The Honorable Lisa P. Jackson
Administrator
U.S. Environmental Protection Agency
1200 Pennsylvania Avenue, NW
Washington, DC 20460

Subject: Clean Air Scientific Advisory Committee's (CASAC) Peer Review of *EPA's Risk and Exposure Assessment to Support the Review of the Secondary National Ambient Air Quality Standard for Oxides of Nitrogen and Sulfur: Second Draft*

Dear Administrator Jackson:

The Clean Air Scientific Advisory Committee (CASAC or Committee), augmented by subject-matter-experts to form the CASAC NOx & SOx Secondary NAAQS Review Panel (hereafter referred to as the Panel, roster provided in Attachment B) held a public meeting on July 22-23, 2009 to review EPA's *Risk and Exposure Assessment (REA) to Support the Review of the Secondary National Ambient Air Quality Standard for Oxides of Nitrogen and Sulfur: Second Draft*. **(To be inserted pending review/approval by CASAC: "**The Chartered CASAC held a public teleconference on August 20, 2009 to review and approve the report.") and provide advice on the Agency's framework for developing the forthcoming Policy Assessment, set to be published September 2009. We also address the timing and schedule for completion of the current review of the secondary NOx and SOx NAAQS, and its implications on the policy options for the secondary standards under consideration by the Agency. The Panel's responses to EPA's charge questions and advice for improving the REA are presented in Enclosure A. The CASAC and Panel membership is listed in Enclosure B. Finally, Enclosure C is a compilation of individual panel member comments.

Overall, the CASAC NOx-SOx Secondary Panel found the second draft REA greatly improved over the prior version and responsive to CASAC's advice. EPA staff is to be commended on their efforts, particularly for providing the information that will be essential in the development of a set of standards to address multiple ecosystem outcomes that result from the exposure to multiple pollutants, some of which are not criteria pollutants. In this regard, EPA is breaking new ground that is consistent with our knowledge of the science, responsive to the advice of previous CASAC Panels and recommended in National Research Council reports. The Panel considers the most important issues to be addressed in finalizing the REA as: the completeness of the Executive Summary, the inadequacy of the case study synthesis in Chapter 7, the treatment of uncertainty throughout the REA, and the treatment of the often decades-long recovery of affected ecosystems. Additionally, the Panel would like the REA to acknowledge the potential benefits of N-deposition on N-deficient ecosystems.

The Executive Summary (ES), as acknowledged by EPA Staff, is still not a comprehensive summary of the REA. The Panel maintains that the ES is a very important part of the REA and, in its current form, does not fully capture the conclusions and findings presented in the REA. Chapter Seven provides a summary of the disparate case studies, but does not fully synthesize their results. The chapter also fails to provide the type of contextual information needed to extend these results to broader national scales. The treatment of uncertainty in the current draft REA should be improved to strengthen the analysis in this review. The application of the various steady state, dynamic, and statistical air quality and ecosystem process models is the foundation of the REA, and the final REA should incorporate a more complete evaluation of those models as time allows. The Panel strongly recommends the addition of a model performance overview, which would describe their strengths and limitations, especially with respect to spatial and temporal predictions, and how the models can

be used to inform the decision-makers about the time needed for ecosystem recovery. A table summarizing model characteristics and capabilities would be especially useful in the ES.

The schedule for completion of the current NOx and SOx NAAQS reviews is a major concern of the Panel. To meet the Agency's court-ordered deadlines, EPA staff informed the Panel that there will not be adequate time to complete the level of analysis needed to sufficiently formulate and justify recommendations for a secondary NAAQS for NOx and SOx. Following the recommendation of CASAC and other subject-matter experts, the Agency undertook separate reviews of the health and welfare standards to provide the appropriate platform to address the current scientific understanding of the harmful effects of NOx and SOx deposition on ecosystems. However, in order to meet statutory obligations and deadlines, EPA will likely propose one of three alternatives for rule-making:

1. Retain the current secondary standards,
2. Revise the current NO2 secondary standards to make it identical to the primary and retain the current secondary standard for SO2, or
3. Revoke the current secondary standards for NO2 and SO2.

