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Plan and Schedule for NAPAP's 1989 and 1990 Assessment Reports

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Plan and Schedule for NAPAP's 1989 and 1990 Assessment Reports

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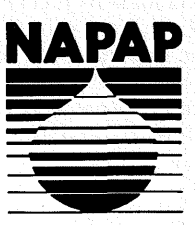

On the following pages is an excerpt from the Overview and Summary (Part 1) of the recently published 300-page National Acid Precipitation Assessment Program (NAPAP) document* that describes the planned activities of the Program for the next two years. This document has been made available for public review and an open meeting was held on November 17 in Washington, D.C. to receive comments on it. The Plan will be revised following consideration of these comments and published in January 1989.

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NAPAP was created by Congress in 1980 (Public Law 96-294) as a 10-year program designed to provide the nation with comprehensive scientific, technological, and economic information on the causes and effects of acidic deposition and on the effectiveness of various measures that might be adopted to mitigate the adverse effects. NAPAP has the responsibility to provide periodic reports and recommendations to the Congress and the President, based on the technical and economic analyses it has conducted and its critical review of other relevant studies.

NAPAP will conclude in 1990 with the publication and public review of a comprehensive Integrated Assessment on the causes and effects of acidic deposition, combined with analyses of the costs and effectiveness of various emission reduction strategies. NAPAP's 1989 and 1990 State-of-Science/Technology Reports and 1990 Integrated Assessment are intended to provide substantial documentation, guidance, and recommendations on the major issues related to acidic deposition, based on the full complement of available technical information. Although the activities of NAPAP will be completed on schedule in 1990, essential continuing analysis on acidic deposition issues is expected to be pursued in the appropriate federal agencies beyond 1990. At a minimum, the continuing work will likely include trends monitoring, long-term effects research, further studies of cause-effect relationships, and analyses of control program effectiveness.

Purpose of the Plan: Communication among Preparers and Users of the Assessment Information

The Plan is intended to be a major element in the technical dialogue that is essential for the preparation of a useful integrated assessment of acidic deposition causes, effects, and control measures. The necessary dialogue is both internal (within NAPAP) and external (between NAPAP and potential users of the Assessment). Acidic deposition issues involve significant complexity and uncertainty. To be of maximum benefit in resolving such issues, the Integrated Assessment must be based on a framework well understood by all of its preparers and users.

The expected users of the NAPAP Integrated Assessment include the President, members of Congress and their staff; policy, technical, and regulatory officials of the Executive Branch; representatives of state and local government units; representatives of provincial and federal government units in Canada; representatives of environmental, health, and other public-interest groups; representatives of industry, utility, coal, and economic development organizations; representatives of labor organizations; representatives of control technology developers and vendors; interested scientists and engineers; and interested representatives of international organizations and other government units.

Plan Update: Details of Future Scenario Cases

NAPAP's assessment methodology, which is the general subject of Part 3 of this document, incorporates a comparative approach for evaluating future scenarios. The number of plausible scenarios that might be evaluated is prohibitively large to allow comprehensive treatment. NAPAP is currently developing specifications of illustrative scenarios for evaluation in the Integrated Assessment. The illustrative scenarios will conform to the three key guidelines below.

- The scenarios will be based on plausible combinations of controls.
- The scenarios will reflect the range of controls commonly discussed in the national debate about acidic deposition. NAPAP, however, will not analyze specific legislative or other public proposals. NAPAP data and methods will be available for specialized analyses by other investigators.

* *Plan and Schedule for NAPAP Assessment Reports, 1989–1990.* State of Science, State of Technology, Integrated Assessment. Public Review Draft, October 1988. National Acid Precipitation Assessment Program. Office of the Director, 722 Jackson Place, NW, Washington, D.C.

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- The scenarios will be selected to address a wide range of situations in order to allow adequate briefing relating to questions such as, "How much difference (in control costs, effects patterns, etc.) does it make to adopt one strategy as opposed to another?"

NAPAP plans to report on the specification of illustrative scenarios for analysis in the Integrated Assessment in an "Assessment Plan Update" document to be published in July 1989.

Approach for the Assessment

NAPAP's assessment will be developed in two principal parts: (1) State-of-Science/Technology (SOS/T) Reports—comprehensive analyses and discussions of relevant technical information prepared for specialist readers, and (2) the Integrated Assessment—a structured compilation of policy-relevant technical information presented in a form suitable to assist policymakers and the public in evaluating the key questions concerning acidic deposition causes, effects, and control strategies (see Figure 1).

