September 8, 1995

EPA-SAB-EPEC-95-019

Honorable Carol M. Browner
Administrator
U.S. Environmental Protection Agency
401 M Street, S.W.
Washington, DC 20460

Subject: Review of the Acid Deposition Standard Feasibility Study Report to Congress

Dear Ms. Browner:

On April 12, 1995, the Acid Deposition Effects Subcommittee of the Ecological Processes and Effects Committee of the Science Advisory Board met to review the draft Acid Deposition Standard Feasibility Study Report to Congress (the Study). The Subcommittee concurs with the conclusion of the Study that the current state-of-the-science with regard to acid deposition effects on terrestrial and aquatic ecosystems does not support an acid deposition standard at this time. We compliment the Agency for the significant effort expended to develop an approach for assessing acid deposition and the need for an acid deposition standard. The Study relates many complex scientific issues in a generally clear and concise manner. While the Congress explicitly directed the Agency to assess the implications of an acid deposition standard for ecological resources, a more detailed evaluation of human health and other possible benefits would be important were the Agency to develop an acid deposition standard at some future time.

The Subcommittee had a number of reservations, however, about the modeling approach employed by the Agency to project future effects of acid deposition under various emission scenarios, as well as the conclusions which are drawn in the Study. While our report contains a number of specific recommendations for improving the Study, we would like to emphasize the following general concerns:

1) The Study should contain a clear statement of the ecological resources and resource endpoints to be protected and the level of protection desired. In the absence of such a statement, it is difficult, if not impossible, to determine the relevant science questions, assumptions and assessment methods which should be pursued by the Agency.

2) The models utilized for the Study do not include the biological processes which control nitrogen cycling in ecosystems; in our report, we recommend a number of alternative models that simulate nitrogen cycling in a more thorough and realistic manner.

3) While the Study frequently alludes to the uncertainties associated with model outputs, the Study should better characterize and quantify these uncertainties to allow policy makers to judge whether the differences in surface water acidification under different emission scenarios are significant.

4) The Executive Summary, which may be the most widely read part of the Study, is misleading in that it contains a number of summary conclusions that are inconsistent with language in the body of the report or are unsupported by current science.

We appreciated the opportunity to review the draft Acid Deposition Standard Feasibility Study Report to Congress. We recognize the difficulty in developing such a report and we hope that our comments will be helpful to the Agency.

Sincerely,

Genevieve M. Matanoski

Dr. Genevieve Matanoski, Chair
Executive Committee

Mark A. Harwell

Dr. Mark A. Harwell, Chair
Ecological Processes and
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William H. Smith

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U.S. Environmental Protection Agency

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ABSTRACT

The Acid Deposition Effects Subcommittee of the Ecological Processes and Effects Committee met on April 12, 1995, to review the draft Acid Deposition Standard Feasibility Study Report to Congress (the Study). The Subcommittee reviewed material in the Study relating to scientific aspects of an acid deposition standard, but did not evaluate portions of the Study dealing with non-ecological benefits, implementation options, and compliance costs. The Subcommittee agreed with the conclusion of the Study that development of an acid deposition standard is not recommended at this time because scientific uncertainties are too great. The models utilized for the Study, the Regional Acid Deposition Model (RADM) and the Model of Acidification of Groundwater in Catchments (MAGIC), are relevant models but have significant limitations. The Subcommittee recommended that the Agency utilize an alternative acid deposition model that more thoroughly and realistically simulates nitrogen cycling in ecosystems. The Subcommittee also recommended that the Agency develop an overall conceptual framework identifying relevant science questions for the broader set of acid deposition effects, clarify what ecological resources and resource endpoints are to be protected and the level of protection desired, better characterize and quantify uncertainties in model projections of acid deposition effects, and place greater reliance on references from peer-reviewed literature published in science journals. The Subcommittee also noted the importance of environmental monitoring of deposition and effects to complement modeling efforts.

KEYWORDS: Acid Deposition, Ecological Modeling, Environmental Monitoring, Peer Review

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1. EXECUTIVE SUMMARY

The Acid Deposition Effects Subcommittee of the Ecological Processes and Effects Committee met on April 12, 1995, to review the draft Acid Deposition Standard Feasibility Study Report to Congress (the Study). The Subcommittee reviewed material in the Study relating to scientific aspects of an acid deposition standard, but did not evaluate portions of the Study dealing with non-ecological benefits, implementation options, and compliance costs.