None of these three options would lead to a NAAQS(s) that contain the appropriate indicators, levels, forms, and averaging times of a secondary NAAQS tailored to address welfare effects. The Integrated Science Assessment (ISA) and the REA both provide ample evidence that deposition of NOx and SOx is adversely impacting sensitive ecosystems at the present levels. Given that no areas of the US currently exceed the secondary standards, it is clearly evident that these standards are not sufficiently protective of sensitive ecosystems.

The development of credible, multi-pollutant standards to address multiple endpoints will require more time than EPA has to complete the analysis and review. Although it is not within the Panel's purview to grant the Agency more time, we recommend the Agency complete the current reviews for NOx and SOx to fulfill its statutory and legal obligations, and simultaneously continue with the analyses to support ecologically appropriate welfare standards. The Panel estimates that a fast-track approach to the development of the framework for an alternative Policy Assessment, and the associated rulemaking, building upon the ISA and REA completed in the current review would take not more than one or two years.

Previous CASAC panels and the National Research Council have called upon EPA to do exactly what is being attempted in the current NOx and SOx reviews. It is critical that the Agency's initial foray into setting ecologically relevant welfare standards is comprehensive and does not inhibit future efforts. The Panel recognizes the complexities involved in developing the information needed to support an ecologically relevant, multi-pollutant standard. The Panel also believes that said complexities could be overcome if EPA had sufficient time to finish the efforts now underway, flowed by appropriate review and revision. It would be a grave disservice to abandon the work done in this groundbreaking approach to the setting of ecologically appropriate secondary standards for NOx and SOx for any reason other than lack of scientific evidence. We look forward to working further with EPA on the Policy Assessment document.

Sincerely,

Response to Charge Questions:

*Executive Summary:*

1. *In response to the Panel's review of the first draft Risk and Exposure Assessment, we have included an executive summary of this document. Does the Executive Summary adequately summarize and characterize the key issues driving this review as well as the important findings of the analyses? Does the Panel have any suggestions for clarification or refinement of the Executive Summary?*

The Panel is pleased to see an Executive Summary (ES) in this draft of the REA. As acknowledged by EPA staff, the ES is still not a comprehensive summary of the REA. Where the ES does a good job summarizing the ecological effects of NOx/SOx deposition, it fails to capture the major findings presented in Chapters 3 – 7. One way to highlight the important results of the REA would be to replace the current "Conclusions" section with one entitled "Key Findings", similar to the format of the ES in the ISA. Both the ES and Chapter One list a number of important policy- relevant questions. The ES should explain that these questions are not answered in the REA to set the stage for their discussion in the forthcoming policy assessment document. Also, the list of policy-relevant questions is not consistent from the ES to Chapter 1. It would be helpful if the sequence of questions followed the logical layout of Fig ES-2.

The introduction to the ES should explain why the review focuses on the ecological effects of NOx/SOx deposition, but excludes other potential welfare effects such as foliar injury from gaseous phases of NOx/SOx and other effects of deposition such as injury to materials. An explanation of the selection of the case studies is also missing from the ES. The reader is left to ponder if the justification is based on data availability, representativeness, sensitivity, or some combination thereof. The ES should provide a sense of what percentage of the US exhibit similar problems as represented in each of the four categories of the ecological effects. The treatment of reduced forms of nitrogen (N) is much improved in this second draft. However, the regional nature of ammonia and reduced forms of N needs to be clearly acknowledged in the ES and throughout the REA. One way to illustrate the regional nature nitrogen deposition would be to supplement Fig.ES-7 with two new figures, one for reduced N and the other for oxidized N.