State of Science/Technology

The SOS/T Reports are intended to provide a comprehensive statement of the technical information concerning acidic deposition available from all sources, i.e., both NAPAP-sponsored studies and all other relevant studies reported in the technical literature. These surveys will be subjected to several levels of review: interagency review by the NAPAP

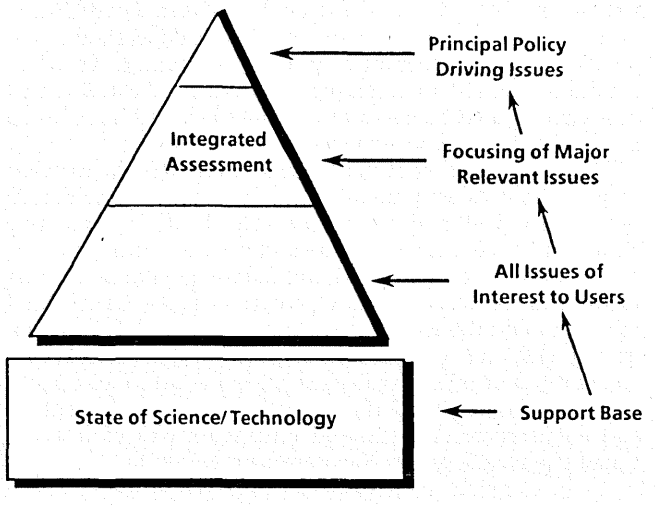

Figure 1. Schematic illustration of the relationship between the State-of-Science/Technology Reports and the Integrated Assessment.

cooperating agencies, peer review by independent scientists, and open review by all interested persons at an international meeting convened specifically to evaluate the Reports. Following the extensive review, the SOS/T Reports will be published in final form in 1990, and, combined with the updated Assessment Plan, will be used as the basis for the technical findings, analysis methods, and projection and comparison methodologies that are the key elements of the Integrated Assessment. The emphasis on full reporting and extensive external review of the SOS/T Reports is intended to ensure that the Integrated Assessment is based on the broadest available, fully reviewed technical information. Also, a lay summary of each of the SOS/T Reports will be prepared (with scientific and public review), to ensure that the principal information is available to a wider audience of interested readers. The summary will also be a resource for scholastic and public educational programs dealing with acidic deposition issues.

Currently, 27 Reports, prepared by approximately 100 specialist authors, are planned to provide a survey of all the pertinent SOS/T areas. The scope of the documents will include (1) emissions, transport, transformation, air concentrations, and deposition of acidic and associated pollutants; (2) effects of acidic deposition and associated pollutants in all principal areas of concern (surface waters, forests, agricultural crops, exposed materials, human health and visibility in the atmosphere); and (3) economic and technological evaluation of control and mitigation measures, and economic evaluation methods relevant to acidic deposition effects.

Integrated Assessment

The Integrated Assessment is intended to translate scientific information, with its associated uncertainties, into results that can be used to address relevant questions for the policymaking audience. The Integrated Assessment will aid public officials and other interested individuals by focusing the scientific and technological information on the principal issues of concern, and by interpreting the importance of the available technical information. The Integrated Assessment will be structured around five key questions that address both present knowledge (Questions I and II) and future projections (Questions III, IV, and V).

Present Knowledge

- Question I: What are the effects of concern, and what is the relationship between current levels of acidic deposition/air pollutant concentrations and these effects?
- Question II: What is the relationship between emissions of the precursor pollutants and acidic deposition/air pollutant concentrations currently observed in North America?

Future Projections

- Question III: What does available technical information indicate about the sensitivity to change for the relationship between (a) emissions and future conditions related to economic, energy, and technological developments; (b) control costs and changes in emission levels; (c) emissions levels and resulting deposition/air concentration levels; and (d) air concentration/deposition levels and effects?
- Question IV: What are the estimates of future conditions (emissions, costs, deposition, and effects) with and without additional emissions reduction strategies?
- Question V: What differences emerge from comparative evaluations of future scenarios?

Guiding Principles and Scope for the Assessment

NAPAP plans to complete its assessment activities within the 10-year Congressionally mandated period, resulting in publication of its Integrated Assessment in September 1990. NAPAP will receive comments after publication of the Integrated Assessment, and will conclude all program activity with a document summarizing and responding to issues raised in the public response to the Assessment. Publication of this supplementary document is scheduled for December 1990.

During the next two years, NAPAP will conduct several parallel activities: (1) completion and documentation of its program of sponsored research; (2) production and review of the extensive series of State-of-Science/Technology Reports; and (3) completion of assessment analyses, involving scientific, technological, and economic evaluations. The principal dates for these NAPAP activities are scheduled as follows:

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NAPAP's 1990 Integrated Assessment is intended to provide users with comprehensive scientific, technological, and economic information on the causes and effects of acidic deposition, and on the effectiveness of various illustrative control measures in mitigating the adverse effects. NAPAP has the responsibility to provide users with objective, broadly reviewed data and analyses, which can serve as a basis for policy considerations. The Assessment will not make "public value" recommendations (such as "What is the desirable trade-off between employment in the coal mining sector vs. a targeted reduction in deposition levels in New England?"), although it will provide the technical information and analyses that help illuminate such public value decisions. NAPAP's assessment methodology is intended to facilitate the development of useful information for a wide range of state-regional- and national-level policy questions.

NAPAP has adopted several operating principles for the development of the Integrated Assessment.