The Subcommittee compliments the Agency on the significant effort expended to develop an approach for assessing acid deposition and the need for a national standard. The Study relates many complex scientific issues in a generally clear and concise manner. However, the complexity of the approach used to model acid deposition and effects results in uncertainties in the model outputs. Thus, the Subcommmittee agrees with the conclusion of the Study that development of an acid deposition standard is NOT recommended at this time because scientific uncertainties are too great. The models utilized for the Study, the Regional Acid Deposition Model (RADM) and the Model of Acidification of Groundwater in Catchments (MAGIC), are relevant models but have significant limitations. For example, an important shortcoming of the Study is its inappropriate treatment of nitrogen dynamics; alternative models are available to better characterize nitrogen dynamics in ecosystems. Further, the Subcommittee concluded that scientific uncertainties have not been adequately characterized in the Study.

Our specific recommendations for improving the Study include the following:

a) The Agency should develop an overall conceptual framework which identifies the relevant science questions for the broader set of acid deposition effects (human health, ecological resource health, visibility, materials erosion, atmospheric chemistry, and other socioeconomic effects). While the Congress explicitly directed the Agency to assess the implications of an acid deposition standard for ecological resources, a more detailed evaluation of human health and other possible benefits would be important were the Agency to develop an acid deposition standard at some future time.

b) The Study should contain a clear statement of the ecological resources and resource endpoints to be protected by an acid deposition standard and the level of protection desired.

c) The Study should better characterize and quantify the uncertainties in model projections of acid deposition effects.

d) The Agency should carefully review the Executive Summary of the Study for two types of misstatements: 1) summary conclusions which are inconsistent with the wording of the body of the report, and 2) conclusions which are not adequately supported by available scientific evidence.

e) The Study should clearly emphasize the distinction between sensitive (at risk) ecological resources (the focus of the Study) and the general populations of ecological resources which are more resistant or fully resistant to adverse impact via acid deposition.

f) Technical conclusions in the Study should be based primarily on references from the peer-reviewed science-journal literature.

h) The Agency should utilize acid deposition models that include the biological processes controlling nitrogen dynamics; MAGIC does NOT include these processes.

i) The Study should more clearly characterize the scientific uncertainty regarding terrestrial ecosystem nitrogen saturation.

j) The Study should identify and emphasize the importance of environmental monitoring of deposition, ecological indicators, and ecological endpoints as a parallel and complementary strategy to modeling in order to assess ecological resource risk from acid deposition.

2. INTRODUCTION

The Acid Deposition Effects Subcommittee of the Ecological Processes and Effects Committee of the Science Advisory Board met on April 12, 1995, in Washington, DC to review the draft Acid Deposition Standard Feasibility Study Report to Congress (the Study). The Study was prepared by the Agency in response to section 404 of the Clean Air Act Amendments (CAAA) of 1990, which required the Agency to evaluate the feasibility and effectiveness of an acid deposition standard to protect sensitive aquatic and terrestrial resources. The Study utilizes the Regional Acid Deposition Model (RADM) and the Model for Acidification of Groundwater in Catchments (MAGIC) to project possible future effects of sulfur and nitrogen deposition under a range of emission scenarios, including scenarios with emission reductions beyond those required by the CAAA of 1990.

The Charge to the Subcommittee from the Office of Air and Radiation's Acid Rain Division included the following questions:

a) Have the models (RADM, MAGIC) been applied in a credible manner and/or within the bounds of applicability for the scientific analyses and assessments in the feasibility study?

b) Have the modeling results been appropriately integrated? In what ways might the integration be improved?

c) Are the conclusions drawn in the study consistent with the state of the science and the state of modeling? What conclusions are insupportable or weak? For what reasons? How might they be improved?

d) Are there important conclusions from other published modeling studies that should be included in the feasibility study?

e) Have the scientific uncertainties associated with the conclusions drawn in the feasibility study been adequately characterized?