The ES needs to identify the key data gaps and present EPA's intention/recommendations on filling those data gaps. The Panel was pleased with the inclusion of an explanation of the concept of ecosystem services and how this concept may help to determine what an adverse welfare effect. However, if specific examples such as recreation usage are included in the ES, these need to be tied at least qualitatively to the effects of deposition on the quality and abundance of these ecosystem services. The Panel maintains that the ES is a very important part of the REA and, in its current form, does not fully capture the conclusions and findings presented in the REA.

*Air Quality Analyses (Chapter 3):*

1. *This chapter describes an approach for characterizing the spatial and temporal patterns of nitrogen and sulfur deposition in the case study locations including both oxidized and reduced nitrogen, and both wet and dry deposition of oxidized nitrogen, reduced nitrogen, and sulfur. Are the uncertainties associated with these analyses appropriately identified and described?*

2. *In response to CASAC's recommendation, the RSM analysis presented in the first draft Risk and Exposure Assessment was replaced by an analysis of results from a new series of CMAQ simulations designed to explore the relative contributions of NOx and $NH_3$ emissions to total, reduced and oxidized nitrogen deposition and the relative contribution of $SO_2$ emissions to sulfur deposition. Does this approach enable us to adequately examine the contribution of NOx to total nitrogen deposition?*

3. *The CMAQ application and model performance evaluation is presented in Appendix 3-1, as recommended by the Panel. Is this analysis sufficient to support the use of the model in this review?*

The Panel was encouraged to see that the Chapter 3 characterization of emissions, air quality and deposition information was a substantial improvement over the previous draft, especially in combination with the Appendix 1 performance evaluation of the CMAQ model, which is prominently employed in the air quality and deposition estimates. The detailed map presentations of the various emissions, air quality and deposition patterns are informative and directly responsive to prior CASAC requests.

It would also be informative to see a number of "ratio" or "difference" maps. For example, maps showing the ratios of wet, dry and total sulfur deposition to SO2 concentration and to SO2 emissions, and ratios of wet, dry and total N, and oxidized N deposition to NO2 concentrations and to NOx emissions would be informative. Ratio or difference maps would also be an informative way to present additional details on CMAQ model performance. For example, what is the ratio of or difference between CMAQ modeled wet S (or N) deposition and measured (interpolated NADP) wet S (or N) deposition?

A relatively complete "listing" of uncertainties associated with the air quality-related characterizations is provided in section 3.5. However, the discussion is minimal and the absence of any quantitative uncertainty estimates substantially limits the usefulness of this section. The Panel recommends that some quantitative estimates of uncertainty be provided here, even if these are not intended to be comprehensive. For example, the (informative, but graphic-only) comparison of various model and measurement-based sulfur deposition estimates for the Adirondack case study area could be enhanced by scatter plots which show quantitative differences among the estimates. Some of the CMAQ model performance metrics from Appendix 1 might also be summarized in Chapter 3, along with a comparison of results from CMAQv4.6 vs. CMAQv4.7. At a minimum, some indication should be provided of the relative uncertainties of the different air quality and deposition estimates, which are presumably greater for dry than for wet deposition and greater for NHx than for SOx. For example, EPA has done some work on quantifying uncertainties in ammonia emissions that could be included here.

Some explanation should also be given for why potentially important contributions to NOx emissions from lightning and soils and from increased S and N deposition from cloud water at higher elevations were excluded from the analyses, along with some discussion of the potential magnitudes of effects from these sources and deposition mechanisms.

The evaluation of CMAQ model performance in Appendix 1 is a substantial improvement over the previous draft, and provides added confidence in some of the deposition estimates, their inter-annual variability and their uncertainties. However, the panel recommends that additional model performance metrics be shown to fully assess the model performance to gain confidence in applicability of CMAQ for this assessment. These include showing model performance statistics (and plots) for daily or weekly averaged quantities (based on

available data), using mean normalized bias (and error) instead of normalized mean bias, and showing model performance for specific regions rather than the whole country. It would also be useful if model performance for NOx is also included for whatever data are available. There should also be more discussion of what level of model performance is considered "acceptable", as there were many components for which the model performance did not particularly look good.