- Based on SOS/T Reports—The SOS/T Reports are intended to cover the technical basis for the Assessment. This ensures that the technical information used in the Assessment will be extensively peer reviewed, and available to all users of the Assessment.
- Based on responses to structured questions—The Assessment will be developed in the form of responses to a specific set of questions, allowing the users of the Assessment to review the questions being posed and to suggest other formulations if needed.
- Prioritized summaries of findings—To ensure comprehensive analysis, the Assessment will involve responses to several hundred questions. It is important, however, that key findings and recommendations do not become "lost" in the detail. Therefore, the Assessment results will be reported in a prioritized format, which will allow suitable focus on the most significant questions and issues.
- Explicit treatment of scientific confidence level—Unavoidable scientific uncertainty precludes complete resolution of many key cause-effect issues. Although NAPAP-sponsored and other research has greatly improved understanding of many acidic deposition issues in recent years, uncertainties will remain in 1990. The Assessment will explicitly report NAPAP's best estimate of the level of confidence associated with various statements (ranging from characterizations such as "unsupported hypothesis" to "generally supported by data, generally agreed among investigators"). Reporting of scientific confidence level, after extensive peer review, will aid policy officials in assigning weight to various statements in the Assessment.
- Avoidance of oversimplification—Because of the complexities involved, there is a tendency to develop assessments of acidic deposition causes, effects, and controls in the form of simplified, parameterized analyses. NAPAP has adopted an approach that excludes oversimplified dose-response relationships and integration methods. This approach precludes development of an assessment that can express results in the form of a few key parameters. NAPAP's assessment, based on evaluation of changes in control costs and effects patterns compared to a reference case, will require more complicated interpretation, but will better reflect available observational data.
- Three-part analysis of benefits—NAPAP's authorizing statute requires economic analysis of benefits, as well as control costs. NAPAP will fully review economic analysis methods for valuing environmental benefits in the appropriate SOS/T Reports. In the Assessment, however, NAPAP will not report all benefit valuations in economic form. Instead, three general categories of benefits will be reported: (1) health-related; (2) economically denominated (i.e., those for which agreed economic analysis methodology is available); and (3) conservation-related (including important resource conservation categories for which acceptable economic valuation methods are not generally agreed).
- Assessment based on comparisons to a future reference case—Most of the technical data and projection models available for use in the NAPAP Assessment (e.g., air quality models, aquatic system response models) are better suited to comparative evaluation than to absolute value projections. Thus, a comparative approach allows significantly improved confidence in the Assessment findings, relative to absolute projections. Moreover, most of the relevant policy questions also are comparative. For example, "Given current deposition levels measured in the Adirondack region, what deposition levels would be expected if SO_2 emissions were reduced by 25% in the 31 eastern states?"

Linkage of NAPAP to Other Assessment Issues

A broad view of environmental systems is needed in order to understand and predict the consequences of human activities. Natural and human-caused environmental stresses act together in affecting human health and ecosystems, and it is impossible to understand the effects of one stress independent of others. While concern about acidic deposition continues to be high, the continued nonattainment of the National Ambient Air Quality Standard for ozone in many regions throughout the United States requires the continued development of additional emissions controls, regardless of acidic deposition questions. Other environmental protection issues, including global climate change, multi-media waste management, and control of toxic substances in the environment, also require continuing assessment.

NAPAP is required by statute to focus its Assessment on acidic deposition issues. Therefore, NAPAP will limit its comments on most other environmental issues to summaries of the principal relationships among NAPAP's findings regarding acidic deposition questions (causes, effects, and controls) and the key elements of the other environmental issues.

Tropospheric ozone is a special case. NAPAP will not develop recommendations regarding strategies for attaining the ozone standard. However, oxidant and acidic species are linked in all three aspects of the cause-effect system: (1) emission source patterns and control requirements (some controls are complementary, some can be competitive); (2) atmospheric chemistry (oxidant species participate in the formation of aerosols); and (3) effects (ozone is a primary stress factor for some forest and crop species, while acidic species are suspected secondary or interacting stresses). While the Assessment will not analyze ozone attainment strategies, it will identify situations in which sulfur and nitrogen oxide control options should be evaluated for interaction (both positive and negative) with ozone attainment strategies.

Beyond NAPAP

NAPAP's Assessment findings are intended to provide technical information for policy officials and other individuals interested in evaluating control strategies for acidic deposition. In addition to this primary purpose, the NAPAP Assessment process should provide a useful basis for future assessment activities in several manners.

- Future analyses of specific control and mitigation strategies—The NAPAP analysis methodologies and data bases (including updates) can be used for evaluating specific approaches that may be under consideration. Similarly, the NAPAP Assessment will be a basis for future evaluation of the effectiveness of strategies actually adopted.

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- Specification of future studies—The NAPAP Assessment process will provide guidance on the need for continued trends monitoring and specialized studies of acidic deposition and other environmental concerns beyond 1990.
- Example for assessment of other major environmental issues—The NAPAP Assessment will have the broadest scope of any analysis of a major environmental issue undertaken to date. When complete, the NAPAP process will provide an example to guide the development of future assessments. Elements of the NAPAP process suitable for future issues include (1) problems involving long-term, complex processes, (2) multi-disciplinary and multi-agency perspectives and operation, (3) development of a specific assessment framework and plan, (4) significant involvement of the Assessment user communities in review and comment on the Plan for the Assessment, and (5) separation of the analysis into peer-reviewed technical reports and structured assessment questions based on the technical reports.

