confound assessments of marginal changes in any one stressor or nutrient in forest ecosystems. The ISA notes that only a fraction of the deposited nitrogen is taken up by the forests, most of the nitrogen is retained in the soils (U.S. EPA, 2008, section 3.3.2.1). In addition, the ISA indicates that forest management practices can significantly affect the nitrogen cycling within a forest ecosystem, and as such, the response of managed forests to nitrogen deposition will be variable depending on the forest management practices employed in a given forest ecosystem (U.S. EPA, 2008, Annex C.6.3). Increases in the availability of nitrogen in nitrogen-limited forests via atmospheric deposition could increase forest production over large non-managed areas, but the evidence is mixed, with some studies showing increased production and other showing little effect on wood production (U.S. EPA, 2008, section 3.3.9). Because leaching of nitrate can promote cation losses, which in some cases create nutrient imbalances, slower growth and lessened disease and freezing tolerances for forest trees, the net effect of increased N on forests in the United States is uncertain (U.S. EPA, 2008, section 3.3.9).

The scientific literature has many examples of the deleterious effects caused by excessive nitrogen loadings to terrestrial systems. Several studies have set benchmark values for levels of N deposition at which scientifically adverse effects are known to occur. Large areas of the country appear to be experiencing deposition above these benchmarks. The ISA indicates studies that have found that at 3.1 kg N/ha/yr, the community of lichens begins to change from acidophytic to tolerant species; at 5.2 kg N/ha/yr, the typical dominance by acidophytic species no longer occurs; and at 10.2 kg N/ha/yr, acidophytic lichens are totally lost from the community. Additional studies in the Colorado Front Range of the Rocky Mountain National Park support these findings. These three values (3.1, 5.2,

and 10.2 kg/ha/yr) are one set of ecologically meaningful benchmarks for the mixed conifer forest (MCF) of the Pacific coast regions. Nearly all of the known sensitive communities receive total nitrogen deposition levels above the 3.1 N kg/ha/yr ecological benchmark according to the 12 km, 2002 CMAQ/NADP data, with the exception of the easternmost Sierra Nevadas. The MCFs in the southern portion of the Sierra Nevada forests and nearly all MCF communities in the San Bernardino forests receive total nitrogen deposition levels above the 5.2 N kg/ha/yr ecological benchmark.

Coastal Sage Scrub communities are also known to be sensitive to community shifts caused by excess nitrogen loadings. Studies have investigated the amount of nitrogen utilized by healthy and degraded CSS systems. In healthy stands, the authors estimated that 3.3 kg N/ha/yr was used for CSS plant growth. It is assumed that 3.3 kg N/ha/yr is near the point where nitrogen is no longer limiting in the CSS community and above which level community changes occur, including dominance by invasive species and loss of coastal sage scrub. Therefore, this amount can be considered an ecological benchmark for the CSS community. The majority of the known CSS range is currently receiving deposition in excess of this benchmark. Thus, the REA concludes that recent conditions where oxides of nitrogen ambient concentrations are at or below the current oxides of nitrogen secondary standards are not adequate to protect against anticipated adverse impacts from N nutrient enrichment in sensitive ecosystems.

#### (d) Aquatic Nutrient Enrichment

The REA aquatic nutrient enrichment case studies focused on coastal estuaries and revealed that while current ambient loadings of atmospheric oxides of nitrogen are contributing to the overall depositional loading of coastal estuaries, other non-atmospheric sources are contributing in far greater amounts in total, although atmospheric contributions are as large as some other individual source types. The ability of current data and models to characterize the incremental adverse impacts of nitrogen deposition is limited, both by the available ecological indicators, and by the inability to attribute specific effects to atmospheric sources of nitrogen. The REA case studies used ASSETS EI as the ecological indicator for aquatic nutrient enrichment. This index is a six level index characterizing overall eutrophication risk in a water body. This indicator is not sensitive to

changes in nitrogen deposition within a single level of the index. In addition, this type of indicator does not reflect the impact of nitrogen deposition in conjunction with other sources of nitrogen.

Based on the above considerations, the REA concludes that the ASSETS EI is not an appropriate ecological indicator for estuarine aquatic eutrophication and that additional analysis is required to develop an appropriate indicator for determining the appropriate levels of protection from N nutrient enrichment effects in estuaries related to deposition of oxides of nitrogen. As a result, the EPA is unable to make a determination as to the adequacy of the existing secondary oxides of nitrogen standard in protecting public welfare from nitrogen nutrient enrichment effects in estuarine aquatic ecosystems.

Additionally, nitrogen deposition can alter species composition and cause eutrophication in freshwater systems. In the Rocky Mountains, for example, deposition loads of 1.5 to 2 kg/ha/yr which are well within current ambient levels are known to cause changes in species composition in diatom communities indicating impaired water quality (U.S. EPA, 2008, section 3.3.5.3). This suggests that the existing secondary standard for oxides of nitrogen does not protect such ecosystems and their resulting services from impairment.

#### (e) Other Effects

An important consideration in looking at the effects of deposition of oxides of sulfur in aquatic ecosystems is the potential for production of MeHg, a neurotoxic contaminant. The production of meaningful amounts of MeHg requires the presence of  $\text{SO}_4^{2-}$  and mercury, and where mercury is present, increased availability of  $\text{SO}_4^{2-}$  results in increased production of MeHg. There is increasing evidence on the relationship between sulfur deposition and increased methylation of mercury in aquatic environments; this effect occurs only where other factors are present at levels within a range to allow methylation. The production of MeHg requires the presence of  $\text{SO}_4^{2-}$  and mercury, but the amount of MeHg produced varies with oxygen content, temperature, pH and supply of labile organic carbon (U.S. EPA, 2008, section 3.4). In watersheds where changes in sulfate deposition did not produce an effect, one or several of those interacting factors were not in the range required for meaningful methylation to occur (U.S. EPA, 2008, section 3.4). Watersheds with conditions known to

be conducive to mercury methylation can be found in the northeastern United States and southeastern Canada (U.S. EPA, 2009, section 6).

With respect to sulfur deposition and mercury methylation, the final ISA determined that “[t]he evidence is sufficient to infer a causal relationship between sulfur deposition and increased mercury methylation in wetlands and aquatic environments.” However, the EPA did not conduct a quantitative assessment of the risks associated with increased mercury methylation under current conditions. As such, the EPA is unable to make a determination as to the adequacy of the existing  $\text{SO}_2$  secondary standards in protecting against welfare effects associated with increased mercury methylation.

#### c. Summary of Adequacy Considerations

In summary, the PA concludes that currently available scientific evidence and assessments clearly call into question the adequacy of the current standards with regard to deposition-related effects on sensitive aquatic and terrestrial ecosystems, including acidification and nutrient enrichment. Further, the PA recognizes that the elements of the current standards—indicator, averaging time, level and form—are not ecologically relevant, and are thus not appropriate for standards designed to provide such protection. Thus, the PA concludes that consideration should be given to establishing a new ecologically relevant multi-pollutant, multimedia standard to provide appropriate protection from deposition-related ecological effects of oxides of nitrogen and sulfur on sensitive ecosystems, with a focus on protecting against adverse effects associated with acidifying deposition in sensitive aquatic ecosystems.

#### 2. CASAC Views

In a letter to the Administrator (Russell and Samet 2011a), the CASAC Oxides of Nitrogen and Oxides of Sulfur Panel, with full endorsement of the chartered CASAC, unanimously concluded that:

“EPA staff has demonstrated through the Integrated Science Assessment (ISA), Risk and Exposure Characterization (REA) and the draft PA that ambient  $\text{NO}_x$  and  $\text{SO}_x$  can have, and are having, adverse environmental impacts. The Panel views that the current  $\text{NO}_x$  and  $\text{SO}_x$  secondary standards should be retained to protect against direct adverse impacts to vegetation from exposure to gas phase exposures of these two families of air pollutants. Further, the ISA, REA and draft PA demonstrate that adverse impacts to aquatic ecosystems are also occurring due to deposition of  $\text{NO}_x$  and  $\text{SO}_x$ . Those impacts

include acidification and undesirable levels of nutrient enrichment in some aquatic ecosystems. The levels of the current NO<sub>x</sub> and SO<sub>x</sub> secondary NAAQS are not sufficient, nor the forms of those standards appropriate, to protect against adverse depositional effects; thus a revised NAAQS is warranted.”

In addition, with regard to the joint consideration of both oxides of nitrogen and oxides of sulfur as well as the consideration of deposition-related effects, CASAC concluded that the PA had developed a credible methodology for considering such effects. The Panel stated that “the Policy Assessment develops a framework for a multi-pollutant, multimedia standard that is ecologically relevant and reflects the combined impacts of these two pollutants as they deposit to sensitive aquatic ecosystems.”

### 3. Administrator’s Proposed Conclusions

Based on the above considerations and taking into account CASAC advice, in the proposed rule the Administrator considered the adequacy of the current NO<sub>2</sub> and SO<sub>2</sub> secondary standards with regard to both direct effects on vegetation, as well as on deposition-related effects on sensitive ecosystems. With regard to direct phytotoxic effects on vegetation, the Administrator concluded that the current secondary standards are adequately protective, and thus proposed to retain the current NO<sub>2</sub> and SO<sub>2</sub> secondary standards for that purpose.

With regard to deposition-related effects, the Administrator first considered the appropriateness of the structure of the current standards to address ecological effects of concern. Based on the evidence as well as considering the advice given by CASAC, the Administrator concluded that the elements of the current standards are not ecologically relevant and thus are not appropriate to provide protection of ecosystems. In considering the adequacy of protection with regard to deposition-related effects, the Administrator considered the full nature of ecological effects related to the deposition of ambient oxides of nitrogen and sulfur into sensitive ecosystems across the country. Based on the evidence and information evaluated in the ISA, REA, and PA, and taking into account CASAC advice, the Administrator concluded that current levels of oxides of nitrogen and sulfur are sufficient to cause acidification of both aquatic and terrestrial ecosystems, nutrient enrichment of terrestrial ecosystems and contribute to nutrient enrichment effects in estuaries that could be considered

adverse, and that the current secondary standards do not provide adequate protection from such effects.

Having reached these conclusions, the Administrator determined that it was appropriate to consider alternative standards that are ecologically relevant. These considerations, as discussed below in section III, supported the conclusion that the current secondary standards are neither appropriate nor adequate to protect against deposition-related effects.

#### *C. Comments on Adequacy of the Current Standards*

The above sections outline the effects evidence and assessments (section II.A) used by the Administrator to inform her proposed judgments about the adequacy of the current secondary NO<sub>2</sub> and SO<sub>2</sub> standards with regard to both direct effects associated with gas-phase oxides of nitrogen and sulfur (section II.B.1) as well effects associated with deposition of oxides of nitrogen and sulfur to sensitive aquatic and terrestrial ecosystems (section II.B.2). This section discusses the comments received from the public regarding the adequacy of the current secondary standards with regard to both direct and deposition-related effects. Comments related to the EPA’s authority to address deposition-related effects through the NAAQS are discussed above in section I.E. Comments related to the EPA’s proposed conclusions regarding alternative secondary standards are discussed below in section III.D.

#### 1. Adequacy of Current Secondary Standards To Address Direct Effects

The current secondary NO<sub>2</sub> and SO<sub>2</sub> secondary standards were set in 1971 to protect against direct effects of gaseous oxides of nitrogen and sulfur. For oxides of nitrogen, the current secondary NO<sub>2</sub> standard is an annual standard set to protect against adverse effects on vegetation from direct exposure to ambient oxides of nitrogen. For oxides of sulfur, the current secondary standard is a 3-hour standard intended to provide protection for plants from the direct foliar damage associated with atmospheric concentrations of SO<sub>2</sub>. As discussed above in section II.B.1, the Administrator proposed to conclude that the current secondary standards are adequate to protect against direct phytotoxic effects on vegetation, and proposed to retain the current standards for that purpose. Many commenters supported the EPA’s proposed decision to retain the current secondary standards for various reasons related to their comments on alternative standards (as discussed below in section III.D), a

few commenters (Alliance of Automobile Manufacturers (AAM), Pennsylvania Dept. of Environmental Protection) specifically expressed the view that the current standards provide requisite protection from the direct effects on vegetation from exposures to gaseous oxides of nitrogen and sulfur, and no commenters opposed retention of the current secondary standards.

#### 2. Adequacy of Current Secondary Standards to Address Deposition-Related Effects

As discussed above in section II.B.2, with regard to deposition-related effects, the Administrator proposed to conclude that the elements of the current secondary standards are not ecologically relevant, and thus not appropriate to provide protection of ecosystems, and that they do not provide adequate protection from such acidification and nutrient enrichment effects in both aquatic and terrestrial ecosystems. Having reached these proposed conclusions, she determined that it was appropriate to consider alternative standards that are ecologically relevant.

One group of commenters that addressed the adequacy of the current standards with regard to deposition-related effects included environmental organizations (Earthjustice, on behalf of the Appalachian Mountain Club, National Parks Conservation Association, Sierra Club, and Clean Air Council; the Center for Biological Diversity; the Nature Conservancy; Adirondack Council; Chesapeake Bay Foundation), the U.S. Department of the Interior, NESCAUM, New York Dept. of Environmental Conservation, and two tribes. These commenters generally expressed the view that the current secondary standards do not provide adequate protection from deposition-related effects. More specifically, some of these commenters stated that there was overwhelming evidence of adversity to sensitive aquatic ecosystems from acidifying deposition. These commenters cited a broad range of scientific evidence that aquatic acidification was ongoing under current conditions allowed by the current secondary standards, and that this acidification represented an adverse effect on public welfare. Several commenters noted that CASAC had agreed that deposition-related effects were ongoing and harmful and that current standards were not adequate to prevent these effects.

Among these commenters, some also expressed the view that current standards were not adequate to protect against terrestrial acidification or nutrient enrichment. The Department of

the Interior as well as Earthjustice noted that the current standards were not sufficient for these additional endpoints and cited ongoing harm under current conditions. Two tribes and the Center for Biological Diversity expressed the view that there was sufficient information to judge that the current standards were not adequate to protect against the adverse welfare effect of mercury methylation, contrary to the EPA's proposed conclusion that the available evidence was not sufficient to reach such a judgment. For example, The Forest County Potawatomi Community provided several citations regarding the relationships between aquatic acidification and mercury methylation and stated that there was sufficient evidence to find that the current standards were not adequate.

With regard to the adequacy of the current secondary standards for NO<sub>2</sub> and SO<sub>2</sub>, the EPA concurs with commenters' assertions that the current standards do not provide adequate protection for ecosystems that are sensitive to aquatic acidification and that effects to these ecosystems are ongoing from ambient deposition of oxides of nitrogen and oxides of sulfur. The EPA also agrees that there is sufficient evidence to conclude that ambient deposition under the current secondary standards is causing or contributing to terrestrial acidification as well as nutrient enrichment in sensitive ecosystems. A complete discussion of considerations with regard to adequacy can be found in section II.B above. In short, the ISA has established that the major effects of concern for this review of the oxides of nitrogen and sulfur standards are associated with deposition of nitrogen and sulfur caused by atmospheric concentrations of oxides of nitrogen and sulfur. The current standards are not directed toward depositional effects, and none of the elements of the current NAAQS—indicator, form, averaging time, and level—are suited for addressing the effects of nitrogen and sulfur deposition. Additionally, although the proportion of total nitrogen loadings associated with atmospheric deposition of nitrogen varies across locations, the ISA indicates that atmospheric nitrogen deposition is the main source of new anthropogenic nitrogen to most headwater streams, high elevation lakes, and low-order streams. Atmospheric nitrogen deposition contributes to the total nitrogen load in terrestrial, wetland, freshwater and estuarine ecosystems that receive nitrogen through multiple pathways.

There are expansive data to indicate that the levels of deposition under the

current standards are not sufficient to prevent adverse effects in ecosystems. With regard to aquatic acidification, recent data indicate that in the Adirondacks and Shenandoah areas, rates of acidifying deposition of oxides of nitrogen and sulfur are still well above pre-acidification (1860) conditions. Forty-four percent of Adirondack lakes and 85 percent of Shenandoah streams evaluated exceed the critical load for an ANC of 50 µeq/L, and have suffered loss of sensitive fish species. With regard to terrestrial acidification, the REA evaluated a small number of sensitive areas as case studies and showed the potential for reduced growth. When the methodology was extended to a 27-state region, similar results were found to indicate the potential for growth effects in sensitive forests. Nitrogen deposition can alter species composition and cause eutrophication in freshwater systems. In the Rocky Mountains, for example, current deposition levels, which are within the range associated with ambient nitrogen oxide levels meeting the current standard, are known to cause changes in species composition in diatom communities indicating impaired water quality. With regard to terrestrial nutrient enrichment, most terrestrial ecosystems in the United States are nitrogen-limited, and therefore they are sensitive to perturbation caused by nitrogen additions. Under recent conditions, nearly all of the known sensitive mixed conifer forest ecosystems receive total nitrogen deposition levels above the ecological benchmark for changes in lichen species. In addition, in Coastal Sage Scrub ecosystems in California, nitrogen deposition exceeds the benchmark above which nitrogen is no longer a limiting nutrient, leading to potential alterations in ecosystem composition. Therefore, the EPA concludes that the current standards are not adequate for these effects.

The EPA, however, while agreeing that there is a causal effect between deposition of sulfur and mercury methylation disagrees that there is sufficient evidence to make the quantitative associations that would be necessary to determine that the current standards were not adequate to protect against mercury methylation. The ISA concluded that evidence is sufficient to infer a casual relationship between sulfur deposition and increased mercury methylation in wetlands and aquatic environments. Since the rate of mercury methylation varies according to several spatial and biogeochemical factors whose influence has not been fully

quantified, the correlation between sulfur deposition and methylmercury could not be quantified for the purpose of interpolating the association across waterbodies or regions. Therefore, since we are unable to quantify the relationship between atmospherically deposited oxides of sulfur and mercury methylation we cannot assess adequacy of protection. This subject is discussed more fully in section 6.2 of the REA (U.S. EPA, 2009).

Another group of commenters, (e.g. Utility Air Regulatory Group (UARG), Electric Power Research Institute (EPRI), American Petroleum Institute (API), AAM, and American Road and Transportation Builders Association (ARTBA)) generally took the position that the currently available information was not sufficient to make informed judgments about the adequacy of the current standards to address aquatic acidification effects. These commenters generally based this view on the complex nature of the interactions between pollutants and ecosystems and uncertainties in the models and analyses considered in this review. Several commenters asserted that there was not sufficient data available to determine the relationship between acidifying deposition of oxides of nitrogen and sulfur and adverse effects on aquatic ecosystems, such that there was not sufficient information to allow for the assessment of the adequacy of the current standards to provide appropriate protection from this effect. For example, AAM noted the uncertainties in models relating to dry deposition and questioned the linkages between ambient concentrations of oxides of nitrogen and sulfur and the amount of nitrogen and sulfur deposition. In addition to commenting on data limitations, UARG also expressed the view that the ecosystem services analyses included in the proposal were insufficient to make judgments about adversity to aquatic ecosystems resulting from acidifying deposition and that there is a lack of evidence demonstrating that quantifiable changes in public welfare would result from reductions in acidifying deposition. Many commenters within this group did not directly comment on the adequacy of the current standards to protect against aquatic acidification or other deposition-related effects, but instead expressed the view that the EPA did not have the authority to consider deposition-related effects in general or aquatic acidification in particular through the NAAQS. This comment and

the EPA's response are discussed above in section I.E.

With regard to the adequacy of the current standards to protect against aquatic acidification, the EPA disagrees with commenters' assertion that there is insufficient data to make linkages between deposition from the atmosphere and aquatic acidification effects. To the contrary, the EPA is confident that there is sufficient robust science to conclude that aquatic acidification is ongoing in sensitive ecosystems, that ambient deposition of oxides of nitrogen and oxides of sulfur are causative in many ecosystems nationwide and that the current standards are neither appropriate in form nor adequate in level to protect against such effects. The ISA concluded that there was a causal relationship between deposition of oxides of nitrogen and sulfur and  $\text{NH}_x$  and acidification of ecosystems. In addition, the ISA found that effects of acidifying deposition on ecosystems have been well studied over the past several decades, that vulnerable areas have been identified for the United States and that the wealth of available data has led to the development of robust ecological models used for predicting soil and surface water acidification. With regard to the scope of effects, the REA also concluded that the available data are robust and considered high quality. There is high confidence about the use of these data and their value for extrapolating to larger spatial areas. The EPA TIME/LTM network represents a source of long-term, representative sampling. Data on sulfate concentrations, nitrate concentrations and ANC from 1990 to 2006 used for this analysis as well as the EPA EMAP and Regional Environmental Monitoring and Assessment Program (REMAP) surveys, provide considerable data on surface water trends.

The EPA also disagrees with commenters' assessment of limitations in wet and dry deposition modeling. Further discussion of characterizing deposition with models can be found in section IV.C. Additionally, while the EPA recognizes that there are limitations associated with modeled deposition values, the linkages between model estimates of deposition and areas exhibiting aquatic acidification effects are consistent and persuasive in considering adequacy of the current standard. Section 2.3 of the PA and sections 2.8 and 2.10 of the ISA provide additional detailed discussions of deposition modeling and spatial resolution for deposition. CASAC concurred with the EPA's conclusion on this matter and encouraged the EPA to

move forward in developing a new form of a standard which would address aquatic acidification. Thus, while the EPA is fully mindful of the limitations and uncertainties associated with the data and models, the EPA concludes that the available evidence provides strong scientific support for the view that harm from aquatic acidification is ongoing and attributable in large part to atmospheric deposition of reactive nitrogen and sulfur.

With regard to the commenters' reliance on ecosystem services analyses included in the proposal to make judgments about adversity and public welfare, the EPA disagrees that comprehensive ecosystem services analyses are necessary to determine adversity. Ecosystem services analyses are used in this review to inform the decisions made with regard to adequacy and as such are used in conjunction with other considerations in the discussion of adversity to public welfare. Section 4 of the PA further refines this discussion of adversity to public welfare. Additionally, the paradigm of adversity to public welfare as deriving from disruptions in ecosystem structure and function has been used broadly by the EPA to categorize effects of pollutants from the cellular to the ecosystem level. An evaluation of adversity to public welfare might consider the likelihood, type, magnitude, and spatial scale of the effect as well as the potential for recovery and any uncertainties relating to these considerations. Within this context, ecosystem services analyses are one of many tools used in this review to help inform the Administrator's decision on adversity. The EPA concludes that the analyses performed as part of this review are sufficient to support the decisions made by the Administrator with regard to the adequacy of the current standards.

#### *D. Final Decisions on the Adequacy of the Current Standards*

Based on the considerations discussed above, including CASAC advice and public comments, the Administrator believes that the conclusions reached in the proposed rule with regard to the adequacy of the current secondary standards for oxides of nitrogen and sulfur for direct and deposition-related effects continue to be valid. The Administrator recognizes that the purpose of the secondary standard is to protect against "adverse" effects resulting from exposure to oxides of nitrogen and sulfur, discussed above in section II.A. The Administrator also recognizes the need for conclusions as to the adequacy of the current standards

for both direct and deposition-related effects as well as conclusions as to the appropriateness and ecological relevance of the current standards.

In considering what constitutes an ecological effect that is also adverse to the public welfare, the Administrator took into account the ISA conclusions regarding the nature and strength of the effects evidence, the risk and exposure assessment results, the degree to which the associated uncertainties should be considered in interpreting the results, the conclusions presented in the PA, and the views of CASAC and members of the public. On these bases, the Administrator concludes that the current secondary standards are adequate to protect against direct phytotoxic effects on vegetation. Thus, the Administrator has decided to retain the current secondary standards for oxides of nitrogen at 53 ppb,<sup>4</sup> annual average concentration, measured in the ambient air as  $\text{NO}_2$ , and the current secondary standard for oxides of sulfur at 0.5 ppm, 3-hour average concentration, measured in the ambient air as  $\text{SO}_2$ .

With regard to deposition-related effects, the Administrator first considered the appropriateness of the structure of the current secondary standards to address ecological effects of concern. Based on the evidence as well as considering the advice given by CASAC and public comments on this matter, the Administrator concludes that the elements of the current standards are not ecologically relevant and thus are not appropriate to provide protection of ecosystems. On the subject of adequacy of protection with regard to deposition-related effects, the Administrator considered the full nature of ecological effects related to the deposition of ambient oxides of nitrogen and sulfur into sensitive ecosystems across the country. Her conclusions are based on the evidence presented in the ISA with regard to acidification and nutrient enrichment effects, the findings of the REA with regard to scope and severity of the current and likely future effects of deposition, the synthesis of both the scientific evidence and risk and exposure results in the PA as to the adequacy of the current standards, and the advice of CASAC and public comments. After such consideration, the Administrator concludes that current levels of oxides of nitrogen and sulfur are sufficient to cause acidification of

<sup>4</sup> The annual secondary standard for oxides of nitrogen is being specified in units of ppb to conform to the current version of the annual primary standard, as specified in the final rule for the most recent review of the  $\text{NO}_2$  primary NAAQS (75 FR 6531; February 9, 2010).

both aquatic and terrestrial ecosystems, nutrient enrichment of terrestrial ecosystems and contribute to nutrient enrichment effects in estuaries that could be considered adverse, and the current secondary standards do not provide adequate protection from such effects.