The application of the various steady state, dynamic, and statistical air quality and ecosystem process models is the foundation of the REA. The final REA should incorporate a more complete evaluation of those models as time allows. The Panel strongly recommends the addition of a model performance overview, which would describe their strengths and limitations, especially with respect to spatial and temporal predictions, and how the models can be used to inform the decision-makers about the time needed for ecosystem recovery. A table summarizing model characteristics and capabilities would be especially useful in the ES.

*Case Study Analyses (Chapters 4 & 5):*

*Questions related to the individual case study analyses are presented below. Overarching questions across all the case studies include:*

1. *Are uncertainties appropriately characterized across the case studies? Is there adequate information to allow us to weigh the relative strengths of each case study to inform the standard setting process?*

The discussion of uncertainty was generally well presented in a qualitative sense, but needs to be made more quantitative wherever possible. In particular, it would be useful to convey a sense of the relative importance of the various sources of uncertainty and articulate which are critical for policy assessment. This should include a discussion across the various links in the proposed structure of the standard (Fig. ES-2 and throughout); i.e., consider the impacts of uncertainty in CMAQ inputs and outputs on deposition, and the subsequent impacts of deposition estimates on ANC, and then the impact on critical loads. It is difficult to assess the importance of this uncertainty due to inherent problems in extrapolation from the case studies to various ecozones and larger regions. Some of this uncertainty is related to the case studies not representing the full spectrum of effects associated with the deposition of total reactive nitrogen and sulfur.

2. *In using the Risk and Exposure Assessment to inform the policy assessment, we plan to focus on aquatic acidification as the basis for an alternative multi-pollutant secondary standard as this is the area where we have the most confidence in our ability to characterize adverse effects. Does the Panel agree with this approach?*

The panel agrees with the focus on aquatic acidification, based on the quantity and quality of data available, but strongly recommends that EPA continues to consider multiple indicators and find a way to truly integrate multiple indicators into a standard. Multiple indicators will expand the geographic relevance and scope of the standard and afford protection to a maximum number of sensitive ecosystems. Moreover, recent findings are suggesting that the recovery of soils from acidification may take an extended period and over the long-term this will also affect the rate of recovery of aquatic ecosystems.
Chapters 4 and 5 should also include an overview of the tools and models used in the case studies and present a justification of EPA's choices, in particular with respect to the use of SPARROW and the choice of BC/Al ratios rather than Ca/Al ratios. An additional case study or at least a discussion of a nitrogen-deficient site is needed in order to avoid potential bias in extrapolating from only sensitive sites. Additional discussion on

aquatic-terrestrial linkages would be helpful, as well as explicit information on the relationship between deposition and ANC.

*Acidification:*

The CASAC is generally pleased with the effort to evaluate the effects of acidification on aquatic and terrestrial ecosystems. However, this chapter needs considerable editorial work including the use of proper terminology, reduction of duplication and improvement in the clarity of the text and figures. A more accurate use of concepts is needed and terminology should include descriptions related to ANC and buffering. The "critical loads" concept is important, but the text needs to clarify its utilization in published literature and its adaptation in the REA. Averages and steady state calculations are used in various ways including the application of critical loads and determining the effects of ANC. The advantages and limitations of using averages and steady state calculations need to be provided. Understanding the effect of sulfur and nitrogen deposition needs further descriptions to delineate the relative importance of natural acidification and internal ecosystem processes in affecting the temporal and spatial patterns of acidification.