Scope of the State-of-Science/Technology Reports

The 27 review Reports that are currently planned will summarize and critically evaluate all the scientific and technical information available in each relevant discipline. Titles, detailed outlines, and authors nominated for these Reports are presented in Part 2 of the Plan. Guidelines for authors, including a description of the review process and international meeting, are also presented in the Plan. The following section provides a brief summary of the purpose and emphasis for the SOS/T Reports within each discipline.

Major Scientific and Technological Areas for State-of-Science/Technology Reviews

- Emissions: The first SOS/T Report will describe the sources, magnitudes, and spatial/temporal patterns of emissions contributing to acidic deposition and involved in acidic deposition formation processes.
- Atmospheric Processes: Extensive efforts have been made both within and outside NAPAP to observe and to model individual atmospheric processes that affect acidic deposition. The second SOS/T Report will describe the mechanistic and chemical processes of the atmosphere pertinent to the formation and deposition of acidic species, oxidants, and aerosols, and will present approaches for modeling these processes. The third Report will describe how the information presented in SOS/T Report 2 is represented in the current science of regional deposition and air concentration modeling. The Report will show how regional atmospheric models form a hierarchy with a range of applications. This Report will also discuss procedures for aggregating episodic model output to produce long-term average deposition and air quality information of relevance to the effects analyses. The fourth report will provide a comprehensive description of the Regional Acid Deposition Model (RADM). The purpose of RADM and its attendant aggregation scheme is to provide the estimates of current and future deposition and air concentration patterns. The fifth report will present a summary of evaluation and intercomparison studies for regional acidic deposition and air concentration models. A particular focus of this report will be the program designed to provide field data for evaluation of regional models, such as RADM. Evaluation results will be presented, including the interim evaluation of RADM and the sulfur-only Engineering Model.
- Deposition and Air Quality Monitoring: SOS/T Reports 6 and 7 will describe and analyze the data available from wet and dry deposition and air quality monitoring programs. Data from programs designed for research purposes, long-term trends monitoring, and geographic analysis will be included, along with advances in quality assurance and data base management.
- Source-Receptor Relationships: Report 8 will consolidate the information contained in the emissions, atmospheric processes, and deposition and air quality monitoring reports to present our current understanding of source-receptor linkages. Associations between historical and current emissions and observed deposition and air quality patterns will be described at three levels: (1) descriptive (such as through the use of maps and charts), whereby spatial and temporal emissions data will be compared against spatial and temporal deposition data; (2) statistical (such as through use of regression and trend analysis); and (3) model-based (such as through use of linear and Eulerian model formulations), whereby deposition and air concentration patterns and trends are linked to emissions patterns and trends through simulation of atmospheric processes.
- Aquatic Effects: This series of seven reports (9–15) will summarize our current understanding of the processes that affect surface water chemistry and biology. The Reports will describe current patterns of surface water acidity and report on historical changes in surface waters. Methods for forecasting changes in surface water chemistry will also be discussed. The relationship between surface water chemistry and organism distribution, abundance, and physiology will be described as will mitigation methods.
- Terrestrial Effects: Three State-of-Science Reports will evaluate terrestrial effects. Two reports (16, 17) will discuss the forest and agricultural crop resources in the United States. They will examine factors that influence forest and crop health and productivity, forming the basis for interpreting the influences from air pollutants that will be presented in the third report. Methods of extending interpretation of experimental results to estimate pollutant impacts on growth, production, and management will also be discussed. The third report (18) will discuss the theoretical basis for air pollution effects on plants, experimental results, and our level of understanding regarding the mechanisms of plant response to pollutant exposure.
- Materials Effects: The current state of knowledge regarding the incremental effects of acidic deposition to the degradation of metals, carbonate stone, paint, and other finishing systems will be reviewed in SOS/T Report 19. Patterns of urban deposition to structures will be discussed in SOS/T Report 20. Methodologies for preparing inventories of cultural and construction materials exposed to acidic deposition for the assessment of materials damage will be discussed in Report 21, along with a review of the available data bases.
- Human Health Effects: Scientific issues related to both direct and indirect health effects of air pollutants associated with acidic deposition precursors will be discussed in separate SOS/T Reports. SOS/T Report 22 on direct health effects will examine the effects of particulate matter, sulfur dioxide, acidic aerosols, ozone, and nitrogen dioxide. It will include a presentation of ambient exposures and deposition of the pollutants in the lungs, but the focus will be on health effects and concentrations/times of exposures that cause these effects. Factors that affect susceptibility to these pollutants, such as exercise and pre-existing disease, will also be discussed. Report 23 on indirect health effects of acidic deposition will discuss how acidic deposition can influence exposure of humans to pollutants through mechanisms such as acidity-dependent leaching of pollutants in some drinking water systems and food-chain accumulation of pollutants. Susceptibility factors will also be discussed. Giv-

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en the nature of the data base, this Report will focus on lead, mercury, and asbestos; however, other relevant metals such as cadmium, arsenic, aluminum, copper, and zinc will also be reviewed.