Having reached these conclusions, the Administrator determined that it was appropriate to consider alternative standards that are ecologically relevant, as discussed below in section III. These considerations further support her conclusion that the current secondary standards for oxides of nitrogen and sulfur are neither appropriate nor adequate to protect against deposition-related effects.

### III. Rationale for Final Decisions on Alternative Secondary Standards

This section presents the rationale for the Administrator's final decisions regarding alternative secondary standards for oxides of nitrogen and sulfur to address deposition-related effects. Section III.A provides an overview of the aquatic acidification index (AAI) approach presented in the PA to address such effects related to aquatic acidification. Advice from CASAC on such a new approach is presented in section III.B. The Administrator's proposed conclusions on an AAI-based standard are presented in section III.C. Comments on an AAI-based standard are discussed in section III.D as well as in the Response to Comments document. The Administrator's final decisions regarding alternative secondary standards are presented in section III.E.

#### A. Overview of AAI Approach

Having reached the conclusion in the proposal that the current NO<sub>2</sub> and SO<sub>2</sub> secondary standards are not adequate to provide appropriate protection against potentially adverse deposition-related effects associated with oxides of nitrogen and sulfur, the Administrator then considered what new multi-pollutant standard might be appropriate, at this time, to address such effects on public welfare. The Administrator recognizes that the inherently complex and variable linkages between ambient concentrations of nitrogen and sulfur oxides, the related deposited forms of nitrogen and sulfur, and the ecological responses that are associated with public welfare effects call for consideration of a standard with an ecologically relevant design that reflects these linkages. The Administrator also recognizes that characterization of such complex and variable linkages in this review requires consideration of

information and analyses that have important limitations and uncertainties.

Despite its complexity, an ecologically relevant multi-pollutant standard to address deposition-related effects would still appropriately be defined in terms of the same basic elements that are used to define any NAAQS—indicator, form, averaging time, and level. The form would incorporate additional structural elements that reflect relevant multi-pollutant and multimedia attributes. These structural elements include the use of an ecological indicator, tied to the ecological effect we are focused on, and other elements that account for ecologically relevant factors other than ambient air concentrations. All of these elements would be needed to enable a linkage from ambient air indicators to the relevant ecological effect to define an ecologically relevant standard. As a result, such a standard would necessarily be more complex than the NAAQS that have been set historically to address effects associated with ambient concentrations of a single pollutant.

More specifically, the Administrator considered an ecologically relevant multi-pollutant standard to address effects associated with acidifying deposition-related to ambient concentrations of oxides of nitrogen and sulfur in sensitive aquatic ecosystems. This focus is consistent with the information presented in the ISA, REA, and PA, which highlighted the greater quantity and quality of the available evidence and assessments associated with aquatic acidification relative to the information and assessments available for other deposition-related effects, including terrestrial acidification and aquatic and terrestrial nutrient enrichment. Based on its review of these documents, CASAC agreed that aquatic acidification should be the focus for developing a new multi-pollutant standard in this review. In reaching conclusions about an air quality standard designed to address deposition-related aquatic acidification effects, the Administrator also recognizes that such a standard may also provide some degree of protection against other deposition-related effects.

As discussed in chapter 7 of the PA, the development of a new multi-pollutant ambient air quality standard to address deposition-related aquatic acidification effects recognizes that it is appropriate to consider a nationally applicable standard for protection against adverse effects of aquatic acidification on public welfare. At the same time, the PA recognizes the complex and heterogeneous interactions

between ambient air concentrations of nitrogen and sulfur oxides, the related deposition of nitrogen and sulfur, and associated ecological responses. The development of such a standard also needs to take into account the limitations and uncertainties in the available information and analyses upon which characterization of such interactions are based. The approach used in the PA also recognizes that while such a standard would be national in scope and coverage, the effects to public welfare from aquatic acidification will not occur to the same extent in all locations in the United States, given the inherent variability of the responses of aquatic systems to the effects of acidifying deposition. This contrasts with the relatively more homogeneous relationships between ambient air concentrations of air pollutants and the associated inhalation exposures and related public health responses that are typically considered in setting primary NAAQS.

As discussed above in section II–A, many locations in the United States are naturally protected against acid deposition due to underlying geological conditions. Likewise, some locations in the United States, including lands managed for commercial agriculture and forestry, are not likely to be negatively impacted by current levels of nitrogen and sulfur deposition. As a result, while a new ecologically relevant secondary standard would apply everywhere, it would be structured to account for differences in the sensitivity of ecosystems across the country. This would allow for appropriate protection of sensitive aquatic ecosystems, which are relatively pristine and wild and generally in rural areas, and the services provided by such sensitive ecosystems, without requiring more protection than is needed elsewhere.

As discussed below, the multi-pollutant standard developed in the PA would employ (1) Total reactive oxidized nitrogen (NO<sub>x</sub>) and oxides of sulfur (SO<sub>x</sub>) as the atmospheric ambient air indicators; (2) a form that takes into account variable factors, such as atmospheric and ecosystem conditions that modify the amounts of deposited nitrogen and sulfur; the distinction between oxidized and reduced forms of nitrogen; effects of deposited nitrogen and sulfur on aquatic ecosystems in terms of the ecological indicator ANC; and the representativeness of water bodies within a defined spatial area; (3) a multi-year averaging time, and (4) a standard level defined in terms of a single, national target ANC value that, in the context of the above form, identifies the various levels of

concentrations of NO<sub>y</sub> and SO<sub>x</sub> in the ambient air that would meet the standard. The form of such a standard has been defined by an index, AAI, which reflects the relationship between ambient concentrations of NO<sub>y</sub> and SO<sub>x</sub> and aquatic acidification effects that result from nitrogen and sulfur deposition-related to these ambient concentrations.

In summarizing the considerations associated with such an air quality standard to address deposition-related aquatic acidification effects, as discussed more fully in sections III.A-F of the proposal and in the PA, the following sections focus on each element of the standard, including ambient air indicators (section III.A.1), form (section III.A.2), averaging time (section III.A.3), and level (section III.A.4). Considerations related to important uncertainties inherent in such an approach are discussed in section III.A.5.

1. Ambient Air Indicators

The PA concludes that ambient air indicators other than NO<sub>2</sub> and SO<sub>2</sub> should be considered as the appropriate indicators of oxides of nitrogen and sulfur in the ambient air for protection against the acidification effects associated with deposition of the associated nitrogen and sulfur. This conclusion is based on the recognition that all forms of nitrogen and sulfur in the ambient air contribute to deposition and resulting acidification, and as such, NO<sub>2</sub> and SO<sub>2</sub> are incomplete ambient air indicators. In principle, the indicators should represent the species that are associated with oxides of nitrogen and sulfur in the ambient air and can contribute acidifying deposition. This includes both the species of oxides of nitrogen and sulfur that are directly emitted as well as species transformed in the atmosphere from oxides of nitrogen and sulfur that retain the

nitrogen and sulfur atoms from directly emitted oxides of nitrogen and sulfur. All of these compounds are associated with oxides of nitrogen and sulfur in the ambient air and can contribute to acidifying deposition.

The PA focuses in particular on the various compounds with nitrogen or sulfur atoms that are associated with oxides of nitrogen and sulfur, because the acidifying potential is specific to nitrogen and sulfur, and not other atoms (e.g., H, C, O) whether derived from the original source of oxides of nitrogen and sulfur emissions or from atmospheric transformations. For example, the acidifying potential of each molecule of NO<sub>2</sub>, NO, HNO<sub>3</sub> or PAN is identical, as is the potential for each molecule of SO<sub>2</sub> or ion of particulate sulfate (p-SO<sub>4</sub>). Each atom of sulfur affords twice the acidifying potential of each atom of nitrogen.

a. Oxides of Sulfur

As discussed in the PA (U.S. EPA, 2011, section 7.1.1), oxides of sulfur include the gases sulfur monoxide (SO), SO<sub>2</sub>, sulfur trioxide (SO<sub>3</sub>), disulfur monoxide (S<sub>2</sub>O), and particulate-phase sulfur compounds (referred to as SO<sub>4</sub>) that result from gas-phase sulfur oxides interacting with particles. However, the sum of SO<sub>2</sub> and SO<sub>4</sub> does represent virtually the entire ambient air mass of sulfur that contributes to acidification. In addition to accounting for virtually all the potential for acidification from oxidized sulfur in the ambient air, there are reliable methods to monitor the concentrations of SO<sub>2</sub> and particulate SO<sub>4</sub>. The PA concludes that the sum of SO<sub>2</sub> and SO<sub>4</sub>, referred to as SO<sub>x</sub>, are appropriate ambient air indicators of oxides of sulfur because they represent virtually all of the acidification potential of ambient air oxides of sulfur and there are reliable methods suitable for measuring SO<sub>2</sub> and SO<sub>4</sub>.

b. Oxides of Nitrogen

As discussed in the PA (U.S. EPA, 2011, section 7.1.2), NO<sub>y</sub>, as defined in chapter 2 of the PA, incorporates basically all of the oxidized nitrogen species that have acidifying potential and as such, NO<sub>y</sub> should be considered as an appropriate indicator for oxides of nitrogen. Total reactive oxidized nitrogen is an aggregate measure of NO and NO<sub>2</sub> and all of the reactive oxidized products of NO and NO<sub>2</sub>. That is, NO<sub>y</sub> is a group of nitrogen compounds in which all of the compounds are either an oxide of nitrogen or compounds in which the nitrogen atoms came from oxides of nitrogen. Total reactive oxidized nitrogen is especially relevant as an ambient indicator for acidification in that it both relates to the oxides of nitrogen in the ambient air and also represents the acidification potential of all oxidized nitrogen species in the ambient air, whether an oxide of nitrogen or derived from oxides of nitrogen. The merits of other individual NO<sub>y</sub> species, particularly total nitrate, are discussed in section 2 of the PA.

2. Form

Based on the evidence of the aquatic acidification effects caused by the deposition of NO<sub>y</sub> and SO<sub>x</sub>, the PA (U.S. EPA, 2011, section 7.2) presents the development of a new form that is ecologically relevant for addressing such effects. The conceptual design for the form of such a standard includes three main components: an ecological indicator, deposition metrics that relate to the ecological indicator, and a function that relates ambient air indicators to deposition metrics. Collectively, these three components link the ecological indicator to ambient air indicators, as illustrated below in Fig III-1.

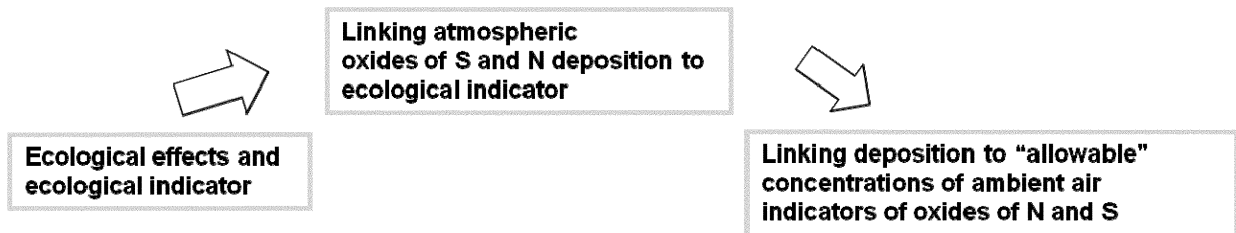


Figure III-1. Conceptual design of the form of an aquatic acidification standard for oxides of nitrogen and sulfur



The simplified flow diagram in Figure III-1 compresses the various atmospheric, biological, and geochemical processes associated with acidifying deposition to aquatic ecosystems into a simplified conceptual picture. The ecological indicator (left box) is related to atmospheric deposition through biogeochemical ecosystem models (middle box), which associate a target deposition load to a target ecological indicator. Once a target deposition is established, associated allowable air concentrations are determined (right box) through the relationships between ambient air concentration and deposition that are embodied in air quality models such as CMAQ. The PA describes the development and rationale for each of these components, as well as the integration of these components into the full expression of the form of the standard using the concept of a national AAI that represents a target ANC level as a function of ambient air concentrations.

The AAI was designed to be an ecologically relevant form of the standard that determines the levels of NO<sub>y</sub> and SO<sub>x</sub> in the ambient air that would achieve a target ANC limit for the United States. The intent of the AAI is to weight atmospheric concentrations of oxides of nitrogen and sulfur by their propensity to contribute to acidification through deposition, given the fundamental acidifying potential of each pollutant, and to take into account the ecological factors that govern acid sensitivity in different ecosystems. The index also accounts for the contribution of reduced nitrogen to acidification. Thus, the AAI encompasses those attributes of specific relevance to protecting ecosystems from the acidifying potential of ambient air concentrations of NO<sub>y</sub> and SO<sub>x</sub>.

a. Ecological Indicator

This section summarizes the rationale in the PA for selecting ANC as the appropriate ecological indicator for consideration. Recognizing that ANC is not itself the causative or toxic agent for adverse aquatic acidification effects, the rationale for using ANC as the relevant ecological indicator is based on the following:

(1) The ANC is directly associated with the causative agents, pH and dissolved Al, both through empirical evidence and mechanistic relationships;

(2) Empirical evidence shows very clear and strong relationships between adverse effects and ANC;

(3) The ANC is a more reliable indicator from a modeling perspective, allowing use of a body of studies and technical analyses related to ANC and acidification to inform the development of the standard; and

(4) The ANC embodies the concept of acidification as posed by the basic principles of acid base chemistry and the measurement method used to estimate ANC and, therefore, serves as a direct index to protect against acidification.

Because ANC clearly links both to biological effects of aquatic acidification as well as to acidifying inputs of NO<sub>y</sub> and SO<sub>x</sub> deposition, the PA concludes that ANC is an appropriate ecological indicator for relating adverse aquatic ecosystem effects to acidifying atmospheric deposition of SO<sub>x</sub> and NO<sub>y</sub>, and is preferred to other potential indicators. In reaching this conclusion, the PA notes that in its review of the first draft PA, CASAC concluded that “information on levels of ANC protective to fish and other aquatic biota has been well developed and presents probably the lowest level of uncertainty in the entire methodology” (Russell and Samet, 2010a). In its more recent review of the second draft PA, CASAC agreed “that acid neutralizing capacity is an appropriate ecological measure for reflecting the effects of aquatic acidification” (Russell and Samet, 2010b; p. 4).

b. Linking ANC to Deposition

There is evidence to support a quantified relationship between deposition of nitrogen and sulfur and ANC. This relationship was analyzed in the REA for two case study areas, the Adirondack and Shenandoah Mountains, based on time-series modeling and observed trends. In the REA analysis, long-term trends in surface water nitrate, sulfate and ANC were modeled using MAGIC for the two case study areas. These data were used to compare recent surface water conditions in 2006 with preindustrial conditions (i.e., preacidification 1860). The results showed a marked increase in the number of lakes affected by acidifying deposition, characterized as a decrease in ANC levels, since the onset of anthropogenic nitrogen and sulfur deposition, as discussed in chapter 2 of the PA.

In the REA, the quantified relationship between deposition and ANC was investigated using ecosystem acidification models, also referred to as acid balance models or critical loads models (U.S. EPA, 2011, section 2 and U.S. EPA, 2009, section 4 and Appendix 4). These models quantify the relationship between deposition of nitrogen and sulfur and the resulting ANC in surface waters based on an ecosystem’s inherent generation of ANC and ability to neutralize nitrogen deposition through biological and physical processes. A critical load is defined as the amount of acidifying atmospheric deposition of nitrogen and sulfur beyond which a target ANC is not reached. Relatively high critical load values imply that an ecosystem can accommodate greater deposition levels than lower critical loads for a specific target ANC level. Ecosystem models that calculate critical loads form the basis for linking deposition to ANC.

As discussed in chapter 2 of the PA, both dynamic and steady-state models calculate ANC as a function of ecosystem attributes and atmospheric nitrogen and sulfur deposition, and can be used to calculate critical loads. Steady-state models are time invariant and reflect the long-term consequences associated with an ecosystem reaching equilibrium under a constant level of atmospheric deposition. Dynamic models are time variant and take into account the time dependencies inherent in ecosystem hydrology, soil and biological processes. Dynamic models like MAGIC can provide the time-series response of ANC to deposition whereas steady-state models provide a single ANC relationship to any fixed deposition level. Dynamic models naturally are more complex than steady-state models as they attempt to capture as much of the fundamental biogeochemical processes as practicable, whereas steady-state models depend on far greater parameterization and generalization of processes that is afforded, to some degree, by not having to account for temporal variability.

In the PA, a steady-state model is used to define the relevant critical load, which is the amount of atmospheric deposition of nitrogen (N) and sulfur (S) beyond which a target ANC is not achieved and sustained.<sup>5</sup> It is expressed as:

<sup>5</sup> This section discusses the linkages between deposition of nitrogen and sulfur and ANC. Section

III.A.2.c then discusses the linkages between

atmospheric concentrations of NO<sub>y</sub> and SO<sub>x</sub> and deposition of nitrogen and sulfur.

$$CL_{ANClim}(N + S) = ([BC]_0^* - [ANC_{lim}])Q + Neco \quad (III-1)$$

Where:

$CL_{ANClim}(N + S)$  is the critical load of deposition, with units of equivalent charge/(area-time);  
 $[BC]_0^*$  is the natural contribution of base cations from weathering, soil processes and preindustrial deposition, with units of equivalent charge/volume;  
 $[ANC_{lim}]$  is the target ANC value, with units of equivalent charge/volume;  
 $Q$  is the catchment level runoff rate governed by water mass balance and dominated by precipitation, with units of distance/time; and  
 $Neco$  is the amount of nitrogen deposition that is effectively neutralized by a variety of biological (e.g., nutrient uptake) and physical processes, with units of equivalent charge/(area-time).

Equation III-1 is a modified expression that adopts the basic formulation of the steady-state models that are described in chapter 2 of the PA. More detailed discussion of the rationale, assumptions and derivation of equation III-1, as well as all of the equations in this section, are included in Appendix B of the PA. The equation simply reflects the amount of deposition of nitrogen and sulfur from the atmosphere,  $CL_{ANClim}(N + S)$ , that is associated with a sustainable long-term ANC target,  $[ANC_{lim}]$ , given the capacity of the natural system to generate ANC,  $[BC]_0^*$ , and the capacity of the natural system to neutralize nitrogen deposition,  $Neco$ . This expression of critical load is valid when nitrogen

deposition is greater than  $Neco$ .<sup>6</sup> The runoff rate,  $Q$ , allows for balancing mass in the two environmental mediums— atmosphere and catchment. This critical load expression can be focused on a single water system or more broadly. To extend applicability of the critical load expression (equation III-1) from the catchment level to broader spatial areas, the terms  $Q_r$  and  $CL_r$  are used, which are the runoff rate and critical load, respectively, of the region over which all the atmospheric terms in the equation are defined.

As presented above, the terms  $S$  and  $N$  in the  $CL_{ANClim}(N + S)$  term broadly represent all species of sulfur or nitrogen that can contribute to acidifying deposition. This follows conventions used in the scientific literature that addresses critical loads, and it reflects all possible acidifying contributions from any sulfur or nitrogen species. For all practical purposes,  $S$  reflects  $SO_x$  as described above, the sum of sulfur dioxide gas and particulate sulfate. However,  $N$  in equation III-1 includes both oxidized forms, consistent with the ambient indicator,  $NO_y$ , in addition to the reduced nitrogen species, ammonia and ammonium ion, referred to as  $NH_x$ . The  $NH_x$  is included in the critical load formulation because it contributes to potentially acidifying nitrogen deposition. Consequently, from a mass balance or modeling perspective, the

form of the standard needs to account for  $NH_x$ , as described below.

c. Linking Deposition to Ambient Air Indicators

The last major component of the form illustrated in Figure III-1 addresses the linkage between deposition of nitrogen and sulfur and concentrations of the ambient air indicators,  $NO_y$  and  $SO_x$ . To link ambient air concentrations with deposition, the PA defines a transference ratio,  $T$ , as the ratio of total wet and dry deposition to ambient concentration, consistent with the area and time period over which the standard is defined. To express deposition of  $NO_y$  and  $SO_x$  in terms of  $NO_y$  and  $SO_x$  ambient concentrations, two transference ratios were defined, where  $T_{SO_x}$  equals the ratio of the combined dry and wet deposition of  $SO_x$  to the ambient air concentration of  $SO_x$ , and  $T_{NO_y}$  equals the ratio of the combined dry and wet deposition of  $NO_y$  to the ambient air concentration of  $NO_y$ .

As described in chapter 7 of the PA, reduced forms of nitrogen ( $NH_x$ ) are included in total nitrogen in the critical load equation, III-1. Reduced forms of nitrogen are treated separately, as are  $NO_y$  and  $SO_x$ , and the transference ratios are applied. This results in the following critical load expression that is defined explicitly in terms of the indicators  $NO_y$  and  $SO_x$ :

$$CL_{ANClim}(N + S) = ([BC]_0^* - [ANC_{lim}])Q + Neco = [NO_y]T_{NO_y} + [SO_x]T_{SO_x} + NH_x \quad (III-2)$$

This is the same equation as III-1, with the deposition associated with the critical load translated to deposition from ambient air concentrations via transference ratios. In addition, deposition of reduced nitrogen, oxidized nitrogen and oxidized sulfur are treated separately.

Transference ratios are a modeled construct, and therefore cannot be compared directly to measurable

quantities. Section III.B.3 of the proposal discusses approaches to quantifying these ratios that consider blending observational data and models. The PA more fully discusses the rationale underlying transference ratios, as well as analyses illustrating the relative stability and variability of these ratios.

d. Aquatic Acidification Index

Having established the transference ratios that translate atmospheric concentrations to deposition of nitrogen and sulfur and the various expressions that link atmospheric deposition of nitrogen and sulfur to ANC, the PA derived the following expression of these linkages, which separates reduced forms of nitrogen,  $NH_x$ , from oxidized forms:

$$ANC_{calc} = \{ANClim + CL_r/Q_r\} - NH_x/Q_r - T_{NO_y}[NO_y]/Q_r - T_{SO_x}[SO_x]/Q_r \quad (III-3)$$

<sup>6</sup> Because  $Neco$  is only relevant to nitrogen deposition, in rare cases where  $Neco$  is greater than

the total nitrogen deposition, the critical load would be defined only in terms of acidifying

deposition of sulfur and the  $Neco$  term in equation III-1 would be set to zero.

Equation III-3 is the basic expression of the form of a standard that translates the conceptual framework into an explicit expression that defines ANC as a function of the ambient air indicators, NO<sub>y</sub> and SO<sub>x</sub>, reduced nitrogen deposition,<sup>7</sup> and the critical load

$$AAI = F1 - F2 - F3[NO_y] - F4[SO_x] \tag{III- 4}$$

where the AAI represents the long-term (or steady-state) ANC level associated with ambient air concentrations of NO<sub>y</sub> and SO<sub>x</sub>. The factors F1 through F4 convey three attributes: a relative measure of the ecosystem's ability to neutralize acids (F1), the acidifying potential of reduced nitrogen deposition (F2), and the deposition-to-concentration translators for NO<sub>y</sub> (F3) and SO<sub>x</sub> (F4).

Specifically:

F1 = ANClim + CL<sub>r</sub>/Q<sub>r</sub> ;

F2 = NH<sub>x</sub>/Q<sub>r</sub> = NH<sub>x</sub> deposition divided by Q<sub>r</sub>;

F3 = T<sub>NO<sub>y</sub></sub>/Q<sub>r</sub> ; T<sub>NO<sub>y</sub></sub> is the transference ratio that converts ambient air concentrations of NO<sub>y</sub> to deposition of NO<sub>y</sub>; and

F4 = T<sub>SO<sub>x</sub></sub>/Q<sub>r</sub> ; T<sub>SO<sub>x</sub></sub> is the transference ratio that converts ambient air concentrations of SO<sub>x</sub> to deposition of SO<sub>x</sub>.

All of these factors include representative Q<sub>r</sub> to maintain unit (and mass) consistency between the AAI and the terms on the right side of equation III-4.

The F1 factor is the target ANC level plus the amount of deposition (critical load) the ecosystem can receive and still achieve the target level. It incorporates an ecosystem's ability to generate acid neutralizing capacity through base cation supply ([BC]<sup>\*</sup><sub>o</sub>) and to neutralize acidifying nitrogen deposition through *Neco*, both of which are incorporated in the CL term. As noted above, because *Neco* can only neutralize nitrogen deposition (oxidized or reduced) there may be rare cases where *Neco* exceeds the combination of reduced and oxidized nitrogen deposition. Consequently, to ensure that the AAI equation is applicable in all cases that may occur, equation III-4 is conditional on total nitrogen deposition, {NH<sub>x</sub> + F3[NO<sub>y</sub>]}, being greater than *Neco*. In rare cases where *Neco* is greater than {NH<sub>x</sub> + F3[NO<sub>y</sub>]}, F2, F3, and *Neco* would be set equal to 0 in the AAI equation. The consequence of setting F2 and F3 to zero is simply to constrain the AAI calculation just to SO<sub>x</sub>, as nitrogen would have no bearing on acidifying contributions in this case.