*1. Section 4.2 and Appendix 4 describe the analyses used to evaluate the effect of aquatic acidification. The analysis evaluates the ANC in selected lakes and streams in the Adirondacks and Shenandoah relative to three potential ANC cutoff levels (20, 50, and 100 ueq/L) to determine the impact of current levels of deposition in these areas as well as a larger assessment area. Are these data adequate to establish critical loads of deposition for the case study area?*

The use of ANC to evaluate the impacts of current levels of deposition is appropriate. The emphasis on using the results from aquatic ecosystems for analysis and model predictions on acidification is appropriate based upon available historical and temporal data sets. The implementation and uses of models (e.g., CMAQ, MAGIC, SSWC) are integral to this chapter and the focus of the REA in ascertaining on the effects of acidification. The analysis of uncertainty within models focuses mostly on variation in parameter estimates and how this variation affects model output. Further discussion on why specific models were selected and the implicit limitations of the various models (e.g., processes not covered, representation of internal elemental cycling, appropriateness of scale both spatially and temporally, etc.) would help the reader evaluate the appropriateness of model results and applicability for predicting acidification temporal and spatial patterns.

*2. The ecological effect function for aquatic acidification (section 4.2.7) attempts to characterize the relationship between deposition and ANC. In order to estimate the amount of NOx and SOx deposition that will maintain an ANC level above a given limit requires the knowledge of the average catchment flux of base cation from weathering of soils and bedrock (i.e., preindustrial cation flux (BC0)). How might we generalize from location specific inputs (F-factor approach) to using this approach on a broader scale - watershed, regionally, or some other way - to generalize beyond individual locations? What other methods should be examined for estimating catchment weathering rates nationwide for surface acidity?*

This is a challenging question and a difficult but critical problem. More attention is needed on the contribution of weathering rates especially the input of soil base cations in affecting the recovery of terrestrial and aquatic ecosystems from acidification. The determination of base cation supply rates is critical predicting the effects of sulfur and nitrogen deposition on rates of acidification and possible recovery from acidification. Unfortunately there are no effective ways to estimate element weathering rates. Clarification is also needed on the utilization of the Bc (sum of base cations)/Al versus the more commonly used Ca/Al ratio in evaluating effects of soil acidity. Also, how the F-factor is applied in predicting the spatial and temporal patterns of base

cation supplies and resultant effects on acidity needs to be discussed.

It is vital to separate the capacity effects from intensity effects in assessing sensitivity to aquatic and terrestrial ecosystems to acidification and the potential recovery from acidification. An acidic soil is a necessary but not sufficient condition for the acidification of waters – the second requirement for acidification of waters is the introduction of mobile acid strong acid anion such as sulfate and nitrate. Soils that are already naturally acidic will produce acidic waters nearly instantaneously with the introduction of mobile strong acid anions, and conversely, acidic waters in these cases will recover almost instantaneously when such mobile strong acid anions are removed. On the other hand, acidification of a soil that was not historically acidic is not so easily reversed.

In the consideration of impacts on ecosystem services, acidification effects are placed in a broader context. The section on ecosystem services is a good summary of helpful information related to ecosystem services and acidification issues. It is useful that the REA explicitly states some of the issues in estimating directly how ecosystem services are affected by terrestrial and aquatic acidification.

*3. Section 4.3 and Appendix Y describe the analyses used to evaluate the effect of terrestrial acidification. This analysis uses the Simple Mass Balance Model to determine the impact of current deposition levels on Bc/Al levels relative to three potential Bc/Al cutoff levels (0.6, 1.2, and 10.0) for sugar maple in the Kane Experimental Forest and red spruce in the Hubbard Brook Experimental Forest and a larger assessment area based on the FIA database for 17 states. Is this approach adequate to develop critical loads of deposition for the broader terrestrial acidification case study area? Is the regression analysis between Bc/Al ratios and tree health sufficiently described and are uncertainties adequately characterized?*