- Visibility Effects: This report will present a thorough review of aerosol impacts on atmospheric visibility. The document will decribe pertinent theory, results of controlled experiments, and analysis of ambient observations. To the degree possible, the chain of relationships between emission sources, pollutant concentrations, and perceived visibility will be discussed.
- Control Measures: SOS/T Report 25 will discuss the performance, costs, and applicability of available and emerging technologies and other techniques for emissions reduction. SOS/T Report 26 will describe models for projecting future emissions and estimating control costs and will represent results of selected sensitivity runs of those models.
- Economic Evaluations: SOS/T Report 27 will be divided into two sections. The first section will provide a general review of the methods used to estimate the economic values associated with environmental changes. The second section will focus on models, methods, and issues specific to valuing acidic deposition effects.

Scope of the Integrated Assessment

The Integrated Assessment will structure the scientific information from the SOS/T Reports to focus on the principal policy-driving issues. These issues will be raised in a series of questions organized into five principal categories that will be addressed in the Assessment. The approach, assumptions, information sources, and uncertainties associated with answering these questions are described in Part 3 of the Plan. The guidelines for contributors to the Integrated Assessment, including a description of the review process and the protocol for evaluating the confidence level of the answers, are also provided in the Plan. The Integrated Assessment will be developed by the same technical specialists who have been involved in the production of the Plan and by the authors of the SOS/T Reports. The purpose, approach, and major focus for each of the five principal questions to be addressed in the Assessment are described below.

Question I: What are the Effects of Concern and What is the Relationship Between Acidic Deposition/Air Pollutant Concentrations and these Effects?

Purpose and Approach

The basis for concern about acidic deposition is its possible effects. Thus, the Integrated Assessment will begin with a summary of the effects that have been hypothesized and an evaluation of the role of acidic deposition and associated pollutants in causing the effects currently observed. The evaluation will be conducted in a sequence of steps, beginning with a description of the current status and rate of change for aquatic resources, forest health, crop production, materials resources, human health, and visibility. The approach, assumptions, and information sources that will be used to provide this information for each effects category are given in Part 3 of the Plan. The predicted level of confidence in the information is also provided.

The important hypotheses that relate the effects of concern to acidic deposition and associated pollutants are then listed along with an estimated confidence level for the information available to test each hypothesis.

The approach, assumption, and information available to test each hypothesis are grouped into categories of evidence from exposure-response studies and evidence from correlative studies (such as epidemiological studies). These two categories of evidence are then integrated and assessed along with information on the role of other stress factors to determine the cause(s) of the effects of concern. A well-established cause-and-effect relationship can be developed only when there is a strong pattern of consistency and responsiveness, and a proven biological mechanism between observed effects and the suspected causal factor. The answers to this question are meant to systematically document the determination of causality for the effects of concern.

Major Focus

- Aquatics: This section will focus on describing existing patterns of surface water chemistry in sensitive regions of the United States and the status of fish populations associated with these lakes and streams. Hypotheses regarding the factors that may have contributed to these patterns will be evaluated on a regional basis.
- Forests: Concern about trees and forests results from the possibility that acidic deposition and associated pollutants may result in leaching of nutrients from leaves, leaching of nutrients from soil, reduction of photosynthesis, alteration of growth characteristics, damage to leaf tissues, defoliation, reduction of long-term soil productivity, and interaction with other stresses that generally affect tree health. This section will focus on these effects and their causes.
- Crops: There is concern that agricultural losses through decreased crop production and increased management demands will occur because of acidic deposition, its precursors (SO_2 and NO_x), and associated pollutants (O_3). The role that these pollutants have in causing crop yield losses and changes in soil fertility and damage from pests will be evaluated.
- Materials: The types of changes in materials caused by natural weathering processes and the concomitant effects of pollutants will be described in the form of dose-response functions. The dose-response functions are based on theoretical models and controlled laboratory exposure experiments for galvanized steel and carbonate stone. Correlative field observations will be used in the analysis.
- Human Health: For each of the major pollutants of interest for direct and indirect health effects that are regulated by national human health standards, the focus will be on the types of health effects observed and population exposures to levels above those standards. For chemicals of interest not having existing standards, such as acidic aerosols and asbestos in water, available information on quantitative exposure-response relationships will be analyzed.
- Visibility: This section will relate the air pollutants associated with acidic deposition (sulfates and nitrates) to visibility impairment. The primary purpose of this section is to estimate the fraction of present total visibility degradation that is caused by acidic deposition-related pollutants for each region of the country.

Question II: What Is the Relationship Between Acidic Deposition, Air Quality, and Emissions?