3. GENERAL COMMENTS

3.1 The Interdependence of Policy and Science

The Study includes, by design, a combination of scientific and policy issues. The portions of the report dealing with non-ecological benefits, implementation options for an acid deposition standard, and compliance costs of various options were not reviewed by the Subcommittee. The primary focus of the Subcommittee was on the utility and application of the models, the quality of peer review which they received, and the extent to which the technical findings in the Study can be supported by current science. The overall policy goals must be considered in order to evaluate whether the models are providing useful simulations and predictions.

Recommendation 1: **While the Congress explicitly directed the Agency to assess the implications of an acid deposition standard on ecological resources, policy questions will change as decision makers and societal priorities change. Thus, the Agency should develop a conceptual framework which identifies the relevant science questions for the broader set of acid deposition effects (human health, ecological resource health, visibility, materials erosion, atmospheric chemistry, and other socioeconomic effects).**

Policy questions will influence the science questions that should be addressed by the acid deposition research. However, the policy questions will change as decision makers and societal priorities change. Therefore, the Agency should develop a conceptual framework that shows how the different elements of the acid deposition issues interact (e.g., air quality, ecological effects, socioeconomic effects, human health effects and material effects) and how they contribute to addressing particular science questions. Then, the scientific assumptions and questions of the current approach can be specified. The framework will also help determine the choice of particular endpoints for the research (e.g., water chemistry as compared to aquatic life). The clarification provided by the framework will give the reader a context for the Study. The framework will also provide the means to interpret the cost-benefit analysis of the different components of the research and will provide a basis for setting future research priorities.

In the event that the Agency were to develop an acid deposition standard at some future time, a more detailed evaluation of human health and other possible benefits would be important. These issues have been dealt with more fully in Agency documents prepared to support National Ambient Air Quality Standards for NO_x and SO_2 and reviewed by the SAB's Clean Air Science Advisory Committee (CASAC) (EPA-SAB-CASAC-LTR-94-007, EPA-SAB-CASAC-LTR-93-015, EPA-SAB-CASAC-LTR-92-017).

Recommendation 2: **The Study should contain a clear statement of the ecological resources and resource endpoints to be protected by an acid deposition standard and the level of protection desired.**

The Study deals only minimally with the subjects of "ecosystem effects" and "resources at risk." Instead, it focuses almost exclusively on protecting the environment from further degradation of acid neutralizing capacity (ANC). Refining models for projecting ANC will not necessarily lead to better information on the effects of acid deposition on key species or species diversity in sensitive ecoregions. In addition, the Study points to the importance of episodic acidification in causing biological effects, both through mobilization of aluminum and through abrupt changes in pH during critical biological events such as spawning. However, the design of an acid deposition standard to protect sensitive aquatic resources from episodic acidification would likely differ from a standard designed to protect sensitive resources from chronic acidification.

3.2 Scientific Uncertainty and an Acid Deposition Standard

The Study sends a mixed message on the question of whether or not it is feasible to set an acid deposition standard; both the Executive Summary and Chapter 6 conclude that "it would be feasible to set sulfur and nitrogen deposition standards to protect aquatic resources," whereas Chapters 1 and 6 include statements that "scientific uncertainties associated with the response of specific sensitive regions to acid deposition" and "scientific uncertainty regarding watershed nitrogen saturation makes determining a standard difficult at this time."

At the meeting of April 12, the Agency presented as a "key conclusion":

> "Although developing an acid deposition standard may be feasible, based on the scientific uncertainty in determining the level [of the standard], an acid deposition standard is not recommended at this time."

We agree that the scientific uncertainty in the models used is too great to support an acid deposition standard. This conclusion should be clearly stated in the Executive Summary of the Study.

Although the impact of sulfur on aquatic systems is clear, there are unknown levels of scientific uncertainty associated with impacts of nitrogen and sulfur deposition on terrestrial resources and of nitrogen deposition on aquatic resources. As noted in the Study, an important source of uncertainty is that associated with effects of nitrogen deposition and the potential for watershed nitrogen saturation. This topic is dealt with in section 4 of this report.

Recommendation 3: The Study should better characterize and quantify the uncertainties in model projections of acid deposition effects.