The PA concludes that equation III-4 (U.S. EPA, 2011, equation 7-12), which

necessary to achieve a target ANC level. This equation calculates an expected ANC value based on ambient concentrations of NO<sub>y</sub> and SO<sub>x</sub>. The calculated ANC will differ from the target ANC (ANclim) depending on how much the nitrogen and sulfur deposition

defines the AAI, is ecologically relevant and appropriate for use as the form of a national standard designed to provide protection for aquatic ecosystems from the effects of acidifying deposition associated with concentrations of oxides of nitrogen and sulfur in the ambient air. This AAI equation does not, however, in itself, define the spatial areas over which the terms of the equation would apply. To specify values for factors F1 through F4, it is necessary to define spatial areas over which these factors are determined. Thus, it is necessary to identify an approach for spatially aggregating water bodies into ecologically meaningful regions across the United States, as discussed below.

#### e. Spatial Aggregation

As discussed in the PA, one of the unique aspects of this form is the need to consider the spatial areas over which values for the F factors in the AAI equation are quantified. Ecosystems across the United States exhibit a wide range of geological, hydrological and vegetation characteristics that influence greatly the ecosystem parameters, Q, BC<sub>o</sub><sup>\*</sup> and *Neco* that are incorporated in the AAI. Variations in ecosystem attributes naturally lead to wide variability in the sensitivities of water bodies in the United States to acidification, as well as in the responsiveness of water bodies to changes in acidifying deposition. Consequently, variations in ecosystem sensitivity, and the uncertainties inherent in characterizing these variations, must be taken into account in developing a national standard. In developing a secondary NAAQS to protect public welfare, the focus of the PA is on protecting sensitive populations of water bodies, not on each individual water body, which is consistent with the Agency's approach to protecting public health through primary NAAQS that focus on susceptible populations, not on each individual.

associated with NO<sub>y</sub>, SO<sub>x</sub>, and NH<sub>x</sub> differs from the critical load associated with just achieving the target ANC.

Based on equation III-3, the PA defines an AAI that is more simply stated using terms that highlight the ambient air indicators:

The approach used for defining ecologically relevant regions across the United States, along with approaches to characterizing each region as acid sensitive or relatively non-acid sensitive is discussed in detail in the PA (U.S. EPA, 2011, section 7.2.5). This characterization facilitates a more detailed analysis and focus on those regions that are relatively more acid sensitive, as well as avoiding over-protection in relatively non-acid sensitive regions that would receive limited benefit from reductions in the deposition of oxides of nitrogen and sulfur with respect to aquatic acidification effects.

Based on considering available classification schemes for spatial aggregation, the PA concludes that Omernik's ecoregion classification (as described at <http://www.epa.gov/wed/pages/ecoregions>) is the most appropriate method to consider for the purposes of this review. The PA concludes that ecoregion level III (Figure IV-1) resolution, with 84 defined ecoregions in the contiguous United States,<sup>8</sup> is the most appropriate level to consider for this purpose. The PA notes that the use of ecoregions is an appropriate spatial aggregation scheme for an AAI-based standard focused on deposition-related aquatic acidification effects, while many of the same ecoregion attributes may be applicable in subsequent NAAQS reviews that may address other deposition-related aquatic and terrestrial ecological effects. Because atmospheric deposition is modified by ecosystem attributes, the types of vegetation, soils, bedrock geology, and topographic features that are the basis of this ecoregion classification approach also will likely be key attributes for other deposition-related effects (e.g., terrestrial acidification, nutrient enrichment) that link atmospheric concentrations to an aquatic or terrestrial ecological indicator.

The PA used Omernik's original alkalinity data (U.S. EPA, 2011, section

<sup>7</sup> Because NH<sub>x</sub> is characterized directly as deposition, not as an ambient concentration in this

equation, no transference ratio is needed for this term.

<sup>8</sup> We note that an 85th area within Omernik's Ecoregion Level III is currently being developed for California.

2) and more recent ANC data to delineate two broad groupings of ecoregions: acid-sensitive and relatively non-acid sensitive ecoregions. This delineation was made to facilitate greater focus on those ecoregions with water bodies that generally have greater acid sensitivity and to avoid over-protection in regions with generally less sensitive water bodies. The approach used to delineate acid-sensitive and relatively non-acid sensitive regions included an initial numerical-based sorting scheme using ANC data, which categorized ecoregions with relatively high ANC values as being relatively non-acid sensitive. This initial delineation resulted in 29 of the 84 Omernik ecoregions being categorized as acid sensitive. Subsequently, land use data based on the 2006 National Land Cover Data base (NLCD, <http://www.epa.gov/mlrc/nlcd-2006.html>) were also considered to determine to what extent an ecoregion is of a relatively pristine and rural nature by quantifying the degree to which active management practices related to development and agriculture occur in each ecoregion, resulting in 22 relatively acid-sensitive ecoregions (Table III-1).

TABLE III-1—LIST OF 22 ACID-SENSITIVE AREAS

Ecoregion name	Ecoregion number
Ridge and Valley .....	8.4.1
Northern Appalachian Plateau and Uplands .....	8.1.3
Piedmont .....	8.3.4
Western Allegheny Plateau .....	8.4.3
Southwestern Appalachians .....	8.4.9
Boston Mountains .....	8.4.6
Blue Ridge .....	8.4.4
Ouachita Mountains .....	8.4.8
Central Appalachians .....	8.4.2
Northern Lakes and Forests .....	5.2.1
Maine/New Brunswick Plains and Hills .....	8.1.8
North Central Appalachians .....	5.3.3
Northern Appalachian and Atlantic Maritime Highlands .....	5.3.1
Columbia Mountains/Northern Rockies .....	6.2.3
Middle Rockies .....	6.2.10
Wasatch and Uinta Mountains ...	6.2.13
North Cascades .....	6.2.5
Cascades .....	6.2.7
Southern Rockies .....	6.2.14
Sierra Nevada .....	6.2.12
Idaho Batholith .....	6.2.15
Canadian Rockies .....	6.2.4

Consideration was also given to the use of naturally acidic conditions in defining relatively non-acid sensitive areas. For example, several of the ecoregions located in plains near the coast exhibit elevated dissolved organic carbon (DOC) levels, which is associated

with naturally acidic conditions. The DOC in surface waters is derived from a variety of weak organic acid compounds generated from the natural availability and decomposition of organic matter from biota. Consequently, high DOC is associated with “natural” acidity, with the implication that a standard intended to protect against atmospheric contributions to acidity is not an area of focus. The evidence suggests that several of the more highly managed ecoregions in coastal or near coastal transition zones are associated with relatively high DOC values, typically exceeding on average 5 milligrams per liter, compared to other acid sensitive areas. Although there is sound logic to interpret naturally acidic areas as relatively non-acid sensitive, natural acidity indicators were not explicitly included in defining relatively non-acid sensitive areas as there does not exist a generally accepted quantifiable scientific definition of natural acidity. Approaches to explicitly define natural acidity likely will be pursued in future reviews of the standard.

Having concluded that the Omernik level III ecoregions are an appropriate approach to spatial aggregation for the purpose of a standard to address deposition-related aquatic acidification effects, the PA uses those ecoregions to define each of the factors in the AAI equation. As discussed below, factors F1 through F4 in equation III-4 are defined for each ecoregion by specifying ecoregion-specific values for each factor based on measured and modeled data.

i. Factor F1

As discussed above, factor F1 reflects a relative measure of an ecosystem’s ability to neutralize acidifying deposition, and is defined as:  $F1 = \frac{AN_{clim} + CL_r}{Q_r}$ . The value of F1 for each ecoregion would be based on a calculated critical load used to represent the ecoregion ( $CL_r$ ) associated with a single national target ANC level ( $AN_{clim}$ , discussed below in section III.D), as well as on a runoff rate ( $Q_r$ ) to represent the region. To specify ecoregion-specific values for the term  $Q_r$ , the PA used the median value of the distribution of Q values that are available for water bodies within each ecoregion. To specify ecoregion-specific values for the term  $CL_r$  in factor F1, a distribution<sup>9</sup> of calculated critical loads

<sup>9</sup>The distribution of critical loads was based on CL values calculated with Neco at the lake level. Consideration could also be given to using a distribution of CLs without Neco and adding the ecoregion average Neco value to the nth percentile critical load. This would avoid cases where the lake-level Neco value potentially could be greater

was created for the water bodies in each ecoregion for which sufficient water quality and hydrology data are available.<sup>10</sup> The specified critical load was then defined to be a specific percentile of the distribution of critical loads in the ecoregion. Thus, for example, using the 90th percentile means that within an ecoregion, the goal would be for 90 percent of the water bodies to have higher calculated critical loads than the specified critical load. That is, if the specified critical load were to occur across the ecoregion, the goal would be for 90 percent of the water bodies to achieve the national ANC target or better.

The specific percentile selected as part of the definition of F1 is an important parameter that directly impacts the critical load specified to represent each ecoregion, and therefore the degree of protectiveness of the standard. A higher percentile corresponds to a lower critical load and, therefore, to lower allowable ambient air concentrations of  $NO_y$  and  $SO_x$  and related deposition to achieve a target AAI level. In conjunction with the other terms in the AAI equation, alternative forms can be appropriately characterized in part by identifying a range of alternative percentiles. The choice of an appropriate range of percentiles to consider for acid-sensitive and relatively non-acid sensitive ecoregions, respectively, is discussed below.

For relatively acid-sensitive ecoregions, the PA concludes it is appropriate to consider percentiles in the range of the 70th to the 90th percentile (of sensitivity). This conclusion is based on the judgment that it would not be appropriate to represent an ecoregion with the lowest or near lowest critical load, so as to avoid potential extreme outliers that can be seen to exist at the extreme end of the data distributions, which would not be representative of the population of acid sensitive water bodies within the ecoregion and could lead to an overly protective standard. At the same time, in considering ecoregions that are inherently acid sensitive, it is judged to be appropriate to limit the lower end of the range for consideration to the 70th percentile, a value well above the median of the distribution, so that a substantial majority of acid-sensitive water bodies are protected. Since the percentile value influences the relative

than total nitrogen deposition. The CL at the lake level represents the CL for the lake to achieve the specified national target ANC value.

<sup>10</sup>The PA judged the data to be sufficient for this purpose if data are available from more than 10 water bodies in an ecoregion.

degree of protectiveness afforded by the AAI approach, the degree of confidence in characterizing the representativeness of sampled water bodies relative to all water bodies within an ecoregion is a critical issue, and it is important to continually improve this confidence.

For relatively non-acid sensitive ecoregions, the PA concludes it is appropriate to consider the use of a range of percentiles that extends lower than the range identified above for acid-sensitive ecoregions. Consideration of a lower percentile would avoid representing a relatively non-acid sensitive ecoregion by a critical load associated with relatively more acid-sensitive water bodies. In particular, the PA concludes it is appropriate to focus on the median or 50th percentile of the distribution of critical loads so as to avoid over-protection in such ecoregions.

#### ii. Factor F2, F3 and F4

As discussed above, factor F2 is the amount of reduced nitrogen deposition within an ecoregion, including the deposition of both ammonia gas and ammonium ion, and is defined as:  $F2 = NH_x/Q_r$ . The PA calculated the representative runoff rate,  $Q_r$ , using a similar approach as noted above for factor F1; i.e., the median value of the distribution of  $Q$  values that are available for water bodies within each ecoregion. In the PA, 2005 CMAQ model simulations over 12-km grids are used to calculate an average value of  $NH_x$  for each ecoregion. The  $NH_x$  term is based on annual average model outputs for each grid cell, which are spatially averaged across all the grid cells contained in each ecoregion to calculate a representative annual average value for each ecoregion. The PA concludes that this approach of using spatially averaged values is appropriate for modeling, largely due to the relatively rapid mixing of air masses that typically results in relatively homogeneous air quality patterns for regionally dispersed pollutants. In addition, there is greater confidence in using spatially averaged modeled atmospheric fields than in using modeled point-specific fields.

This averaging approach is also used for the air concentration and deposition terms in factors F3 and F4, which are the ratios that relate ambient air concentrations of  $NO_y$  and  $SO_x$  to the associated deposition, and are defined as follows:  $F3 = T_{NO_y}/Q_r$  and  $F4 = T_{SO_x}/Q_r$ .  $T_{NO_y}$  is the transference ratio that converts ambient air concentrations of  $NO_y$  to deposition of  $NO_y$  and  $T_{SO_x}$  is the transference ratio that converts ambient air concentrations of  $SO_x$  to

deposition of  $SO_x$ . The transference ratios are based on the 2005 CMAQ simulations, using average values for each ecoregion, as noted above for factor F2. More specifically, the transference ratios are calculated as the annual deposition of  $NO_y$  or  $SO_x$  spatially averaged across the ecoregion and divided by the annual ambient air concentration of  $NO_y$  or  $SO_x$ , respectively, spatially averaged across the ecoregion.

#### f. Summary of the AAI Form

The PA developed an ecologically relevant form of an ambient air quality standard to address deposition-related aquatic acidification effects using an equation to calculate an AAI value in terms of the ambient air indicators of oxides of nitrogen and sulfur and the relevant ecological and atmospheric factors that modify the relationships between the ambient air indicators and ANC. Recognizing the spatial variability of such factors across the United States, the PA concludes it is appropriate to divide the country into ecologically relevant regions, characterized as acid-sensitive or relatively non-acid sensitive, and specify the value of each of the factors in the AAI equation for each such region.

Using the equation, a value of AAI can be calculated for any measured values of ambient  $NO_y$  and  $SO_x$ . For such a NAAQS, the Administrator would set a single, national value for the level of the AAI used to determine achievement of the NAAQS, as summarized below in section III.A.4. The ecoregion-specific values for factors F1 through F4 would be specified by the EPA based on the most recent data and CMAQ model simulations, and codified as part of such a standard. These factors would be reviewed and updated as appropriate in the context of each periodic review of the NAAQS.

#### 3. Averaging Time

Reflecting a focus on long-term effects of acidifying deposition, the PA developed the AAI that links ambient air indicators to deposition-related ecological effects, in terms of several factors, F1 through F4. As discussed above, these factors are all calculated as annual average values, whether based on water quality and hydrology data or on CMAQ model simulations. In the context of a standard defined in terms of the AAI, the PA concludes that it is appropriate to consider the same annual averaging time for the ambient air indicators as is used for the factors in the AAI equation. As noted in chapter 3 of the ISA, protection against episodic

acidity events can be achieved by establishing a higher chronic ANC level.

The PA also considered interannual variability in both ambient air quality and in precipitation, which is directly related to the deposition of oxides of nitrogen and sulfur from the ambient air. While ambient air concentrations show year-to-year variability, often the year-to-year variability in precipitation is considerably greater, given the highly stochastic nature of precipitation. The use of multiple years over which annual averages are determined would dampen the effects of interannual variability in both air quality and precipitation. Consequently, the PA concludes that an annual averaging time based on the average of each year over a consecutive 3- to 5-year period is appropriate to consider for the ambient air indicators  $NO_y$  and  $SO_x$ .

#### 4. Level

The PA concludes that the level of a standard for aquatic acidification based on the AAI would be defined in terms of a single, national value of the AAI. Such a standard would be met at a monitoring site when the multi-year average of the calculated annual values of the AAI was equal to or *above* the specified level of the standard.<sup>11</sup> The annual values of the AAI would be calculated based on the AAI equation using the assigned ecoregion-specific values for factors F1 through F4 and monitored annual average  $NO_y$  and  $SO_x$  concentrations. Since the AAI equation is based on chronic ANC as the ecological indicator, the level chosen for the standard would reflect a target chronic ANC value. The combination of the form of the standard, discussed above in section III.A.2, defined by the AAI equation and the assigned values of the F factors in the equation, other elements of the standard including the ambient air indicators (section III.A.1) and their averaging time (section III.A.3), and the level of the standard determines the allowable levels of  $NO_y$  and  $SO_x$  in the ambient air within each ecoregion. All of the elements of the standard together determine the degree of protection from adverse aquatic acidification effects associated with oxides of nitrogen and sulfur in the ambient air. The level of the standard plays a central role in determining the degree of protection provided and is discussed below.

Based on associations between pH levels and target ANC levels and

<sup>11</sup> Unlike other NAAQS, where the standard is met when the relevant value is at or below the level of the standard since a lower standard level is more protective, in this case a higher standard level is more protective.

between ANC levels and aquatic ecosystem effects, as well as consideration of episodic acidity, ecosystem response time, precedent uses of target ANC levels, and public welfare benefits, the PA concludes that consideration should be given to a range of standard AAI levels from 20 to 75  $\mu\text{eq/L}$ . The available evidence indicates that target ANC levels below 20  $\mu\text{eq/L}$  would be inadequate to protect against substantial ecological effects and potential catastrophic loss of ecosystem function in some sensitive aquatic ecosystems. While ecological effects occur at ANC levels below 50  $\mu\text{eq/L}$  in some sensitive ecosystems, the degree and nature of those effects are less significant than at levels below 20  $\mu\text{eq/L}$ . Levels at and above 50  $\mu\text{eq/L}$  would be expected to provide additional protection, although uncertainties regarding the potential for additional protection from adverse ecological effects are much larger for target ANC levels above about 75  $\mu\text{eq/L}$ , as effects are generally appreciably less sensitive to changes in ANC at such higher levels.

The PA recognizes that the level of the standard together with the other elements of the standard, including the ambient air indicators, averaging time, and form, determine the overall protectiveness of the standard. Thus, consideration of a standard level should reflect the strengths and limitations of the evidence and assessments as well as the inherent uncertainties in the development of each of the elements of the standard. The implications of considering alternative standards, defined in terms of alternative combinations of levels and percentile values that are a critical component of factor F1 in the form of the standard, are discussed in section III.E of the proposal and more fully in the PA.

##### 5. Characterization of Uncertainties

The characterization of uncertainties is intended to address the relative confidence associated with the linked atmospheric-ecological effects system described above, and is described in detail in the PA (U.S. EPA, 2011, section 7.6 and Appendices F and G) and summarized in section III.F of the proposal. A brief overview of uncertainties is presented here in the context of the major structural components underlying the standard, as well as with regard to areas of relatively high uncertainty.

As discussed in the PA (U.S. EPA, 2011, Table 7–3), there is relatively low uncertainty with regard to the conceptual formulation of the overall structure of the AAI-based standard that incorporates the major associations

linking biological effects to air concentrations. Based on the strength of the evidence that links species richness and mortality to water quality, the associations are strongly causal and without any obvious confounding influence. The strong association between the ecosystem indicator (ANC) and the causative water chemistry species (dissolved aluminum and hydrogen ion) reinforces the confidence in the linkage between deposition of nitrogen and sulfur and effects. This strong association between ANC and effects is supported by a sound mechanistic foundation between deposition and ANC. The same mechanistic strength holds true for the relationship between ambient air levels of nitrogen and sulfur and deposition, which completes the linkage from ambient air indicators through deposition to ecological effects.

There are much higher uncertainties, however, in considering and quantifying the specific elements within the structure of an AAI-based standard, including the deposition of  $\text{SO}_x$ ,  $\text{NO}_y$ , and  $\text{NH}_x$  as well as the critical load-related component, each of which can vary within and across ecoregions. Overall system uncertainty with an AAI approach relates not just to the uncertainty in each element, but also to the combined uncertainties that result from linking these elements together within the AAI-based structure and over the defined spatial scale (i.e., ecoregions). Some of these elements—including, for example, dry deposition, pre-industrial base cation production, and reduced nitrogen deposition—are estimated with less confidence than other elements (U.S. EPA, 2011, Table 7.3). The uncertainties associated with all of these elements, and the combination of these elements through the AAI equation and over the ecoregion spatial scale, are summarized below.

The lack of observed dry deposition data, which affects confidence in the AAI on an ecoregion scale, is constrained in part by the lack of efficient measurement technologies. Progress in reducing uncertainties in dry deposition will depend on improved atmospheric concentration data and direct deposition flux measurements of the relevant suite of  $\text{NO}_y$  and  $\text{SO}_x$  species.

Pre-industrial base cation productivity by definition is not observable. Contemporary observations and inter-model comparisons are useful tools that help reduce the uncertainty in estimates of pre-industrial base cation productivity used in the AAI equation. In characterizing contemporary base cation flux using basic water quality

measurements (i.e., major anion and cation species as defined in equation 2.11 in the PA), it is reasonable to assume that a major component of contemporary base cation flux is associated with pre-industrial weathering rates. To the extent that multiple models converge on similar solutions within and across ecoregions, greater confidence in estimating pre-industrial base cation production within the AAI and ecoregion frameworks would be achieved.

While characterization of  $\text{NH}_x$  deposition has been evolving over the last decade, the high uncertainty in characterizing  $\text{NH}_x$  deposition is due to both the lack of field measurements and the inherent complexity of characterizing  $\text{NH}_x$  with respect to source emissions and dry deposition.<sup>12</sup> Because ammonia emissions are generated through a combination of man-made and biological activities, and ammonia is semi-volatile, the ability to characterize spatial and temporal distributions of  $\text{NH}_x$  concentrations and deposition patterns is limited. While direct measurement of  $\text{NH}_x$  deposition is resource intensive because of the diffuse nature of sources (i.e., area-wide and non-point sources), there have been more frequent deposition flux studies, relative to other nitrogen species, that enable the estimation of both emissions and dry deposition. Also, while ammonia has a relatively high deposition velocity and traditionally was thought to deposit close to the emissions release areas, the semi-volatile nature of ammonia results in re-entrainment back into the lower boundary layer of the atmosphere resulting in a more dispersed concentration pattern exhibiting transport characteristics similar to longer lived atmospheric species. These inherent complexities in source characterization and ambient concentration patterns significantly increase the degree of uncertainty in  $\text{NH}_x$  deposition in general, and in the AAI equation applied on an ecoregion scale in particular. However, the PA notes that progress is being made in measuring ammonia with cost efficient samplers and anticipates the gradual evolution of a spatially robust ammonia sampling network that would help support analyses to reduce underlying uncertainties in  $\text{NH}_x$  deposition.

In characterizing uncertainties with respect to available measurement data and the use of ecological and

<sup>12</sup> Field measurements of  $\text{NH}_x$  have been extremely limited, but have begun to be enhanced through the NADP's passive ammonia network (AMoN).

atmospheric models, as summarized in sections III.F.2–3 of the proposal, the PA identified data gaps and model uncertainties in relative terms by comparing, for example, the relative richness of data between geographic areas or environmental media. As discussed in the proposal and more fully in the PA, from an uncertainty perspective, gaps in field measurement data increase uncertainties in modeled processes and in the specific application of such models. As noted above, processes that are embodied in an AAI-based standard are modeled using the CMAQ atmospheric model and steady-state ecological models. These models are characterized in the ISA as being well-established and have undergone extensive peer review. Nonetheless, the application of these models for purposes of specifying the factors in the AAI equation, on an ecoregion scale, is a new application that introduces uncertainties, especially in areas with limited observational data that can be used to evaluate this specific application. Understanding uncertainties in relevant modeled processes thus involves consideration of the uncertainties associated with applying each model as well as the combination of these uncertainties as the models are applied in combination within the AAI framework applied on an ecoregion scale.

Our confidence in improving critical load estimates can be increased by expanding water quality data bases used as inputs and evaluation metrics for critical load models. With regard to water quality data, the PA notes that such data are typically limited relative to air quality data sets, and are also relatively sparse in the western United States. While there are several state and local agency water quality data bases, it is unclear the extent to which differences in sampling, chemical analysis and reporting protocols would impact the use of such data for the purpose of better understanding the degree of protectiveness that would be afforded by an AAI-based standard within sensitive ecoregions across the country. In addition, our understanding of water quality in Alaska and Hawaii and the acid sensitivity of their ecoregions is particularly limited. Expanding the water quality data bases would enable clearer delineation of ecoregion representative critical loads in terms of the  $n^{\text{th}}$  percentile. This would provide more refined characterization of the degree of protection afforded by a given standard. Longer term, the availability of water quality trend data (annual to monthly sampled) would

support accountability assessments that examine if an ecoregion's response to air management efforts is as predicted by earlier model forecasting. The most obvious example is the long-term response of water quality ANC change to changes in calculated AAI, deposition, ambient  $\text{NO}_y$  and  $\text{SO}_x$  concentrations, and emissions. In addition, water quality trends data provide a basis for evaluating and improving the parameterizations of processes in critical load models applied at the ecoregion scale related to nitrogen retention and base cation supply. A better understanding of soil processes, especially in the southern Appalachians, would enhance efforts to examine the variability within ecoregions of the soil-based adsorption and exchange processes which moderate the supply of major cations and anions to surface waters and strongly influence the response of surface water ANC to changes in deposition of nitrogen and sulfur.

Steady-state biogeochemical ecosystem modeling is used to develop critical load estimates that are incorporated in the AAI equation through factor F1. Consequently, the PA notes that an estimate of the temporal response of surface water ANC to deposition and air concentration changes is not directly available. Lacking a predicted temporal response impairs the ability to conduct accountability assessments down to the effects level. Accountability assessments would examine the response of each step in the emissions source through air concentration—deposition—surface water quality—biota continuum. The steady-state assumption at the ecosystem level does not impair accountability assessments through the air concentration/deposition range of that continuum. However, in using steady-state ecosystem modeling, several assumptions are made relative to the long-term importance of processes related to soil adsorption of major ions and ecosystem nitrogen dynamics. Because these models often were developed and applied in glaciated areas with relatively thin and organically rich soils, their applicability is relatively more uncertain in areas such as those in the non-glaciated clay-based soil regions of the central Appalachians. Consequently, it is desirable to develop the information bases to drive simple dynamic ecosystem models that incorporate more detailed treatment of subsurface processes, such as adsorption and exchange processes and sulfate absorption.