Purpose and Approach

Question II is meant to explain deposition and air concentration patterns and the linkage between emissions sources and deposition.

The first part of Question II will relate to the current status of deposition and air quality relevant to the effects discussed in Question I, and will rely on current measurements of deposition and air pollutant concentrations and on surrogates for deposition data to provide a historical perspective of long-term trends. Since historical deposition

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data are lacking, long-term emissions and visibility trends can be used to infer historical deposition trends. The second part of Question II will relate to source-receptor linkages, based on knowledge derived from observations and models. The third part of Question II will provide information on our current ability to detect changes in deposition and air quality that may result from future changes in emissions.

Major Focus

Question II is to provide an account of the current understanding of source-receptor linkages and how they can be used for estimating changes in deposition when emissions change, and to what extent nonlinear processes in the atmosphere influence these linkages.

Background information to answer questions on source-receptor linkages will be provided in SOS/T Report 8, and information on the ability to detect change in emissions-deposition relationships will be presented in SOS/T Reports 6 and 7.

Question III: What Is the Sensitivity to Change?

Purpose and Approach

The ability to estimate future impacts is an important aspect of environmental assessment. In order to evaluate the potential for future changes, a general methodology must be available for examining a wide range of relevant factors. For acidic deposition, this methodology involves the use of models and other methods to describe functional relationships. Three major categories of models to be used in this Assessment are (1) emissions projection, (2) source-receptor, and (3) dose-response. These models range from very simple empirical relationships to integrated series of functions.

The answers to Question III will describe the sensitivity in model output to incremental changes over a wide range of the input factors. This analysis will also evaluate the relative importance of key input parameters. This question is intended to provide the transition between the current state of knowledge, as summarized in Questions I and II, and future projections, as summarized in Questions IV and V.

Sensitivity to change will be evaluated for four areas: (1) emissions, using different assumptions for future conditions; (2) control costs, with emissions changes for a selected set of emission-reduction strategies; (3) deposition/air quality, with incremental emissions changes; and (4) effects, with incremental deposition/air quality changes. For the purposes of this question, effects sensitivity will not be linked directly to the sensitivity analyses for emissions and deposition/air concentrations. This linkage will be developed in the answers to Questions IV and V.

The approach to be used to analyze the sensitivity of emissions, control costs, acidic deposition and air pollution concentrations, and effects, is discussed below.

- Emissions: NAPAP has developed an integrated set of models to project future emissions and costs of emissions control. This set includes "sector" models, each dealing with a particular type of emissions source—electric utilities, industrial boilers, industrial processes, industrial volatile organic compound sources, residential/commercial sources, and transportation. Although the sector models vary in their degree of complexity, they are all sensitive to some extent to input assumptions, such as future economic and energy growth, new technology penetration, changes over time in the population of sources, and others. In addition, the model set includes modules that connect the sector models to ensure consistency across sectors and to allow interrelationships among sectors to be explicitly considered. Emissions sensitivity will be analyzed by exercising this integrated model set. Two methods of examining sensitivity will be employed. First, the sensitivity of emissions changes projected by each sector model will be examined by individually varying certain important assumptions, while keeping the other inputs constant. Second, emissions from all sectors will be projected for several future scenarios, to show possible future ranges of total emissions. The scenarios will represent reasonable combinations of the important factors affecting future emissions. These scenarios will be run using the entire model set in a fully integrated manner, so that the emission projections reflect a consistent set of conditions, in equilibrium.
- Control Costs: Control costs will be examined through use of the NAPAP integrated model set. A series of illustrative scenarios will be developed that reflects a wide range of future emission control options more stringent than those required under current legislation. Costs of these representative emission reduction strategies will be assessed by executing the model set. Secondary effects associated with the scenarios (e.g., effects on fuel prices, GNP, employment) will be explicitly modeled. These control scenarios will be comparatively analyzed against the scenarios in which no additional acidic deposition control initiatives have been assumed, so that ranges of incremental costs for various levels of emission reduction can be obtained.
- Deposition/Air Concentrations: Current understanding of the potential change in deposition and air concentrations that might be expected when emissions change will be evaluated. Regional-scale models that represent atmospheric processes will be used in the analysis. To understand how deposition and air concentrations might change when both sulfur and nitrogen emissions change, results from Regional Acid Deposition Model (RADM) runs will be examined. The RADM Engineering Model will be used to estimate the changes in deposition resulting from changes in sulfur emissions alone. As knowledge is gained on deposition and air concentration changes using representative emission changes in the atmospheric models, a subset of emissions scenarios for further analysis will be developed. This iterative approach maximizes resource use for atmospheric model runs (such as RADM) that will be applied to the illustrative control scenarios developed for Question IV.
- Effects: Models that describe functional relationships between specific pollutants and specific effects of concern will be used to evaluate effects sensitivity. All major effects linked to acidic deposition and associated pollutants, as assessed in Question I, will be evaluated. The level of confidence associated with each model output will be described. Where quantitative models do not exist for a particular effect, quantitative sensitivity analyses will not be possible. However, if the available information is adequate to support qualitative assessment, this will be done with a full discussion of the associated uncertainties.