There are multiple sources of uncertainties that contribute to the estimation of the extent of surface water alkalinity under different emission scenarios. These include uncertainties in emission projections, in the RADM and MAGIC formulations, and the calibration and parameterization of the models. Estimates of these uncertainties and calculation of their propagation through the models is needed to judge whether the differences in estimates of the extent of acidification of surface waters under different deposition scenarios are significant. This will allow the placement of confidence levels around the predictions. With regard to uncertainties in emission projections, the Agency should ensure that the emission scenarios bracket the possible emission levels; although the Study includes scenarios with nitrogen emissions either increasing or held constant at 1985 levels, reductions in nitrogen emissions resulting from replacement of the current motor vehicle fleet with lower NO_x-emitting vehicles and from state efforts to meet ozone attainment goals contained in the CAAA of 1990 may result in nitrogen emissions lower than 1985 levels. In fact, initial state inventories of nitrogen emissions indicate that this is already occurring.

Aluminum mobilization due to acid deposition is known to cause toxic effects on sensitive fish in freshwater lakes with depressed pH levels. However, as acknowledged in the Study, the results of the model (MAGIC) analysis of aluminum mobilization and transport are highly uncertain and further improvements in the model would be needed if the Agency decides to use MAGIC to predict aluminum mobility.

Application of the three effects models evaluated by the Agency (the Trickle-Down Model, the Integrated Lake Watershed Acidification Study--ILWAS--Model, and MAGIC) gave comparable results for Northeast lakes, but inconsistent results for Southern Blue Ridge streams. It is critically important to determine the source/cause of these differing results in order to select the most appropriate model for the Study. Sensitivity analyses of the models would be appropriate and may reveal the reasons for differences in model projections.

3.3 Unsupported or Inconsistent Conclusions

A number of the conclusions in the Executive Summary are not consistent with language in the body of the report or are not supported by current scientific studies. Since the Executive Summary may be the most widely read part of the Study, it is particularly important that the conclusions drawn are accurate and supported by the remainder of the document.

Recommendation 4: The Agency should carefully review the Executive Summary for two types of misstatements: a) summary conclusions which are inconsistent with the wording of the body of the report, and b) conclusions which are not adequately supported by available scientific evidence.

In some cases, conclusions in the Executive Summary are stated without the caveats that accompany the conclusions in the body of the report. For example, section headings such as "CAAA Provides Clear Benefits To Surface Waters; Further Reductions May Be Necessary For Full Protection; and Emission Trading Is Cost Effective And Maintains Environmental Benefits" imply greater certainty in model projections than can be justified by current science. Further, statements in the Study that describe high-elevation red spruce forests as being among the systems most at risk from acidic deposition are not justified by the available scientific evidence and should be deleted.

In contrast to the case for aquatic effects, the evidence linking acid deposition to effects on red spruce is far from conclusive. This conclusion is based on a chain of inferences that involves indirect and correlative evidence and the lack of other explanations for the decline of red spruce. Several explanations for the occurrence of winter injury are being investigated. There is no agreement on the components of acidic deposition that are involved in reductions of cold tolerance of red spruce foliage found in controlled experiments. The chain of events between deposition of sulfur and nitrogen compounds in high-elevation forests and mortality of trees is not understood. Consequently, benefits, if any, to red spruce forests cannot be identified.

<u>Recommendation 5:</u> **The Study should clearly emphasize the distinction between sensitive (at risk) ecological resources (the focus of the Study) and the general populations of these ecological resources which are more resistant or fully resistant to adverse impact via acid deposition.**

The National Surface Water Survey (NSWS) was designed to provide assessment of the chemical status of aquatic systems in regions of the U.S. thought to be at high risk to acid deposition effects due to various sensitivity factors. The NSWS sample, therefore, represents only a small fraction of all lakes and streams in the U.S. (the general population). Subsequent reference to NSWS lakes, without reference to the fact that this is a small portion of all lakes, can mislead the reader regarding the general significance of adverse effects to these high-risk lakes. The graphic developed for Exhibit 6 in Chapter 2 (p. 29) is useful to make this important distinction. If possible, a similar graphic should be developed based on <u>actual</u> proportional differences and be moved forward in the document to both the Executive Summary and Introduction (Chapter One).

<u>Recommendation 6:</u> **Technical conclusions in the Study should be based primarily on references from the peer-reviewed science-journal literature.**

Many technical statements in the report are not specifically referenced; instead, sections are broadly referenced by summary documents. Also, the sections on episodic acidification include estimates of the extent of episodic acidification which are not referenced. In general, the Agency should focus more attention on citing primary sources in peer-reviewed science-journals rather than referring to "gray" literature; i.e., Agency documents which have not received independent peer review as journal articles. In this case, the Nitrogen Bounding Study (NBS), which forms much of the technical basis of the Study, did receive some level of peer review. However, as a yet-to-be-published Agency document, the NBS has not had the benefit of review by the broader scientific community.