*Nutrient Enrichment:*

The title of the chapter should be changed to "Nutrient Excess", because nutrient enrichment commonly occurs but does not necessarily result in an environmental problem unless the ecosystem is not able to fully assimilate nitrogen inputs. Further background information should be provided on nitrogen as a limiting nutrient in terrestrial, freshwater aquatic and coastal ecosystems. Most temperate terrestrial ecosystems are nitrogen deficient and increased deposition may cause increased growth, which can be viewed as positive or negative. Recent evidence suggests that nitrogen limitation is more common than once thought for freshwater ecosystems. A major challenge in developing protocols for returning ecosystems to a level of lower nutrient enrichment is defining what attributes and their specific values are necessary for the restoration of ecosystem structure and function. The attributes that control sensitivity of different ecosystem types to nitrogen loading needs further clarification. It would be helpful to indicate the spatial extent of those areas in the West (e.g., Rocky Mountains of Colorado) that are impacted by relatively low levels of atmospheric nitrogen inputs.

*1. Section 5.2 and Appendix 6 describe the analyses used to evaluate the effect of aquatic nutrient enrichment. The analysis uses the SPARROW model on one stream reach (Potomac River and Neuse River) to determine the impact of atmospheric total nitrogen deposition on the eutrophication index for the estuary. Does the Panel think that the model is adequately described and appropriately applied?*

The SPARROW model and its links to the CMAQ model's deposition data and to the ASSETS EI's estimates of current or future occurrences of eutrophication are well described in the Appendices. However, better description of the SPARROW model is needed in the main document. EPA should bringing forward some of

the model's description in the Appendix 6 to improve readability of this chapter. Also, it would be helpful to clearly indicate that SPARROW is a statistically-based, steady-state model. The limitations of using this model for extrapolation to conditions of lower atmospheric nitrogen deposition should be given.

The discussion of the case studies related the application of SPARROW to the Potomac River/Potomac Estuary Case and Neuse River/Neuse River Estuary. The broader extrapolation of these results is also helpful. The discussion of the uncertainty estimates provides important information on the application of the model simulations. A summary of which of these components of uncertainty is most important with respect to policy recommendations should be provided.

*2. Section 5.3 and Appendix 7 describe the analyses used to evaluate the effect of terrestrial nutrient enrichment. This qualitative analysis describes the impacts due to nitrogen deposition on the Coastal Sage Scrub community in California and in mixed conifer forests in the San Bernardino and Sierra Nevada Mountains and larger areas where possible. In addition, the effects of nitrogen deposition in the Rocky Mountain National Park supplemental case study location are summarized. How would the Panel apply the threshold values presented in this case study to allow for a broader geographic application that accounts for regional variability? Have the associated uncertainties been adequately characterized?*

The "patchwork quilt" of species and ecosystem types from across the United States used for this chapter is reasonable and probably the best option considering a general scarcity of data on the ecological effects of excessive atmospheric N deposition. The Panel finds that translating the results from these case studies to other ecosystems to be difficult. Research results from the ecosystems selected for the case studies represent ecologically sensitive regions to total reactive N deposition that a standard may be developed to protect. However, these case study sites represent only sites where N deposition is known to be excessive and the panel recommends that the situation for N-limited ecosystems (which are far more common than these cases) should be duly considered as well.

The emphasis on the California coastal sage scrub (CSS) and San Bernardino Mountains mixed conifer forest (MCF) systems seems appropriate due to their importance with respect to population centers. Also linkages with other environmental issues, such as fire susceptibility and the potential effects on biodiversity and threatened species, are important for these case study areas. The alpine ecosystems of the Rocky Mountains were also considered and the suggestion that these systems have "the ecological benchmarks ….comparable to the benchmarks from CSS and MCF ecosystems" (p. 5-57) needs to be reconsidered since these systems are especially sensitive to low levels of nitrogen deposition. The section on "Uncertainty and Variability" (5.3.8) is a good summary of the major issues with a particular focus on the CSS and MCF case studies. On the other hand the "Conclusions" (5.4) section should be expanded, linking the chapter with the entire document.

The main question still remains in this chapter – how to translate ecological changes caused by the total deposition of reactive nitrogen into ambient concentrations of just the criteria pollutant, NOx. The critical loads approach based on deposition of total reactive N should be considered for setting a new secondary standard.