Major Focus

- Emissions: Projections of emissions over time (to the year 2030) will be generated based on sensitivity runs of the individual sector models. In addition, ranges of plausible future emissions for all sectors combined will be presented.
- Control Costs: Emissions reductions that are achievable and the associated direct and indirect costs of various control scenarios will be assessed. Thus, cost effectiveness, in terms of incremental costs per unit emission reduction, will be evaluated.
- Atmospheric Processes: This section will focus on the sensitivity of deposition and air concentration levels and patterns to changes in emissions, assuming all levels of

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other variables affecting source-receptor relationships remain constant. The choice of models for analysis depends in part on whether only sulfur emissions or sulfur, nitrogen and VOC emissions change. The RADM Engineering Model can be used for the former; the full RADM or an equivalent model based on first principles is required for the latter.

- Aquatics: This section will compare model forecasts of future surface water chemistry and biological changes associated with alternative deposition scenarios. Fifty-year forecasts will be presented for regional populations of surface waters (in 10-year increments to 2035). Comparisons of forecasted surface water chemistry and biological status among the deposition levels evaluated will illustrate the sensitivity to changes within the aquatic resources.
- Forests: This section will evaluate responses of trees to different deposition and pollutant concentration levels. Quantitative analyses will be based on the results of controlled exposure experiments presented in the SOS/T Reports. Quantitative descriptions of the exposure-response relationships will be available for several eastern and western tree species. Most results will be from experiments on seedlings and saplings conducted over periods of two to four years. Limited results will be available from exposure experiments on parts of mature trees. Where data are insufficient to enable quantitative analyses, tree response to different levels of pollutants will be described qualitatively.
- Agricultural Crops: Changes in crop production and crop management practices will be evaluated to assess the sensitivity of agricultural crops to changes in deposition and air pollutant concentrations. Response functions that predict crop yield and soil fertility on the basis of rain chemistry and the concentrations of pollutant gases in the air will be used to estimate changes in crop production and management.
- Materials: Estimates of the current rate of change of galvanized steel and carbonate stone due to both natural and pollutant-affected processes will be estimated for selected urban areas based on meteorological, air quality, and rain chemistry data and the dose-response functions. Ambient environmental conditions for the areas selected are based on model output and air quality monitoring data. Future rates of change are predicted for specified changes in deposition rates. The consequences of materials changes are estimated for galvanized steel used in construction, and for the preservation of bronze and carbonate stone monuments and historic stone buildings.
- Visibility: This section will assess the sensitivity of visibility to specific changes in sulfate and nitrate levels. A visibility index (proportional to perceived changes in visibility and developed from the information in the SOS/T Reports) will be the primary indicator of visibility change. Computer-generated photographs will be included to aid the reader in understanding the visibility index. Results will be displayed on maps using visibility index contours and in tables summarized by geographic region.
- Human Health: The discussion will have two primary components: exposure sensitivity analyses and health sensitivity analyses. Of necessity, considering the state-of-the-art, the presentation will focus on the uncertainty involved in both classes of analyses. In the limited cases where possible, the relationship between changes in exposure and changes in health effects will be evaluated. The focus will be on acidic aerosols, particulate matter, sulfur dioxide, ozone, (for direct effects) and lead and asbestos (for indirect effects). The uncertainties are relatively great, effectively precluding most quantitative analyses.
- Mitigation Options: This section will describe how effects may change through the use of various mitigation options that involve treatment of the receptor (e.g. liming). Possible mitigation methods for aquatic, terrestrial, and materials effects will be described. The advantages, possible undesirable effects, and costs for each method will be evaluated.
- Economics: The economics section will include quantitative estimates of economic values for effects changes that meet several criteria. First, it must be possible to estimate or aggregate the physical effects in a way that is useful for the economic analysis. Second, the economic method must be sufficiently well developed and the associated uncertainties understood. Third, there will be an emphasis on quantifying the value of what are likely to be the largest economic effects. (Information on the larger effects is more useful in comparing and contrasting the illustrative emission reduction strategies in Question V.) Specific areas in which quantitative analysis is unlikely include non-user values and the valuation of pain and suffering associated with health effects. NAPAP is monitoring ongoing research on visibility and will report plans to include quantitative economic values for this area in its July 1989 Plan update.

Question IV: What Are the Estimates of Future Conditions?

Purpose and Approach

A two-part answer to this question will be provided: (1) estimates of future conditions without changes in current policy and legislation directed at acidic deposition control, and (2) estimates of future conditions with illustrative emission reduction strategies for SO_2 and NO_x.

The importance of a possible environmental stress can be assessed by projecting the future influence of that stress and by evaluating the future conditions if that stress is reduced. Answers to this question will provide the basis to compare outcomes among control strategies addressed in Question V. An evaluation of changes in effects expected to result from a wide range of scenarios will allow focus on the more effective sets of options. This evaluation will also include calculations of costs for each control option. The models used in the sensitivity analyses for Question III will be linked together to project future changes in effects for Question IV. While the output of these linked models may not have a high level of confidence in absolute terms, comparative analyses based on changes from reference cases will generally allow higher confidence levels.