### B. CASAC Views

The CASAC has advised the EPA concerning the ISA, the REA, and the PA. The CASAC supported the EPA's interpretation of the science embodied in the ISA and the assessment approaches and conclusions incorporated in the REA.

Most recently, CASAC considered the information in the final PA in providing its recommendations on the review of the new multi-pollutant standard developed in that document and discussed above (Russell and Samet, 2011a). In so doing, CASAC expressed general support for the conceptual framework of the standard based on the underlying scientific information, as well as for the conclusions in the PA with regard to indicators, averaging time, form and level of the standard that are appropriate for consideration by the Agency in reaching decisions on the review of the secondary NAAQS for oxides of nitrogen and sulfur:

“The final *Policy Assessment* clearly sets out the basis for the recommended ranges for each of the four elements (indicator, averaging time, level and form) of a potential NAAQS that uses ambient air indicators to address the combined effects of oxides of nitrogen and oxides of sulfur on aquatic ecosystems, primarily streams and lakes. As requested in our previous letters, the *Policy Assessment* also describes the implications of choosing specific combinations of elements and provides numerous maps and tabular estimates of the spatial extent and degree of severity of NAAQS exceedances expected to result from possible combinations of the elements of the standard.”

“We believe this final PA is appropriate for use in determining a secondary standard to help protect aquatic ecosystems from acidifying deposition of oxides of sulfur and nitrogen. The EPA staff has done a commendable job developing the innovative Aquatic Acidification Index (AAI), which provides a framework for a national standard based on ambient concentrations that also takes into account regional differences in sensitivities of ecosystems across the country to effects of acidifying deposition.”

(Russell and Samet, 2011a).

With respect to indicators, CASAC supported the use of  $\text{SO}_x$  and  $\text{NO}_y$  as ambient air indicators (discussed above in section III.A) and ANC as the ecological indicator (discussed above in section III.B.1). With respect to averaging time (discussed above in section III.C), CASAC agreed with the conclusions in the PA that “an averaging time of three to five years for the AAI parameters is appropriate.” CASAC noted that “a longer averaging time would mask possible trends of AAI, while a shorter averaging time would make the AAI being more influenced by the conditions of the

particular years selected” (Russell and Samet, 2011a).

With respect to the form of the standard (discussed above in section III.B), CASAC stated the following:

“EPA has developed the AAI, an innovative “form” of the NAAQS itself that incorporates the multi-pollutant, multi-media, environmentally modified, geographically variable nature of SO<sub>x</sub>/NO<sub>y</sub> deposition-related aquatic acidification effects. With the caveats noted below, CASAC believes that this form of the NAAQS as described in the final Policy Assessment is consistent with and directly reflective of current scientific understanding of effects of acidifying deposition on aquatic ecosystems.” (Russell and Samet, 2011a)

“CASAC agrees that the spatial components of the form in the Policy Assessment are reasonable and that use of Omernik’s ecoregions (Level III) is appropriate for a secondary NAAQS intended to protect the aquatic environment from acidification \* \* \*”

(Russell and Samet, 2011a).

The caveats noted by CASAC include a recognition of the importance of continuing to evaluate the performance of the CMAQ and ecological models to account for model uncertainties and to make the model-dependent factors in the AAI more transparent. In addition, CASAC noted that the role of DOC and its effects on ANC would benefit from further refinement and clarification (Russell and Samet, 2011a). While CASAC expressed the view that the “division of ecoregions into ‘sensitive’ and ‘non-sensitive’ subsets, with a more protective percentile applied to the sensitive areas, also seems reasonable” (Russell and Samet, 2011a), CASAC also noted that there was the need for greater clarity in specifying how appropriate screening criteria would be applied in assigning ecoregions to these categories. Further, CASAC identified potential biases in critical load calculations and in the regional representativeness of available water chemistry data, leading to the observation that a given percentile of the distribution of estimated critical loads may be protective of a higher percentage of surface waters in some regions (Russell and Samet, 2011a). Such potential biases led CASAC to recommend that “some attention be given to our residual concern that the available data may reflect the more sensitive water bodies and thus, the selection of the percentiles of waterbodies to be protected could be conservatively biased” (Russell and Samet, 2011a).

With respect to level as well as the combination of level and form as they are presented as alternative standards (discussed above in sections III.D–E), CASAC agreed with the PA conclusions

that consideration should be given to standard levels within the range of 20 and 75 µeq/L. CASAC also recognized that the level and the form of any AAI-based standard are so closely linked that these two elements should be considered together:

“When considered in isolation, it is difficult to evaluate the logic or implications of selecting from percentiles (70th to 90th) of the distribution of estimated critical loads for lakes in sensitive ecoregions to determine an acceptable amount of deposition for a given ecoregion. However, when these percentile ranges are combined with alternative levels within the staff-recommended ANC range of 20 to 75 microequivalents per liter (µeq/L), the results using the AAI point to the ecoregions across the country that would be expected to require additional protection from acidifying deposition. Reasonable choices were made in developing the form. The number of acid sensitive regions not likely to meet the standard will be affected both by choice of ANC level and the percentile of the distribution of critical loads for lakes to meet alternative ANC levels in each region. These combined recommendations provide the Administrator with a broad but reasonable range of minimally to substantially protective options for the standard.”

(Russell and Samet, 2011a).

CASAC also commented on the EPA’s uncertainty analysis, and provided advice on areas requiring further clarification in the proposed rule and future research. The CASAC found it “difficult to judge the adequacy of the uncertainty analysis performed by the EPA because of lack of details on data inputs and the methodology used, and lack of clarity in presentation” (Russell and Samet, 2011a). In particular, CASAC identified the need for more thorough model evaluations of critical load and atmospheric modeling, recognizing the important role of models as they are incorporated in the form of the standard. In light of the innovative nature of the standard developed in the PA, CASAC identified “a number of areas that should be the focus of further research” (Russell and Samet, 2011a). While CASAC recognized that the EPA staff was able to address some of the issues in the PA, they also noted areas “that would benefit from further study or consideration in potential revisions or modifications to the form of the standard.” Such research areas include “sulfur retention and mobilization in the soils, aluminum availability, soil versus water acidification and ecosystem recovery times.” Further, CASAC encouraged future efforts to monitor individual ambient nitrogen species, which would help inform further CMAQ evaluations and the

specification of model-derived elements in the AAI equation (Russell and Samet, 2011a).

### C. Proposed Conclusions on Alternative Secondary Standards

As discussed in section III.H of the proposal, the Administrator considered whether it is appropriate at this time to set a new multi-pollutant standard to address deposition-related effects associated with oxides of nitrogen and sulfur, with a structure that would better reflect the available science regarding acidifying deposition to sensitive aquatic ecosystems. In so doing, she recognized that such a standard, for purposes of Section 109(b) and (d) of the CAA, must in her judgment be requisite to protect public welfare, such that it would be neither more nor less stringent than necessary for that purpose. In particular, she focused on the AAI-based standard developed in the PA and reviewed by CASAC, as discussed above. Based on consideration of the scientific basis for such a standard and the conclusions reached in the ISA, the Administrator agreed with the conclusion in the PA, and supported by CASAC, that there is a strong scientific basis for development of a standard with the general structure presented in the PA. She recognized that while the standard is innovative and unique, the structure of the standard is well-grounded in the science underlying the relationships between ambient concentrations of oxides of nitrogen and sulfur and the aquatic acidification related to deposition of nitrogen and sulfur associated with such ambient concentrations.

Nonetheless, the Administrator also recognized that such a standard would depend on atmospheric and ecological modeling, based on appropriate data, to specify the terms of an equation that incorporates the linkages between ambient concentrations, deposition, and aquatic acidification, for each separate ecoregion, and that there are a number of inherent uncertainties and complexities that are relevant to the question of whether it is appropriate under Section 109 of the CAA to set a specific AAI-based standard at this time. Based on her consideration of these important uncertainties and limitations, the Administrator recognized that in combination, these limitations and uncertainties result in a considerable degree of uncertainty as to how well the quantified elements of the AAI standard would predict the actual relationship between varying ambient concentrations of oxides of nitrogen and sulfur and steady-state ANC levels across the distribution of water bodies within the



various ecoregions in the United States. Because of this, there is considerable uncertainty as to the actual degree of protectiveness that such a standard would provide, especially for acid-sensitive ecoregions. The Administrator recognized that the AAI equation, with factors quantified in the ranges discussed above and described more fully in the PA, generally performs well in identifying areas of the country that are sensitive to such acidifying deposition and indicates, as expected, that lower ambient levels of oxides of nitrogen and sulfur would lead to higher calculated AAI values. However, the uncertainties discussed here are critical for determining the actual degree of protection that would be afforded such areas by any specific target ANC level and percentile of water bodies that would be chosen in setting a new AAI-based standard, and thus for determining an appropriate AAI-based standard that meets the requirements of Section 109.

The Administrator noted that setting a NAAQS generally involves consideration of the degree of uncertainties in the science and other information, such as gaps in the relevant data and, in this case, limitations in the evaluation of the application of relevant ecological and atmospheric models at an ecoregion scale. She noted that the issue here is not a question of uncertainties about the scientific soundness of the structure of the AAI, but instead uncertainties in the quantification and representativeness of the elements of the AAI as they vary in ecoregions across the country. At present, these uncertainties prevent an understanding of the degree of protectiveness that would be afforded to various ecoregions across the country by a new standard defined in terms of a specific nationwide target ANC level and a specific percentile of water bodies for acid-sensitive ecoregions and thus prevent identification of an appropriate standard.

The Administrator judged that the uncertainties are of such nature and magnitude that there is no reasoned way to choose a specific AAI-based standard, in terms of a specific nationwide target ANC level or percentile of water bodies that would appropriately account for the uncertainties, since neither the direction nor the magnitude of change from the target level and percentile that would otherwise be chosen can reasonably be ascertained at this time. Further, she noted that CASAC acknowledged that important uncertainties remain that would benefit from further study and data collection efforts, which might lead to potential revisions or modifications

to the form of the standard developed in the PA, and that CASAC encouraged the Agency to engage in future monitoring and model evaluation efforts to help inform further development of the elements of an AAI-based standard. Based on these considerations the Administrator judged that the current limitations in relevant data and the uncertainties associated with specifying the elements of the AAI based on modeled factors are of such nature and degree as to prevent her from reaching a reasoned decision such that she is adequately confident as to what level and form (in terms of a selected percentile) of such a standard would provide any particular intended degree of protection of public welfare that the Administrator determined satisfied the requirements to set an appropriate standard under Section 109 of the CAA.

Based on the above considerations, the Administrator provisionally concluded that it is premature to set a new, multi-pollutant secondary standard for oxides of nitrogen and sulfur at this time, and as such she proposed not to set such a new secondary standard. Nonetheless, while the Administrator concluded that it is premature to set such a multi-pollutant standard at this time, she determined that the Agency should undertake a field pilot program to gather additional data (discussed below in section IV). She concluded that it is appropriate that such a program be undertaken before, rather than after, reaching a decision to set such a standard.

In reaching her proposed decision not to set a new AAI-based standard at this time, the Administrator recognized that the new NO<sub>2</sub> and SO<sub>2</sub> primary 1-hour standards set in 2010, while not ecologically relevant for a secondary standard, will nonetheless result in reductions in oxides of nitrogen and sulfur that will directionally benefit the environment by reducing NO<sub>y</sub> and SO<sub>x</sub> deposition to sensitive ecosystems. The Administrator proposed to revise the secondary standards by adding secondary standards identical to the NO<sub>2</sub> and SO<sub>2</sub> primary 1-hour standards set in 2010, including a 1-hour secondary NO<sub>2</sub> standard set at a level of 100 ppb and a 1-hour secondary SO<sub>2</sub> standard set at a level of 75 ppb. The EPA noted that while this will not add secondary standards of an ecologically relevant form to address deposition-related effects, it will provide additional protection for sensitive areas. The EPA further noted that this proposed decision is consistent with the view that the current secondary standards are neither sufficiently protective nor appropriate in form, but that it is not

appropriate to propose to set a new, ecologically relevant multi-pollutant secondary standard at this time, for the reasons summarized above.

The EPA solicited comment on all aspects of this proposed decision, as discussed in the following section.

#### *D. Comments on Alternative Secondary Standards*

In this section, comments received on the proposal related to an AAI-based standard are discussed in section III.D.1 and comments related to the proposed decision to set 1-hour NO<sub>2</sub> and SO<sub>2</sub> secondary standards are discussed in section III.D.2.

##### **1. Comments Related to an AAI-Based Standard**

General comments that either supported or opposed the proposed decision not to set an AAI-based standard in this review are addressed in this section. Two groups of commenters offered sharply divergent views on whether it is appropriate for the EPA to set or even consider an AAI-based standard to protect against the effects in aquatic ecosystems from acidifying deposition associated with ambient concentrations of oxides of nitrogen and sulfur. These groups provided strongly contrasting views on the strength and limitations in the underlying scientific information upon which such a standard could be based, as well as on the legal authority and requirements in the CAA for the EPA to set such a standard. These comments are discussed below in section III.D.1.a, and build in part on the overarching issue raised by some commenters as to the EPA's authority under the CAA to include deposition-related effects within the scope of a NAAQS review, which is discussed above in section I.E. Some commenters also expressed views about specific aspects of an AAI-based approach, as discussed below in section III.D.1.b. More technical comments on specific elements and factors of the AAI are discussed in the Response to Comments document. General comments based on implementation-related factors that are not a permissible basis for considering an alternative standard are noted in the Response to Comments document.

##### **a. Comments on Consideration of an AAI-Based Standard**

The first group of commenters, including several industry groups (e.g., EPRI, UARG, and API), individual companies (e.g., East Kentucky Power Cooperative), and two states (TX, SD), strongly supported the EPA's proposed decision not to set an AAI-based

standard in this review. These commenters generally focused on the limitations and uncertainties in the scientific evidence used by the EPA as a basis for its consideration of an AAI-based standard, expressing the view that these limitations and uncertainties were so great as to preclude setting such a standard at this time. Several industry commenters felt the uncertainties were of sufficient magnitude as to invalidate the AAI approach for use in the NAAQS, while others agreed with the EPA's finding that further information and analysis is needed, and further noted that this work should be completed before the EPA could propose a new multi-pollutant standard. More fundamentally, some commenters in this group expressed the view that any consideration of such a standard is inconsistent with various provisions of the CAA and thus unlawful.

With regard to their views on the underlying scientific information, many of these commenters focused on what they asserted were areas of substantial uncertainty in the AAI approach including uncertainties in the individual F factors of the AAI, air deposition modeling, critical loads modeling, and available water quality and watershed data. Several commenters felt a more rigorous uncertainty and variability analysis of the AAI, beyond the analyses that the EPA presented in the PA, would be needed if the EPA were to consider such a standard in the future.

Some commenters expressed concerns with specific aspects of the AAI, such as the adequacy of the Omernik ecoregion approach as a method of waterbody aggregation for critical load calculations and whether ANC was an appropriate ecological indicator. The commenters asserted that the EPA needed to explore different methods for calculating critical loads, collect essential data, and employ mechanistic water chemistry models. The commenters also felt that the EPA was arbitrary in choosing its criteria for sensitive ecoregions and percent waterbodies, and that there was a bias in the field data toward sensitive areas. Several commenters felt a more comprehensive research program was needed to improve characterization of the biogeochemical and deposition processes incorporated into the AAI.

Some industry groups commented on uncertainties in the CMAQ modeling, including high levels of uncertainty surrounding measurement and modeling of chemically reduced forms of nitrogen ( $\text{NH}_x$ ). Other commenters were also critical of the reliance of the AAI on modeling, and expressed the

view that CMAQ would require intensive deposition-focused evaluation.

A second group of commenters, including several environmental groups (e.g., Center for Biological Diversity, Earthjustice, and Adirondack Council), the U.S. Department of Interior and the National Park Service, the New York Department of Environmental Conservation, and two tribes (Fond du Lac Band and Potawatomi) strongly disagreed with the EPA's proposed decision not to set an AAI-based standard in this review. These commenters generally focused on the strengths of the evidence of deposition-related effects, the extent to which analyses presented in the PA addressed uncertainties and limitations in the evidence, and on information regarding the adversity of such effects as a basis for their views that such a standard was warranted at this time. Many of these commenters pointed to CASAC's review of the underlying scientific evidence and its support for moving forward with an AAI-based standard at this time as support for their views.

In general, the environmental group commenters expressed the view that the current standards are clearly not adequate and that a combined  $\text{NO}_x/\text{SO}_x$  standard that links ambient air quality to an ecosystem indicator is appropriate, founded in science, and necessary for protection of public welfare. The commenters stated the current standards are neither sufficiently protective nor appropriate to address deposition-related effects. They also noted that the EPA has worked for decades to solve the acid deposition problem and that in their view the AAI represents an elegant solution to that problem.

With regard to their views on the underlying scientific information, these commenters generally agreed with the EPA's proposed conclusions that there are well-established water quality and biological indicators of aquatic deposition and well-established models that address air deposition, water quality impacts, and effects on biota. Many of these commenters expressed the view that the uncertainties and limitations in the scientific evidence were adequately addressed in the PA, which was reviewed by CASAC. Many of these commenters pointed to CASAC's support for adopting an AAI-based standard in this review while concurrently conducting additional field monitoring and longer-term research that might reduce uncertainties in future reviews of secondary NAAQS for oxides of nitrogen and sulfur.

Some governmental agency commenters were strongly supportive of an AAI-based standard and clearly felt

such a standard should be adopted now. They also noted that the current ambient concentrations of  $\text{NO}_x$  and  $\text{SO}_x$  are causing adverse ecological impacts and they believe that ongoing damage due to acidic deposition and the risks to ecosystems far outweigh the risk of setting an AAI-based standard while some uncertainties remain. They assert that  $\text{NO}_x$  and  $\text{SO}_x$  deposition is causing adversity to public welfare and that the scientific uncertainties do not preclude setting an AAI-based standard, and point to CASAC as generally supporting this view. The commenters believe that the EPA has ample evidence to support a new ecologically based standard and that the AAI is reasonable and scientifically defensible. NY specifically recommended an AAI of 50 with some flexibility built into the F factors.

Some of these agency and environmental group commenters also referenced CASAC's support for specific elements of the AAI-based standard developed in the PA, including (1) The use of ANC as an appropriate ecological indicator for such a standard, (2) the use of  $\text{NO}_y$  and  $\text{SO}_x$  as well-justified indicators of atmospheric concentrations of oxides of nitrogen and sulfur, (3) the use of Omernik Level III ecoregions, (4) the division of ecoregions into sensitive and non-sensitive categories, (5) the use of a 3 to 5 year averaging time, and (6) the appropriateness of an AAI level between 20 to 75  $\mu\text{eq/L}$ .

With regard to their views on the requirements of the CAA, several environmental group commenters stated that given the large body of evidence supporting significant ongoing harm to the public welfare and the EPA's finding the current standards are neither sufficiently protective nor appropriate to address deposition-related effects, the EPA's reliance on uncertainty as grounds for failing to propose protective standards is irrational, arbitrary, and legally flawed. They believe that the EPA cannot lawfully reject a new AAI-based standard while continuing to rely solely on a form of the standard that is inadequate and allows serious harms to the public welfare to continue. When confronted with scientific uncertainties and incomplete data, they feel the EPA must act in a precautionary manner that errs toward stronger protections. Further, they believe that the EPA's reliance on scientific uncertainty as a basis for its inaction is unsupported in light of CASAC's advice and the EPA staff's conclusions in the ISA, REA and PA.

In addition to the two broad groups of commenters discussed above, a few other commenters offered more general

views on an AAI-based standard. For example, some state commenters (NC and PA) expressed support for the concept of developing a multi-pollutant, AAI-based standard, but felt that it would be important to gather additional information before proposing any such standard. One state organization (NESCAUM) expressed concern that the EPA was not following CASAC's recommendation to propose an ecologically relevant level and form for this NAAQS.

The EPA has carefully considered these comments on whether or not an AAI-based secondary standard for oxides of nitrogen and sulfur is appropriate at this time. The EPA agrees with the second group of commenters and CASAC's advice (outlined in section III.B) that there is a strong scientific basis for development of the structure of such a standard, specifically with regard to a standard that would provide protection from deposition-related aquatic acidification in sensitive ecosystems across the country. As discussed in section II.A and supported by several commenters, the available scientific evidence is sufficient to infer a causal relationship between acidifying deposition of nitrogen and sulfur and potential adverse effects to aquatic ecosystems, and that the deposition of oxides of nitrogen and sulfur both cause such acidification under current conditions that are allowed by the current secondary standards (U.S. EPA, 2008, chapter 3). The EPA agrees with commenters that there are well-established water quality and biological indicators of aquatic acidification as well as well-established models that address deposition, water quality, and effects on ecosystem biota, and that ecosystem sensitivity to acidification varies across the country (U.S. EPA, 2011, chapter 7).

The EPA also agrees with the second group of commenters and CASAC that ANC would be an appropriate ecological indicator, reflecting the acidifying effects of deposition of nitrogen and sulfur (U.S. EPA, 2011, chapter 7.2 and Russell and Samet, 2011a). Further, the EPA agrees that the structure of an AAI-based standard is well-grounded in science and would address the combined effects of deposition from oxides of nitrogen and sulfur by characterizing the linkages between ambient concentrations, deposition, and aquatic acidification, and that the structure of the standard takes into account relevant variations in these linkages across the country (section III.B. above and U.S. EPA, 2011, chapter 7).

The EPA disagrees with the first group of commenters that the use of Omernik ecoregions would be inadequate. A full explanation of the EPA's rationale for selecting the Omernik ecoregion scheme for spatial aggregation is found in section 7.2.5 of the PA. Omernik ecoregions include consideration of geology, physiology, vegetation, climate, soils, land use, wildlife, and hydrology. These factors also relate well to sensitivity to acidification. The EPA also evaluated the National Ecological Observatory Network (NEON) and Bailey's ecoregions developed for the U.S. Forest Service and concluded that the Omernik ecoregion classification would be the most appropriate for an AAI-based standard. It offers several levels of spatial delineation, has undergone extensive scientific peer review, and has explicitly been applied to delineating acid sensitive areas of the U.S.

Nonetheless, the EPA agrees with the first group of commenters that there are important and significant remaining scientific uncertainties within the derivation of the AAI, with the data used to specify the factors within the AAI equation, and with the models themselves. These uncertainties are more fully discussed in Appendix F and G of the PA and in section III.A.5 above. These uncertainties have been reviewed by CASAC, and the EPA recognizes that further research would help to reduce the uncertainties. In general, the EPA also recognizes that the AAI would depend on atmospheric and ecological modeling, with inherent uncertainties, to specify the terms of an AAI equation that incorporate the linkages between ambient concentrations, deposition, and aquatic acidification.

The EPA agrees with the first group of commenters that there are several important limitations in the available data upon which elements of the AAI are based (U.S. EPA, 2011, Chapter 7). For example, existing monitors for NO<sub>y</sub> are generally not located in areas that are representative of sensitive aquatic ecosystems, and there is relatively sparse water quality data coverage in sensitive mountainous western areas. Further, even in areas where relevant data are available, small sample sizes impede efforts to characterize the representativeness of the available data for some ecoregions, which was noted by CASAC as being of particular concern (Russell and Samet, 2011a). Also, measurements of reduced forms of nitrogen are available from only a small number of monitoring sites, and emission inventories for reduced forms of nitrogen used in atmospheric

modeling are subject to a high degree of uncertainty.

The EPA agrees with the first group of commenters that uncertainties related to the use of ecological and atmospheric models are difficult to evaluate due to a lack of relevant observational data. For example, relatively large uncertainties are introduced by a lack of data with regard to pre-industrial environmental conditions and other parameters that are necessary inputs to critical load models that are the basis for factor F1 in the AAI equation. Also, observational data are not generally available to evaluate the modeled relationships between nitrogen and sulfur in the ambient air and associated deposition, which are the basis for the other factors (i.e., F2, F3, and F4) in the AAI equation. The EPA recognizes that, in contrast, such model-related uncertainties are not relevant in the consideration of other NAAQS since those NAAQS are not defined in terms of factors based on such models.

The EPA agrees that these data limitations and model uncertainties create a number of inherent uncertainties and complexities in the quantification of the F factors of the AAI and the representativeness of the F factors at an ecoregion scale (U.S. EPA, 2011, Appendix F). These uncertainties and complexities currently lead to a high degree of uncertainty in characterizing the degree of protectiveness that would be afforded by an AAI-based standard with quantified F factors derived as discussed above, within the ranges of levels and forms identified in section III.A above.