A precedent for relying exclusively on published literature can be found in the 1990 decision by the Intergovernmental Panel on Climate Change (IPCC) to cite only peer-reviewed publications in its state-of-the-science assessments. By encouraging the publication of Agency science in peer-reviewed science-journals, a similar commitment by the Agency would do much to improve the scientific credibility of EPA documents.

4. MODELING NITROGEN DEPOSITION AND EFFECTS

4.1 Alternative Models for Nitrogen Cycling

Recommendation 7: The Agency should utilize acid deposition models that include the biological processes controlling nitrogen cycling; MAGIC does not include these processes.

By treating NO_3^- strictly as a strong acid anion moving through watersheds, one can derive a worst case scenario for the effect of nitrate, in addition to sulfate, on surface water acid neutralizing capacity (ANC). However, nitrogen cycling is inherently a biological process, with many alternative pathways through an ecosystem. Because the availability of nitrogen to aquatic systems is tightly linked with terrestrial processes of the surrounding catchment, it is unrealistic to attempt to model nitrogen without taking terrestrial biological processes into account.

A number of empirical studies in natural and agricultural systems over the past 30 years have identified important pathways, controls, and pools of terrestrial nitrogen, all of which influence the amount of potential leakage, and thus nitrogen saturation potential, of terrestrial N into surface waters (Agren and Bosatta, 1988; Kahl et al., 1993; Matson et al., 1992). These include nitrification, ammonification, uptake and storage in woody biomass, burial in soil organic matter with varying turnover times, emissions as N_2O, or leaching into soil and surface waters. In some ecosystems, organic nitrogen, which will not contribute to surface water acidification, is the major nitrogen species leaching into surface waters (Hedin et al., 1995). Land use and land use history, vegetation type and maturity, phenology, and climate, all contribute to the degree to which terrestrial systems are able to sequester nitrogen. These biological processes must be reflected in any model chosen to project effects of nitrogen deposition.

There are a number of models that simulate nitrogen cycling in a more thorough and realistic manner than does MAGIC. These models include the Terrestrial Ecosystem Model (TEM) developed at Woods Hole (Melillo, 1995), the CENTURY model (Parton et al., 1987; 1988, 1993; Sanford et al., 1991; Schimel et al., 1994), the Nutrient Cycling Model(NuCM: Liu et al., 1992), and the RHESSys model (Regional Hydro-Ecosystem Simulation System: Band et al., 1993). RHESSys is a watershed based model that uses TOPMoDEL to route water through soils, similar to MAGIC, and a lumped, 2-soil compartment for moving NO_3^- from soils to surface waters. Many of these models are either developing or have developed capability for spatial simulation. The Agency should incorporate the ecological processes included in these models and, because of the many different ways in which hydrologic and biogeochemical processes are treated in each, should consider comparing model outputs against each other and observed data.

4.2 Nitrogen Saturation Potential

Forest ecosystems are generally recognized as nitrogen-limited; i.e., the biological sink capacity for nitrogen exceeds nitrogen availability. Nitrogen is tightly regulated and recycled in undisturbed forest ecosystems. The Study discusses the hypothesis that forests can become nitrogen saturated if atmospheric deposition of nitrogen causes nitrogen supply to exceed the biological sink capacity. The result of nitrogen saturation could be the export of nitrogen largely in the form of NO_3^- and NH_4^+, which has the potential for numerous adverse effects (e.g., cation depletion, perturbation of nitrogen mineralization or nitrification processes, disturbance of mycorrhizal relationships, and acidification and eutrophication of associated aquatic ecosystems).

Recommendation 8: The Study should more clearly characterize the scientific uncertainty regarding terrestrial ecosystem nitrogen saturation.