<u>*Additional Effects (Chapter 6):*</u>

1. *In this chapter, we have presented results from some qualitative analyses for additional effects including visibility, climate and materials, the interactions between sulfur and methylmercury production, nitrous oxide effects on climate, nitrogen addition effects on primary productivity and*

*biogenic greenhouse gas fluxes, and phytotoxic effects on plants. Are these effects sufficiently addressed in light of the focus of this review on the other targeted effects and in terms of the available data to analyze them?*

The Panel appreciated improvements to the chapter on additional effects of N and S deposition. Notwithstanding specific editorial comments and questions, the Panel concluded that the sections on visibility and materials, sulfur and mercury methylation, $N_2O$ production, methane emissions, phytotoxic effects of gaseous NOx and SOx and productivity changes from N deposition had appropriate content and context for the REA. However, the discussion of N deposition effects on carbon cycle processes and carbon sequestration was found to be inconsistent with the available literature and EPA is requested to look at the specific comments provided by panel members correct the existing text.

*Synthesis of Case Studies (Chapter 7):*

The synthesis chapter provides a summary of the disparate case studies, but does not fully synthesize their results. The chapter also fails to provide the type of contextual information needed to extend these results to broader national scales. Rather than reiterating the case studies' summaries, the Panel suggests revising the chapter to better reflect the sum of the parts and possible linkages between them. Potential foci include developing common category labels (comparable levels of concern for the different environmental effects), exploring how ecosystem services might be used as a way to focus and contrast the different case studies, developing illustrative figures that integrate across case studies, and adding an uncertainty section that synthesizes the net sum of and implications of the multiple uncertainties rather than just listing the individual components. What are the key uncertainties which have the most important policy implications? The chapter should also include a section that identifies the major research and data gaps, including those that would allow spatial scaling of welfare effects and relationships between SOx, NOx and ecological structure and function.

1. *Here, the case study analyses are integrated and synthesized within the conceptual framework of ecosystem services as shown in Figure 7-2. Where possible, we have quantified select ecosystem services associated with the ecological effects targeted in this review. This chapter discusses adversity by characterizing the degree to which ecological effects are occurring under given levels of deposition to inform the discussion of adversity in the policy assessment and standard setting process. To what extent do you think the description of ecosystem services provides a useful framework in the case study analyses for informing standard setting? Does the Panel have suggestions for additional considerations or characterizations for ecosystem services relative to the case studies?*

The concepts of ecosystem services are useful to help explain the implications of the effects of N/S deposition on ecosystems for public welfare, and support the policy assessment of what standards are needed to prevent adverse welfare effects. Be careful to include a comprehensive description of ecosystem services and not be limited by those that are potentially quantified such as recreation activity. What is most important is a description of how the abundance and quality of ecosystem services are affected by the currently observed effects of N/S deposition on ecosystems.

2. *Based on the information presented in the current Risk and Exposure Assessment, given adequate time and resources, is there enough information to inform setting separate standards based on the other targeted ecological effects, specifically, terrestrial acidification, aquatic nutrient enrichment, and*

*terrestrial nutrient enrichment? If not, how can our understanding of these ecological effects be enhanced in time to inform the next 5-yr review?*

Based on the Panel's understanding of the Agency's court-ordered deadlines for completing this review, we have recommended a hybridized approach by which EPA can fulfill its obligations to the letter and intent of the law in setting an ecologically relevant secondary NAAQS. With adequate time and resources, the Panel finds the information in the current REA sufficient to inform setting separate standards for terrestrial acidification, eutrophication of western alpine lakes and terrestrial nutrient enrichment. However, the Panel believes that setting a standard for coastal nutrient enrichment would be difficult because of the substantial inputs of non-atmospheric sources of N to these systems. Further research on cause and effect relationships driven by acidification and excess nutrient enrichment will facilitate future rulemaking.