The EPA disagrees with the first set of commenters that the selection of sensitive ecoregions and percentile waterbodies would be arbitrary. The EPA fully discussed its rationale and selection of sensitive ecoregions and the range of percentiles used in section 7.2.5 of the PA. The EPA relied on available alkalinity and ANC data to draw distinctions between sensitive and non-sensitive ecoregions. The EPA used its judgment in selecting the range of percentiles for sensitive and non-sensitive ecoregions, attempting to be neither over-protective nor under-protective of the set of waterbodies in each ecoregion.

In general, the first set of commenters tends to treat all aspects of the AAI as subject to a high to very high degree of uncertainty. The EPA disagrees with this view, and instead views some parts of the AAI as based on more certain scientific information than others. For example, the EPA believes there is a solid scientific basis for the general

framework of the AAI and for the relationship between ANC and effects on aquatic life. There is a strong basis for selection of ANC as an ecological indicator, for selection of NO<sub>y</sub> and SO<sub>x</sub> as ambient air indicators, for selection of the annual and 3- to 5-year averaging time frame, and for selection of the range of ANC and percentile of water bodies for consideration. Likewise, the EPA believes there is a solid scientific basis for selection of Omernik ecoregions as the geographic basis for development of the AAI F factors. The EPA believes that for many areas there is a strong basis for determining whether an ecoregion is acid sensitive or not acid sensitive, while recognizing there is some uncertainty in some areas as to which category the area should fall in. The EPA's decision not to adopt an AAI-based standard at this time is not driven by uncertainty in these elements of the AAI, but instead in the elements needed to derive the quantified F factors for ecoregions across the country and our ability to evaluate the representativeness of those F factors for an entire ecoregion. The greatest uncertainties concern the F1 and F2 factors, which relate to development of a single critical load to represent a specified percentile of all of the waterbodies in an ecoregion and development of the value for deposition of reduced nitrogen. In addition, there are also important and significant uncertainties related to development of the F3 and F4 factors, which concern the quantified relationship between ambient levels of NO<sub>y</sub> and SO<sub>x</sub> and deposition rates of nitrogen and sulfur. The bases for these uncertainties are discussed in more detail in sections III.A.5 above and are considered as well in section III.E below. Thus, while the EPA agrees in part with the first group of commenters, in general they paint with too broad a brush. The EPA's decision is based instead on taking into account the areas where there is less scientific uncertainty as well as the areas where there remain significant scientific uncertainties.

In general, the second set of commenters does not contest the scientific evidence as discussed by the EPA or the scientific conclusions the EPA draws. They do not contest the existence of scientific uncertainty or the causes of it, and do not present scientific or technical arguments to contest the nature or magnitude of the uncertainty. Instead, they disagree with the conclusions or judgments to draw from the uncertainty. In the view of these commenters, the degree of uncertainty is low enough to warrant

setting an AAI standard at this time. They disagree with the Administrator's policy judgment that the nature and magnitude of uncertainty is of such significance that it warrants not setting an AAI standard at this time. Their primary disagreement is with this judgment, not with the EPA's underlying views on the science and its uncertainties. As discussed in the proposal and below, however, the Administrator's reasoned judgment is that it is not appropriate to establish an AAI-based secondary standard at this time. The uncertainties discussed above prevent a reasoned understanding of the degree of protectiveness that would be afforded to various ecoregions across the country by a new standard defined in terms of a specific nationwide target ANC level and a specific percentile of water bodies for acid-sensitive ecoregions. Therefore, the Administrator is unable to identify an appropriate standard.

The EPA recognizes that the AAI equation, with factors quantified in the ranges discussed in section III.A above and described more fully in chapter 7 of the PA, generally performs well in identifying areas of the country that are sensitive to such acidifying deposition and indicates, as expected, that lower ambient levels of oxides of nitrogen and sulfur would lead to higher calculated AAI values (PA, chapter 7). However, the various uncertainties discussed above are critical for determining with any degree of confidence the actual degree of protection that would be afforded such areas by any specific target ANC level and percentile of water bodies that would be chosen in setting a new AAI-based standard with quantified F factors, and thus for determining an appropriate AAI-based standard that meets the requirements of Section 109 of the CAA. The EPA recognizes that these limitations and uncertainties result in a high degree of uncertainty as to how well the quantified elements of the AAI standard would predict the actual relationship between varying ambient concentrations of oxides of nitrogen and sulfur and steady-state ANC levels across the distribution of water bodies within the various ecoregions in the United States. Because of this, there is a high degree of uncertainty as to the actual degree of protectiveness that such a standard would provide, especially for acid-sensitive ecoregions.

With regard to comments that the EPA cannot lawfully reject a new AAI-based standard, the EPA disagrees with the second group of commenters that the Administrator is required to set an AAI-based standard at this time. Although

the Administrator has concluded that the current secondary standards are neither appropriate nor adequate to protect against potentially adverse deposition-related effects associated with ambient concentrations of oxides of nitrogen and sulfur, such a conclusion does not require the EPA to adopt a new NAAQS where the Administrator cannot reasonably judge that it would meet the criteria for a secondary NAAQS.

The Administrator judges that the current limitations in relevant data and the uncertainties associated with specifying the elements of a new AAI-based NAAQS defined in terms of modeled factors are of such a significant nature and degree as to prevent her from reaching a reasoned decision as to what level and form (in terms of a selected percentile) of such a standard would provide any particular intended degree of protection of public welfare that the Administrator determined satisfied the requirements to set an appropriate standard under Section 109 of the CAA. As a result, the Administrator has determined that she cannot establish an AAI-based standard that is requisite to protect public welfare. The Administrator has made a similar judgment in deciding not to adopt new secondary NAAQS in the form of 1-hour standards identical to the primary NO<sub>2</sub> and SO<sub>2</sub> standards, as discussed below. No other NAAQS revisions to address the effects of acid deposition associated with oxides of nitrogen and sulfur in the ambient air have been suggested or considered by the EPA, CASAC, or commenters in this review.<sup>13</sup> As such, all possible revisions to the secondary NAAQS to address the effects of acid deposition would involve adoption of new secondary standards that are judged by the Administrator to have such a high degree of uncertainty that she cannot make a reasoned decision that a new standard would satisfy the criteria of Section 109(b) of the CAA.

Commenters have pointed to the requirement in Section 109(b)(2) of the CAA that any secondary NAAQS "must specify a level of air quality the attainment and maintenance of which \* \* \* is requisite to protect the public welfare from any know or anticipated adverse effects \* \* \*" in support of the argument that the EPA must adopt a new standard that provides requisite protection, having concluded that the

<sup>13</sup> No one has suggested that the EPA should revise the current 3-hour or annual secondary standards to address the effects of acidifying deposition associated with oxides of nitrogen and sulfur in the ambient air. All revisions under consideration have involved adopting new secondary NAAQS.

current secondary standards are not sufficient to protect against adverse effects. In considering this comment, the EPA has taken into account the statutory language, as well as the bases for the EPA's conclusion that the current standards for oxides of nitrogen and sulfur are neither appropriate nor adequate to provide protection against potentially adverse deposition-related effects and the data and model uncertainties that limit our efforts to characterize the degree of protectiveness that would be afforded by either an AAI-based standard or a 1-hour standard. We have concluded that Section 109 of the CAA does not require the EPA to adopt a new secondary standard where, as here, in the reasoned judgment of the Administrator, the uncertainties associated with such a standard are of such significance that they prevent her from determining whether or not such a NAAQS is requisite to protect public welfare. Section 109(b) of the CAA does not require the EPA to set a new standard under circumstances where the Administrator cannot reasonably judge that it would meet the criteria for a secondary NAAQS.

This is consistent with the decision by the Supreme Court in *Massachusetts v. EPA*, 549 U.S. 497 (2007), which concerned the EPA's authority under Section 202(a) of the CAA. There the Supreme Court determined that scientific uncertainty that "is so profound that it precludes the EPA from making a reasoned judgment" concerning endangerment to public health and welfare from air pollution would justify the EPA not making a finding on endangerment. Id at 534. The Court noted that "[t]he statutory question is whether sufficient information exists to make" an endangerment finding. Id. In this review, the scientific uncertainty is of such a significant nature and degree that sufficient information does not exist for the EPA to make a reasoned judgment as to whether a new secondary standard addressing aquatic acidification would satisfy the criteria of Section 109(b). As such, adding a new AAI secondary standard at this time would not "be appropriate under [Section 109(b)]." CAA Section 109(d)(1).

The EPA recognizes and agrees with the comment from one environmental group that the EPA is not "foreclosed from setting a standard unless it can identify \* \* \* a 'perfect' standard level that is free from any noteworthy uncertainty." However, that is not the situation in this rulemaking. The Agency has concluded that it would not be appropriate to promulgate a standard to address the public welfare effects of

acidifying deposition where the remaining scientific uncertainties are of such significance that they preclude the EPA from making a reasoned determination of the degree of protectiveness that would be afforded by such a standard. The EPA recognizes that as a result of not setting a new secondary standard the current secondary standards continue in place and continue to be neither appropriate nor adequate to protect against potentially adverse deposition-related effects associated with ambient concentrations of oxides of nitrogen and sulfur. However, in the Administrator's view the proper response under the current circumstances is to continue to develop the scientific and technical basis for a future revision to the standards, and not to adopt at this time a new secondary standard that she cannot reasonably judge would comply with Section 109 of the CAA.

Further, the EPA agrees with both groups of commenters and CASAC that collecting further field data would be beneficial. A field pilot program is discussed in detail in section IV below. However, the EPA disagrees with the first group of commenters' assertions that these uncertainties should invalidate or preclude the further development of an AAI-based standard.

#### b. Comments on Specific Aspects of an AAI-Based Approach

This section discusses comments on the following four specific aspects of an AAI-based approach to setting a secondary standard for oxides of nitrogen and sulfur: (1) The inclusion of chemically reduced nitrogen ( $\text{NH}_x$ ), in addition to oxides of nitrogen, in the AAI equation; (2) whether such a standard would be appropriately construed as a national standard versus a regional standard; (3) whether such a standard would be appropriately construed as an ambient air quality standard versus a water quality standard, and (4) whether the EPA has authority under the CAA to set a multi-pollutant NAAQS.

(1) As described above in section III.A, the AAI equation contains a separate factor that accounts for the acidifying potential of  $\text{NH}_x$ , in addition to the factor that accounts for the acidifying potential of oxides of nitrogen. Several industry commenters addressed this issue explicitly, with some expressing the view that  $\text{NH}_x$  should be treated the same as  $\text{NO}_x$  in the AAI, while others felt it should not be included at all in the AAI. Several commenters expressed the view that accounting for  $\text{NH}_x$  in the AAI equation represents a *de facto* regulation of

ammonia, which they assert is unlawful since reduced nitrogen is not a listed air pollutant under Section 108 of the CAA.

Other commenters, including environmental groups and governmental agency commenters, did not explicitly comment on the inclusion of  $\text{NH}_x$  in the AAI equation; however several commenters made note of CASAC's advice on this issue. CASAC advised that it is necessary to include a factor for  $\text{NH}_x$  in the AAI equation, even though it is not a listed pollutant, since aquatic ecosystems respond to inputs of  $\text{NH}_x$  to create acidity just like they do with inputs of  $\text{NO}_x$  and  $\text{SO}_x$ .

The EPA has included  $\text{NH}_x$  deposition explicitly as part of factor F2 in the AAI expression to account for the acidifying potential afforded by ammonia gas and ammonium ion. Inclusion of  $\text{NH}_x$  deposition, in addition to deposition of oxides of nitrogen, is necessary to account for potential effects of all reactive nitrogen species which, in turn, allows for determining the contributions of oxides of N and S to aquatic acidification. This approach is consistent with the requirement in the CAA that where the state of the science provides a basis for considering such effects, the review of the air quality criteria for a pollutant should encompass the ways in which other air pollutants may interact with the criteria pollutant to produce adverse effects. See CAA Section 108(a)(2). In effect, the inclusion of  $\text{NH}_x$  deposition can be viewed as a necessary component consistent with our scientific understanding that links deposition of all nitrogen species to ecological effects.

The EPA recognizes that the NAAQS is established to address the pollutants oxides of nitrogen and oxides of sulfur. Consequently, the ambient concentrations of oxides of sulfur (as  $\text{SO}_x$ ) and nitrogen (as  $\text{NO}_y$ ) are accounted for separately from the deposition of  $\text{NH}_x$  in the AAI equation, thus defining the standard specifically in terms of the acidifying potential of levels of oxides of nitrogen and sulfur in the ambient air. More specifically, compliance with an AAI-based standard would be based on using federal reference or equivalent monitoring methods to measure ambient concentrations of  $\text{NO}_y$  and  $\text{SO}_x$  to determine an area's attainment status. Conversely, there would be no requirement to measure concentrations of  $\text{NH}_x$  to determine compliance with an AAI-based standard. Rather, ecoregion-specific values of  $\text{NH}_x$  deposition would be determined by modeling and would be specified by the EPA in conjunction with setting such a

standard, and would not be a variable in the AAI equation as would SO<sub>x</sub> and NO<sub>y</sub>. The contribution of reduced forms of nitrogen to total nitrogen deposition would represent an ecosystem-specific environmental factor that plays a necessary background role in characterizing the relationship between the measured, variable levels of the ambient air indicators of oxides of nitrogen and sulfur (NO<sub>y</sub> and SO<sub>x</sub>) and the associated degree of aquatic acidification. Section 108 requires the air quality criteria to evaluate to the extent practicable the variable factors such as atmospheric conditions that affect the impact of the ambient air pollutant (in this case oxides of nitrogen and sulfur) on the public welfare. In this review, such variable factors include the deposition of reduced nitrogen in an ecoregion, as well as all of the other elements reflected in the factors F1 to F4, and the designation of an area as acid-sensitive or not acid-sensitive. Section 109 calls for the EPA to base the NAAQS on the air quality criteria, and accounting for the role of reduced nitrogen deposition in the AAI reflects this.

In considering this aspect of an AAI-based standard, the EPA took into account that in applying the AAI equation, all factors, including NH<sub>x</sub> deposition, would be updated as appropriate as part of the periodic reviews of the NAAQS, called for at five-year intervals by the CAA, to account for changing environmental conditions and new data. In determining an ecoregion's status with regard to meeting a particular AAI-based standard, NH<sub>x</sub> deposition reflected in the F2 factor would be treated just as all of the other environmental terms—e.g. critical loads and transference ratios—which influence factors F1, F3 and F4. To the extent that changes in NH<sub>x</sub> deposition occur from one review to the next, the ecoregion-specific F2 factors would be updated to reflect such changes. To the extent that NH<sub>x</sub> deposition decreased from one review to the next, an AAI-based standard updated during a periodic review to reflect this change would allow for potentially higher levels of NO<sub>y</sub> and SO<sub>x</sub> that would meet a specific AAI-based standard; conversely, increased levels of NH<sub>x</sub> deposition would allow for potentially lower levels of NO<sub>y</sub> and SO<sub>x</sub>. Meeting a specific AAI-based standard would only require that the combined levels of NO<sub>y</sub> and SO<sub>x</sub> be such that a calculated AAI value meet or exceed the AAI value set as the level of the standard. Consequently, while the contribution of NH<sub>x</sub> deposition would

be accounted for, NH<sub>x</sub> emissions would not be regulated through the implementation of an AAI-based standard. NH<sub>x</sub> deposition would be treated as an ecologically relevant background value that could be updated over time to reflect changes in circumstances, but accounting for such changes would not be required for purposes of determining compliance with an AAI-based standard. Thus, the incorporation of NH<sub>x</sub> in the AAI equation would not result in *de facto* regulation of NH<sub>x</sub> emissions.

(2) Some commenters raised the issue of whether an AAI-based standard would be a national standard, as required by Section 109 of the CAA, or whether it is in essence a regional standard. One group of commenters (the Center for Biological Diversity and the National Park Service) generally expressed the view that an AAI-based standard would be a national standard, whereas another group, including industry commenters, asserted that an AAI-based standard would be a regional standard and thus not consistent with the requirements of the CAA.

The first group of commenters supported the use of a national ANC indicator, recognizing that an AAI approach would account for regional differences in sensitivity and relevant environmental factors while providing a nationally consistent degree of protection across sensitive ecoregions. For example, the National Park Service stated that the AAI approach provides a uniform level of protection to sensitive ecosystems while appropriately taking into account the variability in deposition, meteorology, and other relevant environmental factors across ecoregions.

The second group of commenters noted that application of the AAI equation in different areas of the country produced different allowable concentrations of NO<sub>y</sub> and SO<sub>x</sub>, asserting as a result that an AAI-based standard would be a regional standard. These commenters asserted that the EPA lacks authority under the CAA to set such a regional NAAQS. For example, UARG states that the AAI is applied differently in different regions of the country (e.g., sensitive vs. non-sensitive ecoregions). The Alliance of Automobile Manufacturers commented that both the EPA and Congress historically have decided that secondary national air quality standards are not an appropriate approach to address regionally variable welfare effects.

The EPA believes that a secondary NAAQS based on the AAI approach could be a national standard, consistent with the CAA. An AAI-based standard

would apply all across the country. It would be defined in part by a single level of the AAI—that is, every part of the country would be expected to meet or exceed a specified AAI level. The scientific basis for setting a national AAI level is rooted in the similarity between AAI and acid neutralizing capacity (ANC), which is a widely accepted ecological health indicator for aquatic acidification. The rationale underlying the use of ANC is that the ecosystem health reflected by an ANC value in one part of the country is generally similar to that in another location, irrespective of regional differences in biogeochemistry and atmospheric conditions. The EPA recognizes that allowable concentrations of the ambient air pollutant indicators for oxides of nitrogen and sulfur in the AAI equation can vary from one location to another and result in the same calculated AAI. The difference between an AAI-based standard and the existing primary standards is that the level of the standard is defined directly in terms of the measured ambient air pollutant indicator. That is, the health-based indicator and the measured ambient air indicator are based on the same chemical entity. In an AAI-based standard, the level of the standard, reflecting a nationally consistent degree of protection, would be defined in terms of an ecological indicator, ANC, and compliance would be determined based on concentrations of the ambient air indicators, NO<sub>y</sub> and SO<sub>x</sub>. From an ecosystem health perspective, it is most relevant to use the ecological indicator, ANC, to establish a single level that, in the context of an AAI, leads to a similar degree of protection across the country. The allowable levels of NO<sub>y</sub> and SO<sub>x</sub> could vary across the country, while the specified AAI level and the corresponding degree of protection, would not. This would facilitate ensuring that such a NAAQS would provide sufficient protection, but not more than was necessary. It should be noted that in the 2006 PM NAAQS decision the EPA set a NAAQS that envisions variation in allowable ambient levels of certain kinds of PM. The EPA set a PM<sub>10</sub> standard with a single numerical level, which then allowed varying levels of coarse PM, a subset of PM<sub>10</sub>. The PM<sub>10</sub> standard was designed to allow lower levels of coarse PM in urban areas and higher levels of coarse PM in non-urban, rural areas. The EPA's goal was to target protection at urban areas, where the evidence showed coarse particles presented a greater risk to public health. The single numerical standard for PM<sub>10</sub> allowed

variable levels of coarse PM, with higher allowable levels where there was less evidence of risk and lower allowable levels where the evidence of risk was greater. This approach was upheld in *American Farm Bur. Fed. v. EPA*, 559 F.3d 512, 533–536 (D.C. Cir. 2009).

In conjunction with consideration of an AAI-based standard, the EPA has recognized that the nation includes some relatively acid-sensitive and some relatively non-acid sensitive ecoregions. This delineation allows for an appropriate application of the AAI equation that increases its relevancy from a national perspective as it avoids creating more than requisite protection in areas that are not acid sensitive. The AAI equation and the selected level of such a standard would be applicable everywhere; however, factors in the AAI equation are appropriately dependent on the sensitive and non-sensitive ecoregion classification. Therefore, the delineation of sensitive and non-sensitive regions allows for a nationally consistent application of the AAI equation as it targets protection on those areas most likely to benefit from reductions in acidifying deposition of oxides of nitrogen and sulfur, and avoids more than requisite protection in areas that would not benefit from such reductions.

(3) Some commenters expressed the view that an AAI-based standard would essentially be a water quality standard, since it would use ANC, a water quality property, as the ecological indicator. For example, UARG expressed this view by noting that an AAI standard would be defined in terms of a single water quality level with multiple allowable air quality concentrations of oxides of nitrogen and sulfur.

The EPA notes that the AAI relates aquatic acidification to ambient air concentrations of oxides of nitrogen and sulfur. An AAI-based standard would be set at a level such that ambient air concentrations would not cause harmful acidification effects to water quality resources, which is within the scope of welfare effects that secondary NAAQS are to address (i.e., welfare effects include, but are not limited to, “effects on soils, water, \* \* \*”). Accordingly, while an AAI-based standard would address effects on water quality, it would do so by defining the allowable ambient air concentrations of oxides of nitrogen and sulfur that would provide appropriate protection against such effects. Compliance with such a standard would be determined by measuring ambient air concentrations of NO<sub>y</sub> and SO<sub>x</sub>, not by measuring the water quality property of ANC. The actual water quality of any body of

water would not be used to determine compliance with the air quality standard, and no body of water would be considered in “non-compliance” with an AAI air quality standard. Thus, an AAI-based standard is appropriately construed as an air quality standard, not a water quality standard.

(4) Some commenters questioned whether the EPA has the authority to establish a NAAQS that jointly addresses ambient concentrations of oxides of nitrogen and oxides of sulfur. Pointing to language in Section 109(b)(2) that a NAAQS must address “adverse effects associated with the presence of *such air pollutant* in the ambient air,” these commenters took the position that the EPA may not allow for tradeoffs between two pollutants in setting a NAAQS. See Section 109(b)(2) (emphasis added). These commenters suggest the NAAQS must be set for “such air pollutant” only. The EPA disagrees that the phrase “such air pollutant” in Section 109(b)(2) would prohibit the Agency from setting a multi-pollutant NAAQS in the form of an AAI. When the Administrator sets a NAAQS, the standard must be “requisite to protect the public welfare from any known or anticipated adverse effects associated with the presence of such air pollutant.” CAA Section 109(b)(2). Oxides of nitrogen and sulfur, pollutants for which the EPA has issued air quality criteria, both cause acidification of aquatic ecosystems, effects that could be considered adverse to public welfare. As such, acidifying deposition is a “known or anticipated adverse effect[ ] associated with the presence of [oxides of nitrogen] in the ambient air.” This known or anticipated adverse effect is also associated with the presence of oxides of sulfur in the ambient air. Given the scientific links between ambient air concentrations of oxides of nitrogen and sulfur, the related deposition of nitrogen and sulfur, and the associated ecological responses, the EPA appropriately considered a multi-pollutant NAAQS in the form of an AAI to protect against the effects of acidifying deposition to aquatic ecosystems that took into account these linkages. Rather than limiting the EPA’s authority, the language cited by the commenters goes to the breadth of the EPA’s obligation and authority to set standards to protect against “any known or anticipated adverse effects.” In addition, the NAAQS are to be based on the air quality criteria, which under Section 108(a)(2) are required to consider the kind of multi-pollutant linkage evident in this review. The EPA does not read

the language of Section 109(b) as prohibiting the Administrator from setting a multi-pollutant NAAQS such as the AAI where such an approach would be judged as the appropriate way to satisfy Section 109(b)’s requirements for each of the pollutants involved.

## 2. Comments on 1-Hour NO<sub>2</sub> and SO<sub>2</sub> Secondary Standards

Comments received on the proposal related to setting new 1-hour NO<sub>2</sub> and SO<sub>2</sub> secondary standards are addressed in this section. Most generally, there was broad and strong opposition to the EPA’s proposed decision to set 1-hour NO<sub>2</sub> and SO<sub>2</sub> secondary standards identical to the 1-hour NO<sub>2</sub> and SO<sub>2</sub> primary standards. For example, strong opposition to this proposed decision was expressed by a diverse set of commenters, including some environmental groups (e.g., Environmental Justice, the Adirondack Council) and industry groups (e.g., UARG, AAM, ASARCO, API, Portland Cement Association, Tri-State Generation and Transmission Association, Louisiana Chemical Association, East Kentucky Power Cooperative, FMMI, Rio Tinto), the U.S. Department of the Interior, and some states (e.g., NY, PA, TX). These commenters offered various arguments in support of their views that the proposed decision is unlawful, arbitrary, and not supported by the record of this rulemaking, as outlined below. One commenter (NC) supported setting secondary standards identical to the 1-hour NO<sub>2</sub> and SO<sub>2</sub> primary standards, while also supporting the EPA’s decision to take additional time to develop a multi-pollutant AAI-based secondary standard. Another commenter (SD) simply supported setting secondary standards that are no more stringent than the primary standards.

In proposing the 1-hour secondary standards, the EPA recognized that such standards would not be ecologically relevant, but concluded that they would nonetheless “directionally provide some degree of additional protection” by reducing deposition to sensitive ecosystems. The EPA also noted that this was consistent with the view that the current secondary standards are neither sufficiently protective nor appropriate in form, but that it is not appropriate to propose to set a new, ecologically relevant multi-pollutant secondary standard at this time.