The Study considers emission scenarios for a range of times to watershed nitrogen saturation and acknowledges the uncertainties associated with this variable. However, although one of the scenarios assumes that nitrogen saturation does not occur, the Study focuses more on those scenarios where nitrogen saturation occurs. Some European studies suggest that nitrogen saturation is occurring in areas receiving much greater nitrogen deposition than presently documented in North America. Although there is evidence that nitrogen saturation may occur in the U.S. at high elevations (e.g., McNulty et al., 1990; Johnson and Lindberg, 1992), there is no science community consensus on the extent of and degree to which nitrogen saturation caused primarily by atmospheric deposition does and can occur.

Another factor influencing nitrogen saturation potential is the potential for vegetation to respond to increasing nitrogen availability. This possibility has been observed in nitrogen fertilization studies, where the response of the ecosystem to added nitrogen was a shift in species and community composition to vegetation more competitive under increased nitrogen availability (Aber, 1992; Bowman et al., 1993). Carbon dioxide fertilization will also stimulate biomass production and as a consequence increase the nitrogen sink.

Some ecosystems, such as those of the Sierra or Rocky Mountains, have the potential to saturate with nitrogen at much lower nitrogen deposition levels than the three provinces the Agency evaluated (Baron et al., 1994). Some of these systems are not forested, and may be more sensitive to nitrogen deposition because of seasonal hydrologic processes not addressed by the MAGIC model.

5. MONITORING

<u>Recommendation 9:</u> **The Study should identify and emphasize the importance of environmental monitoring of deposition, ecological indicators, and ecological endpoints as a parallel and complementary strategy to modeling in order to assess ecological resource issues.**

The National Surface Water Survey (NSWS) of lakes and streams conducted in the mid-1980's sampled "at risk" freshwater ecosystems using a standard protocol. Repeat of this survey ten years later would provide assessment of current status (e.g., ANC, $SO_4^{=}$,NO_3^{-}) and permit a direct assessment of trends. Modeling and monitoring should be viewed as parallel activities that interact and support one another. Monitoring will allow model validation. Modeling will allow more focused monitoring. Decision-makers need models for predictions and monitoring for evaluation of regulations, risk assessment, and priority-setting. Absent direct monitoring evidence for declining ecosystem quality, it is doubtful that incremental regulations, especially if costly, would be implemented based on modeling evidence alone.

6. CONCLUSIONS

The Subcommittee compliments the Agency on the significant effort expended to develop an approach for assessing acid deposition and the need for a national standard. The Study relates many complex scientific issues in a generally clear and concise manner. We concur with the Agency that the current state-of-the-science with regard to acid deposition effects on terrestrial and aquatic ecosystems does not support an acid deposition standard.

The Subcommittee has the following summary responses to the Charge Questions:

a) Have the models (RADM, MAGIC) been applied in a credible manner and/or within the bounds of applicability for the scientific analyses and assessments in the feasibility study?

Not in all cases. The models are appropriate for assessing future effects of sulfur deposition, but lack realistic biological processes necessary for assessing effects of nitrogen deposition.

b) Have the modeling results been appropriately integrated? In what ways might the integration be improved?

Yes, with regard to sulfur dynamics. The modeling results for nitrogen dynamics, however, are not appropriately synthesized. The Subcommittee recommends that the Agency consider several models which more adequately describe the biological controls on nitrogen dynamics.

c) Are the conclusions drawn in the study consistent with the state of the science and the state of modeling? What conclusions are insupportable or weak? For what reasons? How might they be improved?

Not in all cases. A number of the conclusions in the Executive Summary are not consistent with language in the body of the report or are not supported by current scientific studies.

d) Are there important conclusions from other published modeling studies that should be included in the feasibility study?

Yes. A number of alternative nitrogen models are suggested that treat biological nitrogen cycling in a more thorough and realistic manner than does MAGIC.

e) Have the scientific uncertainties associated with the conclusions drawn in the feasibility study been adequately characterized?

No. Uncertainties arising from emission projections, model formulations, and model calibration and parameterization have not been adequately characterized. The lack of adequate documentation of the uncertainty associated with use of the models is a major deficiency of the Study.

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United States Environmental Protection Agency
Science Advisory Board 1400 Washington, DC
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AN SAB REPORT: REVIEW OF THE ACID DEPOSITION STANDARD FEASIBILITY STUDY REPORT TO CONGRESS

PREPARED BY THE ACID DEPOSITION EFFECTS SUBCOMMITTEE OF THE ECOLOGICAL PROCESSES AND EFFECTS COMMITTEE