The inherently uncertain nature of future conditions will cause the answers developed for Question IV of the Assessment to have a lower level of confidence than those developed for Questions I and II, which rely directly on current measurements. The uncertainties about future conditions are different from the uncertainties encountered for Questions I and II; in most cases they can only be resolved over time, rather than by more research. Because of these uncertainties, many assumptions affecting future scenarios that will be used to answer Question IV will be based on conditions that remain constant over time (e.g., land use patterns, natural emissions, tree populations in forests). For comparative purposes, though, the answers to Question IV should allow a reasonable level of confidence in evaluating future conditions.

Major Focus

- Emissions, Controls and Mitigation: Emissions will be projected, as previously described for Question III, for a range of alternative future scenarios and for selected illustrative SO_2 and NO_x reduction scenarios. Direct and

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indirect costs for the illustrative emissions reduction scenarios and mitigation options will be estimated using the NAPAP emissions model set. A few selected future emissions conditions cases will be chosen for analyses with RADM. The cases will be chosen to represent a wide range of possible future emission patterns and control costs. Costs and effects of mitigation options will also be evaluated.

Deposition and Air Concentrations: Deposition and air concentration estimates will be developed from atmospheric models, using estimates of future emissions conditions as input. RADM will be used for those situations in which SO_2, NO_x, and VOC emissions changes are projected. Episodic runs of RADM will be aggregated to produce estimates of annual averages of deposition and air quality. For emissions projections involving changes in sulfur only, RADM Engineering Model runs, aggregated to produce estimates of annual average deposition and air quality, will be used. The future estimates will be presented as changes in deposition/air concentrations relative to deposition/air concentrations in 1985, estimated using the 1985 NAPAP Emissions Inventory. For emissions scenarios, estimates will be presented as changes in deposition relative to scenarios in which no additional acidic deposition control has been assumed.

- Effects: Three major sources of information will be used to answer Question IV on future status of aquatic resources, forests, crops, materials, visibility, and human health; (1) deposition/air quality projections based on atmospheric models using future emissions forecasts as input; (2) natural trends in the status of receptors, when available; and (3) models, algorithms (e.g., exposure-response functions), or standards to relate deposition/air quality to effects. Effects will be categorized according to health, conservation, and economic parameters and prioritized within each of the categories. For most effects, interpolations of data from the sensitivity analyses performed for Question III will provide the basis for estimating the future status of receptors as related to projected deposition/air concentration levels. Where possible, natural trends in the status of receptors over time will provide the base for calculating changes resulting from deposition/air quality. For example, within the next 40 years, significant changes in the age distribution of the human population in the United States will occur. If this change is reflected in the estimates of future impacts on human health from acidic deposition and associated pollutants, the estimates of effects will be improved. In many cases, quantitative forecasts of changes in baseline conditions will reflect increased uncertainty because of influences not directly considered in the analysis (for example, changes in emissions patterns and crop-growing regions resulting from global climate changes). The influence of such adjustments on baseline conditions could significantly affect the outcome of predictive models. Where possible, qualitative statements regarding the impacts of major assumptions on the predictions will be incorporated in the analysis.

Question V: What Differences Emerge from Comparative Evaluations of Future Scenarios?

The objective of Question V is to compare and contrast the results of various projections of future conditions with and without additional future acidic deposition control and mitigation measures. This comparison will be performed by answering a set of policy-relevant questions regarding the need for additional controls, the costs and effectiveness of various levels of control and mitigation, the timing of implementing such measures, and the environmental changes that are expected to result. This information will help define further analyses of key issues. As previously discussed, NAPAP will not develop recommendations regarding optimal control strategies, nor will the analysis be aggregated into a comprehensive benefit-cost framework.

Examples of questions include the following:

- What future trends in emissions and effects, compared to current conditions, are possible if current Clean Air Act authorities are not changed?
- Given the geographic regions of concern for all effects areas, is it most effective to implement a control scenario uniformly for all 31 eastern states or are other scenarios more effective?
- Is the rate of natural resource change sufficiently slow to warrant delaying implementation to await commercialization of new, lower-emitting or possibly more cost-effective technology rather than relying on existing retrofit technology?

A more comprehensive list of questions selected for analysis will be reported in the July 1989 Plan update.

The answers to these questions will be based on quantitative answers from Question IV, as well as information from the SOS/T Reports and other Integrated Assessment questions. In many cases, the answers to Question IV will not provide complete information on the results of the strategies. For example, it is unlikely that effects information will be complete for many of the strategies. In these cases, comparisons among strategies will be made using deposition level and control cost information.

Information on effect changes will be categorized according to health effects, conservation effects, and economic effects. Health effect changes are considered separately because of their general importance and their prominence within regulatory statutes. Conservation effects are related to maintaining or preserving the natural or cultural environment. Economic effects include those that can be expressed in economic terms, by generally agreed methodologies.

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