In arguing that the proposed decision to set 1-hour NO<sub>2</sub> and SO<sub>2</sub> secondary standards identical to the 1-hour NO<sub>2</sub> and SO<sub>2</sub> primary standards is unlawful, commenters asserted that the EPA’s

rationale is not consistent with the requirements of Section 109 of the CAA. Commenters argue that this rationale is not consistent with the CAA requirement that the EPA set secondary NAAQS that are “requisite to protect public welfare;” that is, a standard that is neither more nor less stringent than necessary for this purpose. More specifically, these commenters argue that a standard that is based solely on “directionally” improving the environment, without any evidence or judgment that it would provide “requisite” protection, is not consistent with the requirements of the CAA and is thus unlawful. Some commenters also note that the CAA requires that the EPA revise previously adopted NAAQS as “appropriate” to provide such protection. These commenters assert that since the EPA’s proposal concludes that the 1-hour NO<sub>2</sub> and SO<sub>2</sub> standards are not ecologically relevant to address deposition-related effects on sensitive ecosystems, adding such standards cannot be considered to be an appropriate revision to the NAAQS for the purpose of addressing adverse ecological effects.

Commenters also raised a number of issues in support of their views that the proposed decision is arbitrary and unsupported by the available information in the record of this rulemaking. Some commenters noted that there is no evidence or analysis in the record that addresses the degree of protection that would likely be afforded by 1-hour NO<sub>2</sub> and SO<sub>2</sub> standards, and, further, that the EPA does not claim otherwise. In the absence of such information, commenters argue that the EPA cannot make a reasoned judgment as to what levels of such 1-hour NO<sub>2</sub> and SO<sub>2</sub> standards would be requisite to protect public welfare; in particular, some commenters emphasized that the EPA cannot demonstrate that such standards would not be more stringent than necessary to protect against adverse deposition-related effects to sensitive ecosystems. Thus, in the commenters’ view, any such 1-hour standards would be arbitrary.

One commenter also expressed the view that the EPA’s proposed decision to set new 1-hour NO<sub>2</sub> and SO<sub>2</sub> secondary standards is inconsistent with the reasoning the EPA used as a basis for proposing not to set a new ecologically relevant AAI-based secondary standard at this time. As summarized above, the EPA based its proposed decision not to set an AAI-based standard, which is expressly designed to address important differences in ecosystem sensitivities, in part on uncertainties and limitations in

relevant information that were of such nature and degree as to prevent the Administrator from reaching a reasoned decision at this time as to what level and form of such a standard would provide a particular degree of protection. This commenter asserts that the proposed decision to set new 1-hour NO<sub>2</sub> and SO<sub>2</sub> secondary standards completely ignores such uncertainties inherent in 1-hour standards, which are not even structured to account for differences in ecosystem sensitivities.

Some commenters asserted not only that the EPA has failed to provide any information on the degree of protection that would likely be afforded by the proposed 1-hour NO<sub>2</sub> and SO<sub>2</sub> standards, but that such an analysis cannot be done since there is no rational connection between any of the elements of the proposed 1-hour secondary standards—including the averaging time and level—and the ecological effects the proposed standards are intended to address. In particular, commenters noted that EPA has not presented any rational basis for concluding that standards designed to reduce human health risks associated with short-term peak concentrations of NO<sub>2</sub> and SO<sub>2</sub> have any connection whatsoever to addressing long-term deposition of oxides of nitrogen and sulfur and associated impacts on sensitive ecosystems.

Further, commenters argued that there is no evidence in the record that demonstrates the proposed 1-hour secondary standards would provide any environmental benefit. For example, commenters noted that such standards do not take into account ecosystem sensitivity; they may not result in reductions to long-term deposition that is the relevant time frame for deposition-related effects on sensitive ecosystems; and they would not provide any benefit beyond that which might accrue from the identical primary standards that are already in effect. Some commenters have also noted that many other environmental regulations are already in place that will provide reductions in ambient oxides of nitrogen and sulfur, and that the EPA has not demonstrated that any additional reductions are needed to provide requisite protection.

The EPA agrees that the Agency has not presented evidence or analysis in the record that addresses the degree of protection that would likely be afforded by secondary standards set identical to the current 1-hour NO<sub>2</sub> and SO<sub>2</sub> primary standards. The EPA further agrees that such an analysis cannot reasonably be done in the absence of a demonstrable linkage between peak 1-hour average

concentrations of NO<sub>2</sub> and SO<sub>2</sub> in the ambient air and the impact of deposition-related acidification associated with oxides of nitrogen and sulfur on sensitive aquatic ecosystems that the proposed standards were intended to address. As a result, the EPA agrees that there is no factual basis to make a reasoned judgment as to what levels of 1-hour NO<sub>2</sub> and SO<sub>2</sub> standards would provide a desired degree of protection of the public welfare, such that the EPA cannot demonstrate or judge that the proposed standards would not be more or less stringent than necessary to provide the desired degree of protection against potentially adverse deposition-related effects to sensitive ecosystems.

As to whether the proposed standards would provide any environmental benefit, it is the EPA’s view that it is reasonable to conclude that any standard that would lead to reductions in NO<sub>2</sub> and SO<sub>2</sub> emissions would likely result in some environmental benefit for some acid-sensitive areas. Nonetheless, the EPA recognizes that any such environmental benefit that would result from reductions in NO<sub>2</sub> and SO<sub>2</sub> emissions sufficient to attain the 1-hour standards cannot be specifically quantified or linked to reductions in aquatic acidification in specific ecoregions. In addition, unlike an AAI-based standard, the 1-hour standards would tend to provide more protection than is warranted in areas that are not acid-sensitive.

Further, the EPA recognizes that any benefits that would accrue as a result of actions taken to meet the 2010 1-hour NO<sub>2</sub> and SO<sub>2</sub> primary standards will occur regardless of whether we adopt identical secondary standards. Thus, there is no additional environmental benefit to be gained by making the standards identical. The EPA does not agree, however, that the Agency needs to consider future reductions that may accrue from other environmental regulations in the context of reaching a judgment as to what NAAQS is requisite to protect public welfare.

The EPA notes that the strongly held view of the commenters with respect to the proposed 1-hour standards is that the EPA should reject and not adopt a standard where there is not an adequate scientific or technical basis for judging the degree of protection which such a standard would provide. The EPA agrees with that general point. According to commenters, the 1-hour standards should be rejected because they do not have such a basis, and, as discussed below, the EPA agrees. This is consistent with the reasoning that the EPA has applied to consideration of an



AAI-based standard, as discussed above in response to comments related to an AAI-based standard. As noted above, the limitations and uncertainties in the scientific and technical basis for developing a specific AAI-based standard result in a great degree of uncertainty as to how well the quantified elements of the AAI would predict the actual relationship between varying ambient concentrations of oxides of nitrogen and sulfur and steady-state ANC levels across the distribution of water bodies within the various ecoregions in the United States. Because of this, there is a high degree of uncertainty as to the actual degree of protectiveness that such a standard would provide, especially for acid-sensitive ecoregions. At this time, the Administrator judges that the uncertainties are of such a significant nature and degree that there is no reasoned way to choose a specific AAI-based standard, in terms of a specific nationwide target ANC level or percentile of water bodies that would appropriately account for the uncertainties, since neither the direction nor the magnitude of change from the target level and percentile that would otherwise be chosen can reasonably be ascertained at this time.<sup>14</sup>

The EPA has also considered, in light of the public comments, whether it is necessary or appropriate under Section 109 of the CAA to make any revision to the current secondary standards for oxides of nitrogen and sulfur, having concluded that the current standards are neither adequate nor appropriate. As discussed above in section III.D.1.a, with regard to comments on the EPA's proposed decision not to set a new multi-pollutant AAI-based standard at this time, some commenters argued that the EPA cannot lawfully use uncertainty as a basis to decline to set an ecologically relevant standard, having concluded that the current secondary standards are neither adequately protective nor appropriate to provide protection to ecosystems. In response, the EPA disagrees, stating that data limitations and uncertainties in key elements of a standard, which are of such significant nature and degree as to prevent the Administrator from reaching a reasoned decision as to what specific

<sup>14</sup> Thus, as discussed above, EPA's disagreement with commenters concerning adoption of an AAI-based standard at this time appears to stem from differing views on whether or not there is an adequate scientific or technical basis for judging the degree of protection which an AAI-based standard would afford. There does not appear to be a disagreement with the view that EPA should not adopt a standard absent such a scientific or technical basis.

standard would be appropriate to provide requisite protection, are an appropriate basis for deciding not to set such a standard, even one that is of an ecologically relevant form. The EPA concludes that it is appropriate to apply the same reasoning in reaching a decision as to whether to set new 1-hour NO<sub>2</sub> and SO<sub>2</sub> secondary standards. In this case, the uncertainties are arguably even greater than with an AAI-based standard, since as noted above there is no demonstrable linkage between the elements of such standards and impacts on sensitive ecosystems that the standards would be intended to address.

#### *E. Final Decisions on Alternative Secondary Standards for Oxides of Nitrogen and Sulfur*

In considering the appropriateness of establishing a new multi-pollutant AAI-based standard to provide protection against potentially adverse deposition-related effects associated with oxides of nitrogen and sulfur, or setting new secondary standards identical to the current 1-hour NO<sub>2</sub> and SO<sub>2</sub> primary standards, the Administrator took into account the information and conclusions in the ISA, REA, and PA, CASAC advice, and the views of public commenters. This consideration follows from her conclusion, discussed above in section II.D, that the existing NO<sub>2</sub> and SO<sub>2</sub> secondary standards are neither appropriate nor sufficiently protective for this purpose.

As an initial matter, the Administrator has again considered whether it is appropriate at this time to set a new multi-pollutant standard to provide protection against potentially adverse deposition-related effects associated with oxides of nitrogen and sulfur, with a structure that would better reflect the available science regarding acidifying deposition. In considering this, she recognizes that such a standard, for purposes of Section 109(b) and (d) of the CAA,<sup>15</sup> must in her judgment be requisite to protect public welfare, such that it would be neither more nor less stringent than necessary for that purpose. In particular, she has focused on the new AAI-based standard developed in the PA and reviewed by CASAC, as discussed above in section III.A. In so doing, the Administrator has again considered the extent to which there is a scientific basis for development of such a standard,

<sup>15</sup> Section 109(d)(1) of the CAA requires that " \* \* \* the Administrator shall complete a thorough review \* \* \* and shall make such revisions in such criteria and standards and promulgate such new standards as may be appropriate under \* \* \* subsection 109(b) of this section."

specifically with regard to a standard that would provide protection from deposition-related aquatic acidification in sensitive aquatic ecosystems in areas across the country.

The Administrator notes that the ISA concludes that the available scientific evidence is sufficient to infer a causal relationship between acidifying deposition of nitrogen and sulfur in aquatic ecosystems, and that the deposition of oxides of nitrogen and sulfur both cause such acidification under current conditions in the United States. Further, the ISA concludes that there are well-established water quality and biological indicators of aquatic acidification as well as well-established models that address deposition, water quality, and effects on ecosystem biota, and that ecosystem sensitivity to acidification varies across the country according to present and historic nitrogen and sulfur deposition as well as geologic, soil, vegetative, and hydrologic factors. In considering public comments on the relevant scientific evidence, the Administrator notes that some commenters agree with these conclusions in the ISA, whereas other commenters question the extent to which the scientific information provides evidence of well-established water quality and biological indicators of aquatic acidification and the extent to which relevant models appropriately account for important factors or have been adequately evaluated. The Administrator has carefully considered these comments and the Agency's responses to these comments, as discussed above in section III.D. The Administrator also has considered the views of CASAC, including its general support for the conceptual framework of the AAI-based standard developed in the PA based on the assessments of the underlying scientific information in the ISA and REA.

Based on these considerations, the Administrator again concludes that the general structure of an AAI-based standard addresses the combined effects of deposition from oxides of nitrogen and sulfur by characterizing the linkages between ambient concentrations, deposition, and aquatic acidification, and that it takes into account relevant variations in these linkages across the country. She recognizes that while such a standard clearly would be quite innovative and unique, the general structure of such a standard is nonetheless well-grounded in the science underlying the relationships between ambient concentrations of oxides of nitrogen and sulfur and the aquatic acidification related to deposition of nitrogen and sulfur

associated with such ambient concentrations. Based on these considerations, the Administrator continues to agree with the conclusion in the PA, and supported by CASAC, that there is a strong scientific basis for continued development of a standard with the general structure presented in the PA. Further, the Administrator recognizes that the AAI equation, with factors quantified in the ranges discussed above and described more fully in the PA, generally performs well in identifying areas of the country that are sensitive to such acidifying deposition and indicates, as expected, that lower ambient levels of oxides of nitrogen and sulfur directionally would lead to higher calculated AAI values.

Nonetheless, while the Administrator recognizes the strong scientific foundation for the general structure of an AAI-based standard, she also recognizes that a specific AAI-based standard would depend to a great degree on atmospheric and ecological modeling, in combination with appropriate data, to specify the quantified terms of an equation that incorporates the linkages between ambient concentrations, deposition, and aquatic acidification. This equation, which defines an aquatic acidification index (AAI), has the effect of translating spatially variable ambient concentrations and ecological effects into a potential national standard.

With respect to establishing the specific terms of this equation, there are a number of important and significant uncertainties and complexities that are critical to the question of whether it is appropriate under Section 109 of the CAA to set a specific AAI-based standard at this time, recognizing that such a standard must be one that in the judgment of the Administrator is requisite to protect public welfare without being either more or less stringent than necessary for this purpose. As discussed above in section III.A, these uncertainties and complexities generally relate not to the structure of the standard, but to the quantification of the various elements of the standard, i.e., the F factors, and their representativeness at an ecoregion scale. These uncertainties and complexities, which are unique to this NAAQS review, currently preclude the characterization of the degree of protectiveness that would be afforded by such a standard, within the ranges of levels and forms identified in the PA, and the representativeness of F factors in the AAI equation described above and in the PA. These uncertainties have been generally categorized as limitations in available field data as well as

uncertainties that are related to reliance on the application of ecological and atmospheric modeling at the ecoregion scale to specify the various elements of the AAI.

With regard to data limitations, the Administrator observes that there are several key limitations in the available data upon which elements of the AAI are based. For example, while ambient measurements of  $\text{NO}_y$  are made as part of a national monitoring network, the monitors are not located in locations that have been determined to be representative of sensitive aquatic ecosystems or individual ecoregions. Further, while air and water quality data are generally available in areas in the eastern United States, there is relatively sparse coverage in mountainous western areas where a number of sensitive aquatic ecosystems are located. Even in areas where relevant data are available, small sample sizes in some areas impede efforts to characterize the representativeness of the available data at an ecoregion scale, which was noted by CASAC and some commenters as being of particular concern. Also, measurements of reduced forms of nitrogen are available from only a small number of monitoring sites, and emission inventories for reduced forms of nitrogen used in atmospheric modeling are subject to considerable uncertainty.

With regard to uncertainties related to the use of ecological and atmospheric modeling, the Administrator notes in particular that model results are difficult to evaluate due to a lack of relevant observational data. For example, large uncertainties are introduced by a lack of data to inform the necessary inputs to critical load models that are the basis for factor F1 in the AAI equation. Also, observational data are not generally available to evaluate the modeled relationships between nitrogen and sulfur in the ambient air and associated deposition, which are the basis for the other factors (i.e., F2, F3, and F4) in the AAI equation.

Taking into account the above considerations, the Administrator recognizes that characterization of the uncertainties in the AAI equation as a whole represents a unique challenge in this review primarily as a result of the complexity in the structure of an AAI-based standard. In this case, the very nature of some of the uncertainties is fundamentally different than uncertainties that have been relevant in other NAAQS reviews. She notes, for example, some of the uncertainties uniquely associated with the quantification of various elements of the

AAI result from limitations in the extent to which ecological and atmospheric models, which have not been used to define other NAAQS, have been evaluated. Another important type of uncertainty relates to limitations in the extent to which the representativeness of various factors can be determined at an ecoregion scale, which has not been a consideration in other NAAQS.

In combination, these limitations and uncertainties are of such a nature and degree as to result in a high degree of uncertainty as to how well the quantified elements of the AAI standard would predict the actual relationship between varying ambient concentrations of oxides of nitrogen and sulfur and steady-state ANC levels across the distribution of water bodies within the various ecoregions in the United States. Because of this, the EPA cannot reasonably characterize the actual degree of protectiveness that such a standard would provide, especially for acid-sensitive ecoregions. The uncertainties discussed here are critical for determining the actual degree of protection that would be afforded such areas by any specific target ANC level and percentile of water bodies that would be chosen in setting a new AAI-based standard, and thus for determining an appropriate AAI-based standard that meets the requirements of Section 109 of the CAA.

In considering these uncertainties in light of CASAC's advice, the Administrator notes that CASAC acknowledged that important uncertainties remain that would benefit from further study and data collection efforts, which might lead to potential revisions or modifications to the form of the standard developed in the PA. She also notes that CASAC encouraged the Agency to engage in future monitoring and model evaluation efforts to help inform the specification of model-derived elements in the AAI equation. CASAC supported the view in the PA that there was a scientific basis for consideration of an AAI, and that is what the Administrator has done in that she has fully considered an AAI-based standard. However, CASAC did not indicate that there was such a degree of scientific support for quantifying the terms of the AAI equation and setting a specific AAI-based standard at this time that it would be inappropriate to consider not setting an AAI-based standard in this review in light of the uncertainties that CASAC itself recognized.

Further, in considering these uncertainties in light of the public comments discussed above, the Administrator notes that these

uncertainties and limitations have been highlighted by a number of public commenters in support of their view that it would be inappropriate to establish an AAI-based standard at this time. Other commenters, however, noted that NAAQS decisions are always made in the face of uncertainties, and expressed the view that the uncertainties in this NAAQS review are not so great as to preclude establishing such a standard at this time.

The Administrator agrees with the commenters that note that NAAQS decisions are always made in the face of uncertainties, since the latest available scientific information upon which NAAQS are to be based is often at the leading edge of research. Thus, the EPA Administrator must always consider uncertainties in scientific and other information in reaching decisions on whether to retain or revise an existing NAAQS or to adopt a new NAAQS. As a result, it is clear that the existence of scientific uncertainty does not preclude adoption of a new or revised NAAQS. The issue here, however, is not whether uncertainty exists, but whether it is of such a significant nature and magnitude that it warrants not adopting an AAI-based standard at this time. In that context, the Administrator recognizes that the AAI-based standard considered in this review is by far the most complex form of a NAAQS standard that the EPA has considered, to date, and that this is the first review in which the scientific and technical details of an AAI-based standard have been developed for consideration. This review has served to bring into focus for the first time the nature and degree of the uncertainties associated with quantifying the specific factors in the equation that defines the AAI. Thus, in this review, the Administrator must newly consider not only the scientific basis for the conceptual framework of such a standard, but also the extent to which the available data, models, and analyses provide a reasoned basis to choose a specific AAI-based standard consistent with the requirements of Section 109 of the CAA.

The nature of the uncertainties present in this review, and the implications of those uncertainties for reaching a reasoned decision as to whether an AAI-based NAAQS could be set consistent with the requirements of section 109(b), are in sharp contrast to the nature of uncertainties present in other NAAQS reviews. In other NAAQS reviews, studies are generally available directly linking ambient air concentrations of the pollutant to evidence of effects on public health or welfare. For example, in reviewing a

health-based primary NAAQS the EPA typically considers a wide range of clinical, epidemiologic, toxicologic, and other studies that evaluate the relationship between direct exposure to an ambient air pollutant and human health. The EPA also often considers laboratory or field studies or surveys that evaluate and characterize the relationship between ambient levels of an air pollutant and welfare effects, such as effects of the ambient air pollutant on the growth of plants or on injury to plants. These kinds of scientific studies have provided a reasoned basis in other reviews for the selection of an appropriate level and form of a standard, with the EPA taking into account the nature and degree of uncertainties, for example, in the relationships between varying ambient air concentrations and the impact on human health or the environment.

Further, the uncertainties present in the evidence available for other NAAQS reviews have not been of such a significant nature that they have precluded a reasoned assessment of the degree of protectiveness that would likely be afforded by specific alternative standards under consideration. In this case, however, unlike in other NAAQS reviews, multi-pollutant and multi-media pathways of exposure must be considered, and characterized in terms of an equation with several factors, where the values of those factors vary from ecoregion to ecoregion. The quantification of these factors must be based on the use of ecological and atmospheric modeling at an ecoregion scale. Further, the appropriateness of these factors depends upon analyses that could be used to determine the representativeness of the data at an ecoregion level. These circumstances, which are unique to this review, result in such large uncertainties at this time that in the aggregate they preclude the development of a reasoned assessment of the degree of protectiveness that specific alternative AAI-based standards would provide.

Based on the above considerations, the Administrator has determined that at this time it is not appropriate under Section 109 of the CAA to set a new multi-pollutant standard to address deposition-related effects of oxides of nitrogen and sulfur on aquatic acidification. As the Administrator noted in the proposal, setting a NAAQS properly involves consideration of the degree of uncertainties in the science and other information, such as gaps in the relevant data and, in this case, limitations in the evaluation of the application of relevant ecological and atmospheric models at an ecoregion

scale. As noted above, the issue here is not a question of uncertainties about the scientific soundness of the structure of the AAI, but instead uncertainties in the quantification and representativeness of the elements of the AAI as they vary in ecoregions across the country. At present, in the Administrator's judgment, the unique uncertainties present in this review are of such significance that they preclude a reasoned understanding of the degree of protectiveness that would be afforded to various ecoregions across the country by a new standard defined in terms of a specific nationwide target ANC level and a specific percentile of water bodies for acid-sensitive ecoregions, together with an AAI defined in terms of ecoregion-specific F factors. The Administrator has considered whether these uncertainties could be appropriately accounted for by choosing either a more or less protective target ANC level and percentile of water bodies than would otherwise be chosen if the uncertainties did not prevent a reasoned judgment on the quantification of the AAI factors. However, in the Administrator's judgment, the uncertainties are of such a significant nature and degree that there is no reasoned way to choose such a specific nationwide target ANC level or percentile of water bodies that would appropriately account for the uncertainties, since neither the direction nor the magnitude of change from the target level and percentile that would otherwise be chosen can reasonably be ascertained at this time.

Based on the above considerations, the Administrator judges that the current limitations in relevant data and the uncertainties associated with specifying the elements of the AAI are of such nature and degree as to prevent her from reaching a reasoned judgment as to what level and form (in terms of a selected percentile) of an AAI-based standard would provide the degree of protection that the Administrator determined was requisite. While acknowledging that CASAC supported consideration of moving forward to establish the standard developed in the PA at this time, the Administrator also observes that CASAC supported conducting further field studies that would better inform the continued development or modification of such a standard. Given the current high degree of uncertainties and the large complexities inherent in quantifying the elements of such a standard, largely deriving from the nature of the standard under consideration for the first time in this review, and having fully considered

CASAC's advice and public comments, the Administrator concludes that it would be premature and not appropriate to set a new, multi-pollutant AAI-based secondary standard for oxides of nitrogen and sulfur at this time.

While the Administrator has concluded that it is not appropriate to set such a multi-pollutant standard at this time, she has determined that the Agency should undertake a field pilot program to gather additional data, and that it is appropriate that such a program be undertaken before, rather than after, reaching a decision to set such a standard. As described below in section IV, the purpose of the program is to collect and analyze data so as to enhance our understanding of the degree of protectiveness that would likely be afforded by a standard based on the AAI as developed in the PA. This will provide additional information to aid the Agency in considering an appropriate multi-pollutant standard in future reviews, specifically with respect to the acidifying effects of deposition of oxides of nitrogen and sulfur. Data generated by this field program will also support development of an appropriate monitoring network that would work in concert with such a standard to result in the intended degree of protection. The information generated during the field program can also be used to help state agencies and the EPA better understand how an AAI-based standard would work in terms of the implementation of such a standard.

While not a basis for this decision, the Administrator also recognizes, as she did at the time of the proposal, that a new, innovative AAI-based standard would raise significant implementation issues that would need to be addressed consistent with the CAA requirements for implementation-related actions following the setting of a new NAAQS. It will take time to address these issues, during which the Agency will be conducting a field pilot program to gather relevant data and the environment will benefit from reductions in oxides of nitrogen and sulfur resulting from the new NO<sub>2</sub> and SO<sub>2</sub> primary standards, as noted above, as well as reductions expected to be achieved from the EPA's Cross-State Air Pollution Rule and Mercury and Air Toxics standards. These implementation-related issues are discussed in more detail below in section IV.A.5.

The Administrator has also reconsidered whether it is appropriate at this time to set new secondary standards identical to the current 1-hour NO<sub>2</sub> and SO<sub>2</sub> primary standards. In the proposal, the Administrator recognized

that the new NO<sub>2</sub> and SO<sub>2</sub> primary 1-hour standards set in 2010 were not ecologically relevant for a secondary standard to address deposition-related effects associated with oxides of nitrogen and sulfur. Nonetheless, the Administrator proposed to set new secondary standards identical to the 1-hour NO<sub>2</sub> and SO<sub>2</sub> primary standards on the basis that they would directionally provide some degree of additional protection. At that time, the Administrator reasoned that setting such standards would be consistent with her conclusions that the current NO<sub>2</sub> and SO<sub>2</sub> secondary standards are neither sufficiently protective nor appropriate in form, and that it is not appropriate to set a new, ecologically relevant multi-pollutant secondary standard at this time.

In reconsidering this proposal, the Administrator first notes that although the ISA, REA, and PA did not directly consider secondary standards set identical to the 1-hour NO<sub>2</sub> and SO<sub>2</sub> primary standards, the information and conclusions in those documents provide strong support for the judgment that such short-term, peak standards are not ecologically relevant to address deposition-related effects associated with long-term deposition from ambient concentrations of oxides of nitrogen and sulfur. The Administrator notes that commenters on this aspect of the proposal broadly and strongly supported this view. The Administrator also recognizes that the Agency has not presented in these documents or elsewhere any analysis of the degree of protectiveness that would likely be afforded by such standards with regard to deposition-related effects in general or aquatic acidification effects in particular. She also recognizes, as discussed above in response to comments on this issue, that such an analysis cannot be done since there is no demonstrable linkage between 1-hour average concentrations of NO<sub>2</sub> and SO<sub>2</sub> in the ambient air and the impact of longer-term deposition-related acidification associated with oxides of nitrogen and sulfur on sensitive aquatic ecosystems that the proposed standards were intended to address. As a result, as in the case of an AAI-based standard as discussed above, the Administrator concludes that there is no basis to make a reasoned judgment as to what levels of 1-hour NO<sub>2</sub> and SO<sub>2</sub> standards would be requisite to protect public welfare, such that the EPA cannot demonstrate a reasoned basis for judging that the proposed standards would be sufficient but not more stringent than necessary to

protect against adverse deposition-related effects to sensitive ecosystems.

With regard to considering the views of CASAC, the Administrator notes that the PA did not discuss the alternative of setting secondary standards that are identical to the 1-hour NO<sub>2</sub> and SO<sub>2</sub> primary standards. As a consequence, this alternative was not presented for consideration by CASAC and therefore CASAC has not expressed its views on this alternative set of standards.

In light of the above considerations, and taking into consideration public comments, the Administrator has further considered whether it is necessary or appropriate under Section 109 of the CAA to set such 1-hour NO<sub>2</sub> and SO<sub>2</sub> secondary standards, having concluded that the current NO<sub>2</sub> and SO<sub>2</sub> secondary standards are neither adequate nor appropriate to address potentially adverse deposition-related effects on sensitive ecosystems associated with oxides of nitrogen and sulfur. In reaching this decision, the Administrator concludes that it is appropriate to apply the same reasoning as she did in reaching the decision that it is premature and not appropriate under Section 109(b) to set a new AAI-based standard at this time. In considering such 1-hour standards, the Administrator judges that the uncertainties are likely even greater than with an AAI-based standard, since as noted above there is no demonstrable linkage between the elements of such standards and impacts on sensitive ecosystems that the standards would be intended to address. In addition, with respect to areas that are not acid sensitive, and unlike an AAI standard, it is likely that the proposed 1-hour standards directionally would provide more protection than is warranted. Therefore, the Administrator now concludes that it is neither necessary nor appropriate to set 1-hour NO<sub>2</sub> and SO<sub>2</sub> secondary standards, since in her judgment setting such standards cannot reasonably be judged to provide requisite protection of public welfare.

In summary, for the reasons discussed above, and taking into account information and assessments presented in the ISA, REA, and PA, the advice and recommendations of CASAC, and the public comments on the proposal, the Administrator has decided that it is not appropriate under Section 109(b) to set any new secondary standards at this time to address potentially adverse deposition-related effects associated with oxides of nitrogen and sulfur. Further, as discussed above in section II.D, she has also decided to retain the current NO<sub>2</sub> and SO<sub>2</sub> secondary standards to address direct effects of

gaseous NO<sub>2</sub> and SO<sub>2</sub> on vegetation. Thus, taken together, the Administrator has decided to retain and not revise the current NO<sub>2</sub> and SO<sub>2</sub> secondary standards. Specifically these secondary standards include an NO<sub>2</sub> standard set at a level of 0.053 ppm, annual arithmetic average, and an SO<sub>2</sub> standard set at a level of 0.5 ppm, 3-hour average, not to be exceeded more than once per year.

#### IV. Field Pilot Program and Ambient Monitoring

This section discusses elements of a field pilot program and the evaluation of monitoring methods for ambient air indicators of NO<sub>y</sub> and SO<sub>x</sub> that could be conducted to implement the Administrator's decision to undertake such a field monitoring program in conjunction with her decision not to set a new multi-pollutant secondary standard in this review, as discussed above in section III.E. The PA included considerations related to monitoring methods and network design that could support an AAI-based standard, which were reviewed by the CASAC Ambient Monitoring Methods Subcommittee (AMMS) (Russell and Samet, 2011b). As discussed below, the CASAC AMMS supported the approach of basing a potential future air monitoring network on the existing Clean Air Status and Trends Network (CASTNET) program. In addition, the CASAC AMMS supported the use of the CASTNET filter packs (CFPs) as appropriate methods to measure the oxides of sulfur indicator, SO<sub>x</sub>, and the use of commercially available NO<sub>y</sub> instruments to measure the oxides of nitrogen indicator, NO<sub>y</sub>. CASAC AMMS also supported the inclusion of complementary measurements in any future field monitoring program that would support the evaluation of the monitoring methods and air quality models upon which the AAI developed in the PA was based.

Section IV.A below outlines the objectives, scope, and key elements of the field pilot program as presented in the proposal and section IV.B summarizes the EPA's proposed approach to evaluating monitoring methods. These approaches reflect consideration of the advice of the

CASAC AMMS. Public comments on the field pilot program and evaluation of monitor methods are discussed below in section IV.C. These comments have been helpful in shaping the process that the EPA is now undertaking to develop the field pilot program and monitoring methods evaluation.

The following sections provide insight into the EPA's current ideas about what could be incorporated into the pilot program, but the EPA has not made any final decisions on what will be included. These ideas will be discussed further in a draft white paper to be made available later this year for public comment. The draft white paper will present more detailed plans for the field pilot program and monitoring methods evaluation. The draft white paper is intended to serve as both a draft work plan and a vehicle for continued input from outside interests. Taking into consideration comments received on the draft white paper, the EPA will prepare a final white paper that will serve as a program management and communication document to facilitate engagement with interested stakeholders and convey the EPA's final plans.

##### A. Overview of Proposed Field Pilot Program

As discussed in the proposal, the primary goal of this field pilot program, and the related monitoring methods evaluation summarized below in section IV.B, is to enhance our understanding of the degree of protectiveness that would likely be afforded by a standard based on the AAI, as described above in section III.A. This program is intended to aid the Agency in considering in future reviews an appropriate multi-pollutant standard that would be requisite to protect public welfare consistent with Section 109 of the CAA, through the following objectives:

(1) Evaluate measurement methods for the ambient air indicators of NO<sub>y</sub> and SO<sub>x</sub> and consider designation of such methods as Federal Reference Methods (FRMs);

(2) Examine the variability and improve characterization of concentration and deposition patterns of NO<sub>y</sub> and SO<sub>x</sub>, as well as reduced forms of nitrogen, within and across a number

of sensitive ecoregions across the country;

(3) Develop updated ecoregion-specific factors (i.e., F1 through F4) for the AAI equation based in part on new observed air quality data within the sample ecoregions as well as on updated nationwide air quality model results and expanded critical load data bases, and explore alternative approaches for developing such representative factors;

(4) Calculate ecoregion-specific AAI values using observed NO<sub>y</sub> and SO<sub>x</sub> data and updated ecoregion-specific factors to examine the extent to which the sample ecoregions would meet a set of alternative AAI-based standards;

(5) Develop air monitoring network design criteria for an AAI-based standard;

(6) Assess the use of total nitrate measurements as a potential alternative indicator for NO<sub>y</sub>;

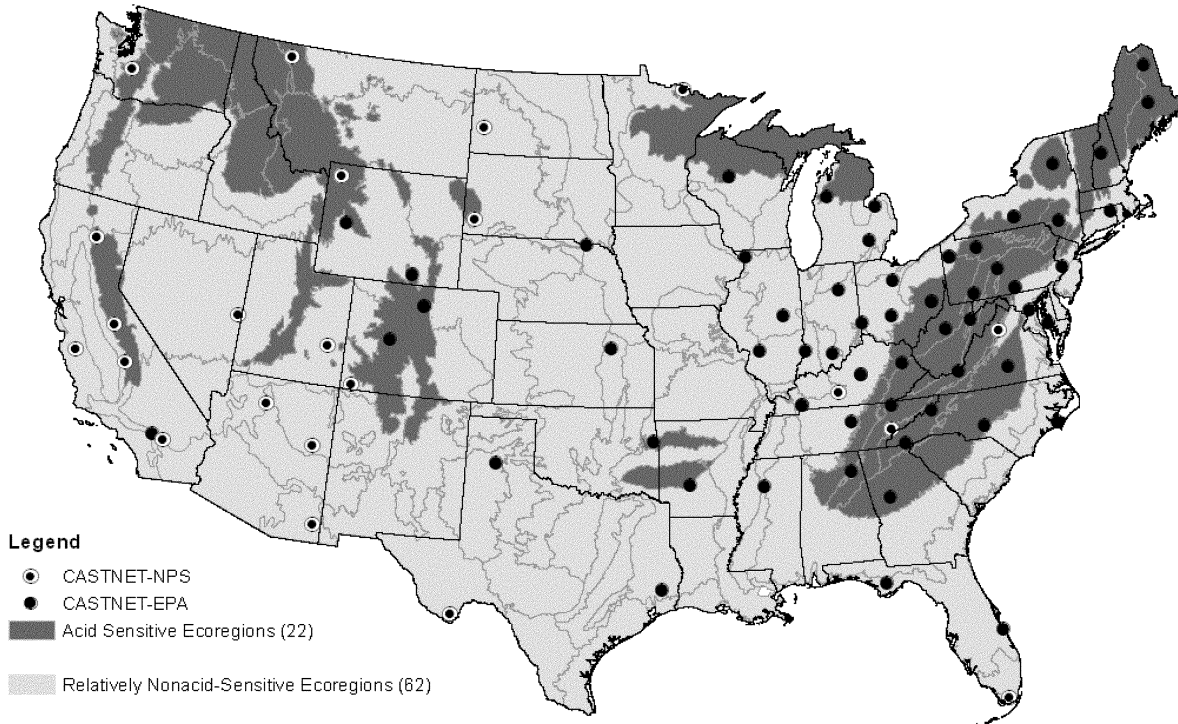
(7) Support related longer-term research efforts, including enhancements to and evaluation of modeled dry deposition algorithms; and

(8) Facilitate stakeholder engagement in addressing implementation issues associated with possible future adoption of an AAI-based standard.

The EPA proposed to use CASTNET sites (Figure IV-1) in selected acid-sensitive ecoregions to serve as the platform for this pilot program, potentially starting in late 2012 and extending through 2018. The CASTNET sites in three to five acid-sensitive ecoregions would collect NO<sub>y</sub> and SO<sub>x</sub> (i.e., SO<sub>2</sub> and p-SO<sub>4</sub>) measurements over a 5-year period. The initial step in developing a data base of observed ambient air indicators for oxides of nitrogen and sulfur requires the addition of NO<sub>y</sub> samplers at the pilot study sites so that a full complement of indicator measurements are available to calculate AAI values. These CASTNET sites would also be used to make supplemental observations useful for evaluation of CMAQ's characterization of factors F2-F4 in the AAI equation.

The selected ecoregions would account for geographic variability by including regions from across the United States, including the east, upper midwest, and west. Each selected ecoregion would have at least two existing CASTNET sites.

**Ecoregions Acid-Sensitivity w. CASTNET Sites**



**Figure IV-1. Location of CASTNET sites in relation to acid sensitive ecoregions.**

Over the course of this 5-year pilot program, the most current national air quality modeling, based on the most current national emissions inventory, would be used to develop an updated set of F2–F4 factors. A parallel multi-agency national critical load data base development effort would be used as the basis for calculating updated F1 factors. As discussed above in section III.A, these factors would be based on average parameter values across an ecoregion. Using this new set of F factors, observations of NO<sub>y</sub> and SO<sub>x</sub> derived from the field pilot program, averaged across each ecoregion, would be used to calculate AAI values in the sample ecoregions. The data from the field pilot program would also be used to examine alternative approaches to generating representative air quality values, such as examining the appropriateness of spatial averaging in areas of high spatial variability.

Beyond this basic overview of the field pilot program, the following sections highlight complementary measurements that may be performed as part of the program (section IV.A.1), complementary areas of related research (section IV.A.2), a discussion of

implementation challenges that would be addressed during the course of the field pilot program (section IV.A.3), and plans for program development and stakeholder participation (section IV.A.4).

**1. Complementary Measurements**

Complementary measurements may be performed at some sites in the pilot network to reduce uncertainties in the recommended methods for measuring ambient oxides of nitrogen and sulfur and to better characterize model performance and application to the AAI. The CASAC AMMS advised the EPA that such supplemental measurements were of critical importance in a field measurement program related to an AAI-based standard (Russell and Samet, 2011b).

Candidate complementary measurements to address sulfur, in addition to those provided by CFPs, include trace gas continuous SO<sub>2</sub> and speciated PM<sub>2.5</sub> measurements. The co-located deployment of a continuous SO<sub>2</sub> analyzer with the CFP for SO<sub>2</sub> will provide test data for determining suitability of continuous SO<sub>2</sub> measurements as a Federal Equivalent

Method (FEM) for an AAI-based standard, as well as producing valuable time-series data for model evaluation purposes. The weekly averaging time provided by the CFP adequately addresses the annual-average basis of an AAI-based secondary standard, but would not be applicable to short-term (i.e., 1-hour) averages associated with the primary SO<sub>2</sub> standard. Conversely, because of the relatively low SO<sub>2</sub> concentrations associated with many acid-sensitive ecoregions, existing SO<sub>2</sub> FRMs designated for use in determining compliance with the primary standard, which typically are used in higher concentration environments, would not necessarily be appropriate for use in conjunction with an AAI-based secondary standard.

Co-locating the PM<sub>2.5</sub> sampler used in the EPA Chemical Speciation Network and the Interagency Monitoring of Protected Visual Environments (IMPROVE) network at pilot network sites would allow for characterizing the relationship between the CFP-derived p-SO<sub>4</sub> and the speciation samplers used throughout the state and local air quality networks. The EPA notes that CASTNET already has several co-

located IMPROVE chemical speciation samplers. Because the AAI equation is based in part on the concentration of p-SO<sub>4</sub>, the original motivation for capturing all particle size fractions is not as important relative to simply capturing the concentration of total p-SO<sub>4</sub>.

Candidate measurements to complement oxidized nitrogen measurements, in addition to the CFP, include a mix of continuous and periodic sampling for the dominant NO<sub>y</sub> species, namely NO, directly measured NO<sub>2</sub>, PAN, HNO<sub>3</sub>, and particulate nitrate, p-NO<sub>3</sub>. The CASAC AMMS (Russell and Samet, 2011b) recommended that the EPA consider the use of total nitrate (t-NO<sub>3</sub>) obtained from CASTNET sampling as an indicator for NO<sub>y</sub>, reasoning that t-NO<sub>3</sub> is typically a significant fraction of deposited oxidized nitrogen in rural environments and CASTNET measurements are widely available. Collection of these data would support further consideration of using the CFP for t-NO<sub>3</sub> as the indicator of oxides of nitrogen for use in an AAI-based secondary standard.

The CASAC AMMS also recommended that total NH<sub>x</sub> (NH<sub>3</sub> and particulate ammonium (p-NH<sub>4</sub>)) be considered as a proxy for reduced nitrogen species, reasoning that the subsequent partitioning to NH<sub>3</sub> and p-NH<sub>4</sub> may be estimated using equilibrium chemistry calculations. Reduced nitrogen measurements are used to evaluate air quality modeling that is used in generating factor F2. Additional studies are needed to determine the applicability of NH<sub>x</sub> measurements and calculated values of NH<sub>3</sub> and ammonium (NH<sub>4</sub>) to the AAI.

The additional supplemental measurements of speciated NO<sub>y</sub>, continuous SO<sub>2</sub> and NH<sub>x</sub> will be used in future air quality modeling evaluation efforts. Because there often is significant lag in the availability of contemporary emissions data to drive air quality modeling, the complete use of these data sets will extend beyond the 5-year collection period of the pilot program. Consequently, the immediate application of those data will address instrument performance comparisons that explore the feasibility of using continuous SO<sub>2</sub> instruments in rural environments, and using the speciated NO<sub>y</sub> data to assess NO<sub>y</sub> instrument performance. Although contemporary air quality modeling will lag behind measurement data availability, the observations can be used in deposition models to compare observed transference ratios with the previously

calculated transference ratios to test temporal stability of the ratios.

An extended water quality sampling effort that would parallel the air quality measurement program would help to address some of the uncertainties related to factor F1 and the representativeness of the nth percentile critical load, as discussed in section III.B.5.b.i of the proposal. The objective of the water quality sampling would be to develop a larger data base of critical loads in each of the pilot ecoregions such that the nth percentile can adequately be characterized in terms of representing all water bodies. Opportunities to leverage and perhaps enhance existing ecosystem modeling efforts enabling more advanced critical load modeling and improved methods to estimate base cation production could be pursued. For example, areas with ongoing research studies producing data for dynamic critical load modeling could be considered when selecting the pilot ecoregions.

## 2. Complementary Areas of Research

The EPA recognizes that a source of uncertainty in an AAI-based secondary standard that would not be directly addressed in the pilot program stems from the uncertainty in the model used to link atmospheric concentrations to dry deposition fluxes. Currently, there are no ongoing direct dry deposition measurement studies at CASTNET sites that can be used to evaluate modeled results. It was strongly recommended by CASAC AMMS that a comprehensive sampling-intensive study be conducted in at least one, preferably two sites in different ecoregions to assess characterization of dry deposition of sulfur and nitrogen. These sites would be the same as those for the complementary measurements described above, but they would afford an opportunity to also complement dry deposition process research that benefits from the ambient air measurements collected in the pilot program. The concerns regarding uncertainties underlying an AAI-based secondary standard suggest that research that includes dry deposition measurements and evaluation of dry deposition models would be a high priority.

Similar leveraging could be pursued with respect to ecosystem research activities. For example, studies that capture a suite of soil, vegetation, hydrological, and water quality properties that can help evaluate more advanced critical load models would complement the atmospheric-based pilot program. In concept, such studies could provide the infrastructure for true multi-pollutant, multimedia "super"

sites assuming the planning, coordination, and resource facets can be aligned. While this discussion emphasizes the opportunity of leveraging ongoing research efforts, consideration could be given to explicitly including related research components directly in the pilot program.

## 3. Implementation Challenges

The CAA requires that once a NAAQS is established, designation and implementation must move forward. With a standard as innovative as the AAI-based standard considered in this review, the Administrator believes that should such a standard be adopted in the future, its success would be greatly improved if, while additional data are being collected to reduce the uncertainties discussed above, the implementing agencies and other stakeholders have an opportunity to discuss and thoroughly understand how such a standard would work. And since, as noted above, emissions reductions that are directionally correct to reduce aquatic acidification will be occurring as a result of other CAA programs, the Administrator believes that this period of further discussion will enable agencies to implement a multi-pollutant standard to address aquatic acidification if one is adopted in a future review.

Consideration of an AAI-based secondary standard for oxides of nitrogen and sulfur would present significant implementation challenges because it involves multiple, regionally-dispersed pollutants and relatively complex compliance determinations based on regionally variable levels of NO<sub>y</sub> and SO<sub>x</sub> concentrations that would be necessary to achieve a national ANC target. The anticipated implementation challenges fall into three main categories: monitoring and compliance determinations for area designations, pre-construction permit application analyses of individual source impacts, and State Implementation Plan (SIP) development. Several overarching implementation questions that we anticipate will be addressed in parallel with the field pilot program's five-year data collection period include:

(1) What are the appropriate monitoring network density and siting requirements to support a compliance system based on ecoregions?

(2) Given the unique spatial nature of the secondary standard (e.g., ecoregions), what are the appropriate parameters for establishing nonattainment areas?

(3) How can new or modified major sources of oxides of nitrogen and oxides of sulfur emissions assess their ambient

impacts on the standard and demonstrate that they are not causing or contributing to a violation of the NAAQS for preconstruction permitting? To what extent does the fact that a single source may be impacting multiple areas, with different acid sensitivities and variable levels of NO<sub>y</sub> and SO<sub>x</sub> concentrations that would be necessary to achieve a national ANC target, complicate this assessment and how can these additional complexities best be addressed?

(4) What additional tools, information, and planning structures are needed to assist states with SIP development, including the assessment of interstate pollutant transport and deposition?

(5) Would transportation conformity apply in nonattainment and maintenance areas for this secondary standard, and, if it does, would satisfying requirements that apply for related primary standards (e.g., ozone, PM<sub>2.5</sub>, and NO<sub>2</sub>) be demonstrated to satisfy requirements for this secondary standard?

#### 4. Monitoring Plan Development and Stakeholder Participation

The existing CASTNET sampling site infrastructure provides an effective means of quickly and efficiently deploying a monitoring program to support potential implementation of an AAI-based secondary standard, and also provides an additional opportunity for federally managed networks to collaborate and support the states, local agencies and tribes (SLT) in determining compliance with a secondary standard. A collaborative effort would help to optimize limited federal and SLT monitoring funds and would be beneficial to all involved. The CASTNET is already a stakeholder-based program with over 20 participants and contributors, including federal, state and tribal partners.

The CASAC AMMS generally endorsed the technical approaches used in CASTNET, but concerns were raised by individual representatives of state agencies concerning the perception of the EPA-controlled management aspects of CASTNET and data ownership. Potential approaches to resolve these issues will be developed and evaluated in existing National Association of Clean Air Agencies (NACAA)/EPA ambient air monitoring and National Atmospheric Deposition Program (NADP) science committees. The EPA Office of Air and Radiation (which includes the Office of Air Quality Planning Standards, OAQPS; and the Office of Atmospheric Program's Clean Air Markets Division, OAP-CAMD), and

their partners on the NACAA monitor steering committee will work to develop a prioritized plan that identifies three to five ecoregions and specific instrumentation to be deployed. Although this pilot program is focused on data collection, the plan will also include data analysis approaches as well as a process to facilitate engagement by those within the EPA and the SLTs to foster progress on the implementation questions noted above.

#### *B. Summary of Proposed Evaluation of Monitoring Methods*

This section provides a brief overview of the EPA's plans for evaluating monitoring methods of NO<sub>y</sub> and SO<sub>x</sub>, as discussed in section IV.B of the proposal. The EPA generally relies on monitoring methods that have been designated as FRMs or FEMs for the purpose of determining the attainment status of areas with regard to existing NAAQS. Such FRMs or FEMs are generally required to measure the air quality indicators that are compared to the level of a standard to assess compliance with a NAAQS. Prior to their designation by the EPA as FRM/FEMs through a rulemaking process, these methods must be determined to be applicable for routine field use and need to have been experimentally validated by meeting or exceeding specific accuracy, reproducibility, and reliability criteria established by the EPA for this purpose. As discussed above in section III.A, the ambient air indicators being considered for use in an AAI-based standard include SO<sub>2</sub>, p-SO<sub>4</sub>, and NO<sub>y</sub>.

The CASTNET provides a well-established infrastructure that would meet the basic location and measurement requirements of an AAI-based secondary standard given the rural placement of sites in acid sensitive areas. In addition, CFPs currently provide very economical weekly, integrated average concentration measurements of SO<sub>2</sub>, p-SO<sub>4</sub>, NH<sub>4</sub> and t-NO<sub>3</sub>, the sum of HNO<sub>3</sub> and p-NO<sub>3</sub>.

While routinely operated instruments that measure SO<sub>2</sub>, p-SO<sub>4</sub>, NO<sub>y</sub> and/or t-NO<sub>3</sub> exist, instruments that measure p-SO<sub>4</sub>, NO<sub>y</sub>, t-NO<sub>3</sub>, or the CFP for SO<sub>2</sub> have not been designated by the EPA as FRMs or FEMs. The EPA's Office of Research and Development has initiated work that will support future FRM designations by the EPA for SO<sub>2</sub> and p-SO<sub>4</sub> measurements based on the CFP. Such a designation by the EPA could be done for the purpose of facilitating consistent research related to an AAI-based standard and/or in conjunction with setting and supporting an AAI-based secondary standard.

Based on extensive review of literature and available data, the EPA has identified potential methods that appear suitable for measuring each of the three components of the indicators. As discussed more fully in section IV.B of the proposal, these methods are being considered as new FRMs to be used for measuring the ambient concentrations of the three components (SO<sub>2</sub>, p-SO<sub>4</sub> and NO<sub>y</sub>) that would be needed to determine compliance with an AAI-based secondary standard.

For the SO<sub>2</sub> and p-SO<sub>4</sub> measurements, the EPA is considering the CFP method, which provides weekly average concentration measurements for SO<sub>2</sub> and p-SO<sub>4</sub>. This method has been used in the EPA's CASTNET monitoring network for 15 years, and experience with this method strongly indicates that it will meet the requirements for use as an FRM for the SO<sub>2</sub> and p-SO<sub>4</sub> concentrations for an AAI-based secondary standard.

Although the CFP method would provide measurements of both the SO<sub>2</sub> and p-SO<sub>4</sub> components in a unified sampling and analysis procedure, individual FRMs will be considered for each. The EPA recognizes that an existing FRM to measure SO<sub>2</sub> concentrations using ultra-violet fluorescence (UVF) exists (40 CFR part 50, appendix A-1) for the purpose of monitoring compliance for the primary SO<sub>2</sub> NAAQS. However, several factors suggest that the CFP method would be superior to the UVF FRM for monitoring compliance with an AAI-based secondary standard.

For monitoring the NO<sub>y</sub> component, a continuous analyzer for measuring NO<sub>y</sub> is commercially available and is considered by the EPA to be likely suitable for use as an FRM. This method is similar in design to the existing NO<sub>2</sub> FRM (described in 40 CFR part 50, appendix F), which is based on the ozone chemiluminescence measurement technique. The method is adapted to and further optimized to measure all NO<sub>y</sub>. However, this NO<sub>y</sub> method requires further evaluation before it can be fully confirmed as a suitable FRM. The EPA is currently completing a full scientific assessment of the NO<sub>y</sub> method to determine whether it would be appropriate to consider for designation by the EPA as an FRM.

On February 16, 2011, the EPA presented this set of potential FRMs to the CASAC AMMS for their consideration and comment. In response, the CASAC AMMS stated that, overall, it believes that the EPA's planned evaluation of methods for measuring NO<sub>y</sub>, SO<sub>2</sub> and p-SO<sub>4</sub> as ambient air indicators is a suitable



approach in concept. On supporting the CFP method as a potential FRM for SO<sub>2</sub>, CASAC stated that they felt that the CFP is adequate for measuring long-term average SO<sub>2</sub> gas concentrations in rural areas with low levels (less than 5 parts per billion by volume (ppbv)) and is therefore suitable for consideration as an FRM. For p-SO<sub>4</sub>, CASAC AMMS generally supports the use of the CFP as a potential FRM for measuring p-SO<sub>4</sub> for an AAI-based secondary standard. The method has been relatively well-characterized and evaluated, and it has a documented, long-term track record of successful use in a field network designed to assess spatial patterns and long-term trends. On supporting the photometric NO<sub>y</sub> method as a potential FRM, CASAC AMMS concluded that the existing NO<sub>y</sub> method is generally an appropriate approach for the indicator of an AAI-based standard. However, CASAC AMMS agreed that additional characterization and research is needed to fully understand the method in order to designate it as an FRM.

### *C. Comments on Field Pilot Program and Monitoring Methods Evaluation*

Public comments on the EPA's proposed plans for a field pilot program and related evaluation of monitoring methods generally fell into the following four topic areas: (1) Goals, objectives, and scope; (2) monitoring network and site selection; (3) complementary measurements and instrumentation; and (4) collaboration and stakeholder participation. An overview of these comments and the EPA's responses are discussed below. In addition, many commenters generally requested that the EPA provide clarification of its plans regarding the field pilot program.

#### **1. Goals, Objectives, and Scope of Field Pilot Program**

There was a mix of comments regarding the need for and the overall purpose and scope of the field pilot program. In general commenters that supported the AAI approach (e.g., DOI/National Park Service (NPS), Nature Conservancy, Adirondack Council, NESCAUM, NY, PA, NC) also supported the concept of deploying a field pilot program as well as the proposed goals and objectives, while offering specific comments on the scope of the proposed monitoring effort. Other commenters supporting the AAI approach, including Earthjustice and the Center for Biological Diversity, expressed the view that a field pilot program was not needed to support adoption of such a standard in this review. A variety of commenters expressed the view that a

field pilot program in 3 to 5 ecoregions was too limited to adequately capture differences in concentrations and deposition patterns across the nation.

Commenters that did not support the adoption or future development of an AAI-based secondary NAAQS (e.g., EPRI, UARG, AAM, NCBA, Aluminum Association, and TX) expressed the view that a field pilot program was therefore not needed. However, these commenters nonetheless expressed the view that if the EPA intended to consider such a standard in future reviews, the field pilot program would need to expand in coverage and incorporate a much more comprehensive research program to address data gaps and uncertainties inherent in such an approach. These commenters suggested that the field pilot program should be more responsive to the issues raised by the members of the CASAC review panel. One commenter (API) expressed the view that even if the EPA intended to consider such a standard in the future, a field study was not appropriate at this time on the basis that the AAI-based approach was still only very preliminary in nature.

These commenters not supporting the AAI and the field pilot program as proposed contended that the proposed program fails to address key scientific uncertainties and data needs with regard to a methodology based on the AAI, and cannot meaningfully reduce the uncertainties that would be associated with such a standard. Some of these commenters offered specific recommendations for areas of research, noted below, that in their view would be necessary to support any further consideration of such a standard. For example, these commenters contended that it was necessary to conduct research in the following areas before further consideration of an AAI-based standard: (1) The effect of other sources, including wastewater pollution from permitted or unpermitted sources and fertilization of farm lands, on aquatic acidification; (2) relationships between measured air quality and deposition rates and related model performance evaluations; (3) improved methods for measuring dry deposition; and (4) characterization of NH<sub>x</sub> concentrations that are representative of specific ecoregions for all ecoregions based on a model performance evaluation.

Additional views were expressed by various commenters in regard to implementation, site selection and data availability. Many commenters from State agencies and industry agreed with the EPA that implementation challenges should be addressed during the course

of the field pilot program. For example, commenters expressed the view that guidance should emerge for monitoring network design accounting for the influence of variability of air concentration and deposition patterns within specific ecoregions. Some commenters also noted that much of the underlying information for the AAI was based on the Adirondacks and Shenandoah regions which are relatively rich data sources and the field pilot program should consider under-sampled areas in other parts of country such as the mountainous West. Also, some commenters requested that relatively non-acid sensitive areas be included in the field pilot program in the interest of broader national applicability or, as one state agency suggested, the availability of a rich data base in the Chesapeake Bay region. Some commenters also expressed the view that results from the field pilot program would not be available for the next periodic review of the secondary standards for oxides of nitrogen and sulfur.

Having considered these comments contending that the scope of the field pilot program is too limited spatially and not sufficiently comprehensive, the EPA maintains that the purpose and scope of the pilot studies program as presented in the proposal remain appropriate. As summarized above in section IV.A, the primary goal of the field pilot program is to collect and analyze data so as to enhance the Agency's understanding of the degree of protectiveness that would likely be afforded by an AAI-based standard. The EPA also intends that data generated by this program would support development of an appropriate monitoring network for such a standard. This field pilot program is not intended to be a research program, but rather to be a more targeted data collection and analysis effort, which will be done in conjunction with ongoing research efforts that are better suited to address some of the issues raised by commenters on the breadth of the field pilot program.

The EPA largely agrees that the scope of the field pilot program is not adequate to address many of the issues raised by the commenters regarding either the ability to adequately capture air quality and deposition patterns in all ecoregions or fully addressing scientific uncertainties related to numerous investigations into measurement development methods and biogeochemical and atmospheric deposition processes. However, as noted earlier, a field pilot program by definition is limited in scope and

intended to guide future broader applications. Toward that end, the field pilot program is intended to provide an intermediate link between initial conceptual design and potential future development and adoption of a standard, where the breadth and depth of spatial coverage would explicitly be addressed through monitoring network rules and implementation guidance.

The relevant ongoing programs addressing underlying atmospheric deposition uncertainties and development of critical load models include the EPA's atmospheric deposition research program and the multi-agency National Critical Load Data Base (NCLDB) program, respectively. In addition, the NAAQS review process of iterative science review and assessment provides a framework for evaluating newly available information that may address current data gaps and scientific uncertainties. These research programs are appropriate venues for addressing comments, including relevant CASAC recommendations, regarding desired improvements in the science underlying an AAI-based standard. In light of these ongoing research programs, it is not appropriate to duplicate these efforts through an expanded scope of the field pilot program. Rather, the most efficient approach is to increase the coordination between the field pilot program and these existing efforts. For example, the EPA plans to explore co-locating planned dry deposition studies at field pilot program sites that would result in mutually beneficial data enhancements that support both pilot program and research program objectives.

With regard to views regarding the importance of water quality monitoring, the EPA agrees with comments recommending increased coordination with water quality sampling and critical load modeling programs. In addition to working closely with the NCLDB, the EPA plans to factor in availability of water quality monitoring data in selecting field pilot program sites. The field pilot program has the potential to spur increased water quality monitoring in under-sampled areas which would improve confidence in generating ecoregion representative critical loads, as well as enhancing longer-term assessment of progress.

In addressing the last group of comments concerning implementation, site selection and data availability, the EPA offers the following views. The field pilot program does provide an opportunity to assist in answering a number of implementation challenges, including the design of a future network that could support an AAI-based

secondary standard. Toward that end, the EPA plans to work closely with its state and local agency partners in utilizing the field pilot program as a test case for implementation-based issues. In optimizing the design of a field pilot program, emphasis will be placed on relatively acid-sensitive areas given that those are areas an AAI-based standard would be intended to protect.

Nevertheless, the EPA will consider ecoregions that may offer advantages in having multiple deposition-based effects beyond aquatic acidification that potentially could support future reviews that consider multiple ecological effects. In addition, nearly all ecoregions have a mix of acid-sensitive and non-acid sensitive water bodies which will allow for assessing some of the AAI applicability to different aquatic systems. The EPA also notes that the field pilot program will provide data and analyses that will help inform consideration of an AAI-based standard in the next review. For example, data and analyses generated as part of the field pilot program will be incorporated into the EPA's characterization of environmental factors and evaluations of alternative approaches to specifying the terms of an AAI that would be included in the exposure/risk assessment and policy assessment prepared as part of the next review.

## 2. Network Design and Role of CASTNET

Most commenters expressed the view that CASTNET was an appropriate program to support the field pilot program and a potential AAI-based standard. While government agencies generally supported the use of CASTNET, some State organizations suggested that the NCore monitoring network may be more efficient given that the costs of adding CASTNET filter packs (CFPs) to NCore locations is less than that of adding NO<sub>y</sub> instruments, which exist at NCore locations, to CASTNET locations. Support also was expressed by New York State and NESCAUM for the use of rural NCore monitoring stations, where appropriate, in combination with CASTNET sites. Some states requested that access to the sampling methods and laboratory analyses used in the program and all data results be made through a national contract for States and local agencies, a concern related to CASTNET operations being managed by the EPA. Environmental groups also supported the use of CASTNET and encouraged the EPA to adopt the multiple stakeholder process of the NCLDB program and to align CASTNET sites with the Temporally Integrated

Monitoring of Ecosystems and Long-Term Monitoring (TIME/LTM) water sampling programs. These water sampling programs should also be extended to other under-sampled areas of the country that are acid sensitive. Some industry commenters raised concerns regarding the CFPs as they have measurement artifacts associated with both mass loss and gain.

Some state agencies commented that states should not be required to fund or implement the pilot monitoring studies, and funding should arise from sources other than State and Territorial Air Grant (STAG) funds. Relatedly, the NPS and environmental groups encouraged the EPA to make this effort a priority for funding.

The EPA has considered all available monitoring networks in the interest of locating the most suitable sites for a pilot study and to effectively leverage resources. The CASTNET monitoring program offers substantially more available platforms in acid-sensitive ecoregions relative to rural NCore sites and CASTNET sites already include the CFP method for measurements of key atmospheric species. Consequently, the financial burden on states, tribes and local air monitoring agencies would be less using this existing infrastructure instead of expanding measurements at or relocating rural NCore sites. The CASTNET siting design originally was intended to discern contributions of acidifying deposition of NO<sub>x</sub> and SO<sub>x</sub> to sensitive ecosystems, which is especially relevant for the AAI applications. NCore was designed as a more generalized network to collect measurements in a variety of geographical areas, with no specific focus on acid-sensitive ecosystems. Moreover, CASTNET has established a track record over the last two decades of providing quality measurements, whereas NCore is a relatively new network that has been fully deployed for less than two years and therefore not been subjected to review and analysis commensurate with the CASTNET program. Nevertheless, as some states suggested, this pilot program should afford an opportunity to explore the use of existing rural NCore sites in acid-sensitive ecoregions. The EPA welcomes the inclusion of rural NCore sites into the pilot study in cases where there are clear advantages of using such sites, and especially where such sites provide additional information likely resulting in more conclusive data findings. The development of site selection criteria and site selection will be conducted in partnership with other federal, state and local agencies. Although CASTNET is managed by the EPA, the agency has

aggressively supported the user community management approach adopted in the NADP and views the field pilot program as an opportunity to expand ownership of CASTNET analysis and data products, which currently can be accessed by the public.

While the field pilot program resources are focused on atmospheric measurements, as noted above the EPA will try to leverage existing water quality monitoring programs such as TIME/LTM in selecting field pilot program site locations. The EPA would rely heavily on the NCLDB critical load work for generating AAI values at monitoring locations as part of the field pilot program. In regard to issues raised by commenters regarding artifacts in the CFP, which would be the basis for SO<sub>x</sub> data in the field pilot program, the EPA notes that these methods have been extensively deployed and evaluated and have exhibited generally excellent performance. As part of the CASAC review on measurement methods, CASAC pointed out that the CFPs are preferred methods for measuring SO<sub>x</sub> in rural, low concentration environments due to the sensitivity of the CFP method.

### 3. Complementary Measurements and Instrumentation

In general, commenters across government agencies, environmental groups and industry supported the use of complementary measurements that would be deployed in addition to the CFP and NO<sub>y</sub> instruments used to measure the indicators, NO<sub>y</sub> and SO<sub>x</sub>. Comments regarding these measurements were provided in different contexts. For example, industry views reflected a position that complementary measurements were necessary to address information gaps, whereas state agencies and environmental groups expressed more general support in the interest of adding additional useful data, but not as a required component of the field pilot program.

Commenters expressed support for including trace gas continuous SO<sub>2</sub> and speciated PM<sub>2.5</sub> measurements in the field pilot program to provide test data for determining the suitability of continuous SO<sub>2</sub> measurements as an FEM for secondary standards and to characterize the relationship between CFP-based particulate sulfate and the national network of speciation samplers used throughout the state and local air quality networks. Industry commenters suggested that dry deposition flux measurements be conducted at the field pilot program sites, while also indicating that having sites in only 3 to

5 ecoregions would be inadequate. Industry commenters also suggested deploying multiple co-located methods measuring the same species as a quality assurance step and advocated measuring individual NO<sub>y</sub> species. Several commenters suggested adding NADP wet deposition samplers.

Several commenters supported the development of an FRM for NO<sub>y</sub> and CFP-based SO<sub>2</sub> and sulfate measurements. Greater attention was addressed to NO<sub>y</sub> measurements as the technology has only recently been used in routine monitoring applications. Some commenters supported the EPA's approach of using the EPA's research office to conduct instrument evaluation as a related but separate program from the field pilot program. Some commenters also recommended testing NO<sub>y</sub> at locations with extreme temperature and relative humidity regimes.

The EPA appreciates the support expressed by commenters regarding the use of complementary measurements. While the EPA agrees with views expressing the importance of additional measurements, complementary measurements will not have the same funding priority as indicator measurements for NO<sub>y</sub> and SO<sub>x</sub>. Nevertheless, it is reasonable to expect that all field pilot program sites will also include NADP precipitation samplers and NADP passive ammonia samplers, both of which are located in roughly half of all CASTNET sites. The EPA agrees that the formal NO<sub>y</sub> FRM development should be decoupled from the pilot studies, while recognizing that separate NO<sub>y</sub> measurements are an important component of the pilot study. Although NO<sub>y</sub> measurement technology is relatively mature, the effort to develop FRM certification will promote more confidence in the data due to standardized operational and quality assurance protocols.

### 4. Collaboration

Most commenters agreed with the EPA's intention to broaden review and participation in the field pilot program, given that the AAI approach cuts across multiple organizations and technical disciplines. Both industry and state governments suggested that some level of initial and ongoing external peer review is needed for evaluating design of the field pilot program and subsequent data analyses, with one state suggesting using NACAA's Monitoring Steering Committee. Some state commenters also reasoned that an agency's participation in the pilot program should be optional, because some states cannot support additional

monitoring even if it were to be fully funded. The NPS in particular indicated a desire to participate with the EPA in the field pilot program. Clearly, many of the comments described above suggesting added emphasis on water quality monitoring and research collectively emphasize strengthening the collaborative aspects of this field pilot program.

The EPA is encouraged by commenters' interest in the field pilot program. While the EPA's Office of Air and Radiation (OAR) will assume primary leadership of this program, OAR will take several actions to promote collaboration across the internal EPA research programs and other government agencies. Paralleling this effort, the EPA will solicit comment on a draft white paper to enable ongoing review and input from the public.

These pilot studies afford an excellent opportunity to coordinate air quality monitoring and related critical load and water quality assessment activities (modeling and measurements). As part of the planning effort for these pilot studies, the EPA will engage other federal agencies (U.S. Geological Survey, NPS, U.S. Forest Service) and state and local agencies primarily through existing NADP and NACAA committee structures.

## V. Statutory and Executive Order Reviews

### A. Executive Order 12866: Regulatory Planning and Review and Executive Order 13563: Improving Regulation and Regulatory Review

Under Executive Order 12866 (58 FR 51735, October 4, 1993), this action is a "significant regulatory action." Accordingly, the EPA submitted this action to the Office of Management and Budget (OMB) for review under Executive Orders 12866 and 13563 (76 FR 3821, January 21, 2011), and any changes made in response to Office of Management and Budget (OMB) recommendations have been documented in the docket for this action.

### B. Paperwork Reduction Act

This action does not impose an information collection burden under the provisions of the Paperwork Reduction Act, 44 U.S.C. 3501 *et seq.* Burden is defined at 5 CFR 1320.3(b). There are no information collection requirements directly associated with the establishment of a NAAQS under Section 109 of the CAA and this rulemaking will retain current standards and will not establish any new standards.

### C. Regulatory Flexibility Act

For purposes of assessing the impacts of today's rule on small entities, small entity is defined as: (1) A small business that is a small industrial entity as defined by the Small Business Administration's (SBA) regulations at 13 CFR 121.201; (2) a small governmental jurisdiction that is a government of a city, county, town, school district or special district with a population of less than 50,000; and (3) a small organization that is any not-for-profit enterprise which is independently owned and operated and is not dominant in its field.

After considering the economic impacts of today's final rule on small entities, I certify that this action will not have a significant economic impact on a substantial number of small entities. This final rule will not impose any requirements on small entities. Rather, this rule will retain the current secondary standards and does not establish any new national standards. See also *American Trucking Associations v. EPA*, 175 F. 3d at 1044-45 (NAAQS do not have significant impacts upon small entities because NAAQS themselves impose no regulations upon small entities).

### D. Unfunded Mandates Reform Act

Title II of the Unfunded Mandates Reform Act of 1995 (UMRA), Public Law 104-4, establishes requirements for Federal agencies to assess the effects of their regulatory actions on State, local, and Tribal governments and the private sector. Under Section 202 of the UMRA, the EPA generally must prepare a written statement, including a cost-benefit analysis, for proposed and final rules with "Federal mandates" that may result in expenditures to state, local, and tribal governments, in the aggregate, or to the private sector, of \$100 million or more in any 1 year. Before promulgating an EPA rule for which a written statement is needed, Section 205 of the UMRA generally requires the EPA to identify and consider a reasonable number of regulatory alternatives and to adopt the least costly, most cost-effective or least burdensome alternative that achieves the objectives of the rule. The provisions of Section 205 do not apply when they are inconsistent with applicable law. Moreover, Section 205 allows the EPA to adopt an alternative other than the least costly, most cost-effective or least burdensome alternative if the Administrator publishes with the final rule an explanation why that alternative was not adopted. Before the EPA establishes any regulatory requirements that may significantly or

uniquely affect small governments, including tribal governments, it must have developed under Section 203 of the UMRA a small government agency plan. The plan must provide for notifying potentially affected small governments, enabling officials of affected small governments to have meaningful and timely input in the development of the EPA regulatory proposals with significant Federal intergovernmental mandates, and informing, educating, and advising small governments on compliance with the regulatory requirements.

This action contains no Federal mandates under the provisions of Title II of the Unfunded Mandates Reform Act of 1995 (UMRA), 2 U.S.C. 1531-1538 for state, local, or tribal governments or the private sector. Therefore, this action is not subject to the requirements of Sections 202 or 205. Furthermore, as indicated previously, in setting a NAAQS the EPA cannot consider the economic or technological feasibility of attaining ambient air quality standards; although such factors may be considered to a degree in the development of state plans to implement the standards. See also *American Trucking Associations v. EPA*, 175 F. 3d at 1043 (noting that because the EPA is precluded from considering costs of implementation in establishing NAAQS, preparation of a Regulatory Impact Analysis pursuant to the Unfunded Mandates Reform Act would not furnish any information which the court could consider in reviewing the NAAQS). Accordingly, the EPA has determined that the provisions of Sections 202, 203, and 205 of the UMRA do not apply to this final decision not to establish new standards.

### E. Executive Order 13132: Federalism

This final rule does not have federalism implications. It will not have substantial direct effects on the states, on the relationship between the national government and the states, or on the distribution of power and responsibilities among the various levels of government, as specified in Executive Order 13132 because it does not contain legally binding requirements. Thus, the requirements of Executive Order 13132 do not apply to this rule.

### F. Executive Order 13175: Consultation and Coordination With Indian Tribal Governments

Executive Order 13175, entitled "Consultation and Coordination with Indian Tribal Governments" (65 FR 67249, November 9, 2000), requires the EPA to develop an accountable process

to ensure "meaningful and timely input by tribal officials in the development of regulatory policies that have tribal implications." This rule concerns the establishment of national standards to address the public welfare effects of oxides of nitrogen and sulfur.

This action does not have tribal implications, as specified in Executive Order 13175 (65 FR 67249, November 9, 2000) as tribes are not obligated to adopt or implement any NAAQS. We recognize, however, that this rule does concern resources of special interest to the tribes. Accordingly, on August 3, 2011, the EPA sent letters to all tribal leaders offering to consult with the tribes on the proposed rule. On October 6, 2011 the EPA held a consultation call with the Forest County Potawatomi Community, with the participation of four other tribes (Fond du Lac Reservation, Southern Ute, Fort Belknap, and San Juan Southern Paiute). The EPA also received public comment from two tribes on this rule. The EPA has responded to the tribal comments in its Response to Comments Document.

### G. Executive Order 13045: Protection of Children From Environmental Health & Safety Risks

This action is not subject to EO 13045 because it is not an economically significant rule as defined in EO 12866.

### H. Executive Order 13211: Actions That Significantly Affect Energy Supply, Distribution or Use

This action is not a "significant energy action" as defined in Executive Order 13211 (66 FR 28355, May 22, 2001), because it will not have a significant adverse effect on the supply, distribution, or use of energy. This action does not establish new national standards to address the public welfare effects of oxides of nitrogen and sulfur.

### I. National Technology Transfer and Advancement Act

Section 12(d) of the National Technology Transfer and Advancement Act of 1995 (NTTAA), Public Law 104-113, 12(d) (15 U.S.C. 272 note) directs the EPA to use voluntary consensus standards in its regulatory activities unless to do so would be inconsistent with applicable law or otherwise impractical. Voluntary consensus standards are technical standards (e.g., materials specifications, test methods, sampling procedures, and business practices) that are developed or adopted by voluntary consensus standards bodies. The NTTAA directs the EPA to provide Congress, through OMB, explanations when the Agency decides

not to use available and applicable voluntary consensus standards.

The EPA is not aware of any voluntary consensus standards that are relevant to the provisions of this final rule.

*J. Executive Order 12898: Federal Actions To Address Environmental Justice in Minority Populations and Low-Income Populations*

Executive Order 12898 (59 FR 7629 (Feb. 16, 1994)) establishes federal executive policy on environmental justice. Its main provision directs federal agencies, to the greatest extent practicable and permitted by law, to make environmental justice part of their mission by identifying and addressing, as appropriate, disproportionately high and adverse human health or environmental effects of their programs, policies, and activities on minority populations, low-income populations, or indigenous populations in the United States.

The EPA has determined that this final rule will not have disproportionately high and adverse human health or environmental effects on minority, low-income populations, or indigenous populations because it retains the level of environmental protection for all affected populations without having any disproportionately high and adverse human health or environmental effects on any population, including any minority, low-income population, or indigenous population.

*K. Congressional Review Act*

The Congressional Review Act, 5 U.S.C. 801, *et seq.*, as added by the SBREFA of 1996, generally provides that before a rule may take effect, the agency promulgating the rule must submit a rule report, which includes a copy of the rule, to each House of the Congress and to the Comptroller General of the United States. The EPA will submit a report containing this final rule and other required information to the United States Senate, the United States House of Representatives and the Comptroller General of the United States prior to publication of the rule in the **Federal Register**. A major rule cannot take effect until 60 days after it is published in the **Federal Register**. This action is not a "major rule" as defined by 5 U.S.C. 804(2). This rule will be effective June 4, 2012.

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**List of Subjects in 40 CFR Part 50**

Environmental protection, Air pollution control, Carbon monoxide, Lead, Nitrogen dioxide, Ozone, Particulate matter, Sulfur oxides.

Dated: March 20, 2012.

**Lisa P. Jackson,**  
*Administrator.*

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