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Report to the Chairman, Subcommittee on Oversight and Investigations, Committee on Energy and Commerce, House of Representatives

December 1985

ACID RAIN

Federal Research Into Effects on Waters and Forests

GAO/RCED-86-7

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GAO

United States
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Resources, Community, and
Economic Development Division

B-220896

December 17, 1985

The Honorable John D. Dingell
Chairman, Subcommittee on
Oversight and Investigations
Committee on Energy and Commerce
House of Representatives

Dear Mr. Chairman:

As requested in your January 30, 1984, letter, and subsequent discussions with your office, this report discusses the status and future direction of the National Acid Precipitation Assessment Program's research to determine acid deposition's effects on our lakes, streams, and forests. This report also provides information on the funding supporting the national program's research effort.

Unless you publicly release its contents earlier, we will make this report available to other interested parties 30 days after the issue date. At that time copies of the report will be sent to appropriate congressional committees; the Administrators of the Environmental Protection Agency and the National Oceanic and Atmospheric Administration; the Secretaries of Agriculture, Energy, and the Interior; the Director, Office of Management and Budget; and the Executive Director, National Acid Precipitation Assessment Program.

Sincerely yours,

J. Dexter Peach
Director

Executive Summary

Acidic lakes and dying forests have raised concern about the role acid deposition has in present and future environmental damage. In response to this concern, the Congress directed that a multi-agency research program be undertaken to study its causes and effects.

At the request of the Chairman, Subcommittee on Oversight and Investigations, House Committee on Energy and Commerce, GAO developed information on

- the status and results of federal research to determine acid deposition's effects on our lakes, streams, other aquatic resources, and forests and
- funding provided for federal acid deposition research.

Background

Acid deposition, commonly referred to as "acid rain," is formed when sulfur dioxide and nitrogen oxides emitted by coal-fueled power plants, motor vehicles, and other man-made or natural sources enter the atmosphere and return to the earth as acid compounds in rain, snow, or gases. (See p. 8.)

Concern over acid deposition and the need for better scientific information on its causes and effects prompted the Congress to enact the Acid Precipitation Act of 1980. The act established the Acid Precipitation Task Force and directed it to develop and implement a comprehensive, 10-year, national program to research the causes and effects of acid deposition. (See pp. 9 and 10.)

The task force has established nine categories of national program research, with a task group in charge of planning and implementing research in each area. Two of the nine groups—the aquatic effects and terrestrial effects task groups—oversee task force research to determine acid deposition's effects on aquatic and terrestrial resources (forests, soils, and crops). Aquatic and terrestrial effects research account for about 41 percent of the $133 million in program funding for fiscal years 1982 through 1985. (See pp. 11 and 12.)

Task force research is carried out and funded by five federal agencies—the Environmental Protection Agency, the National Oceanic and Atmospheric Administration, and the Departments of Agriculture, Energy, and the Interior. In addition to the federal program, states and private organizations are also conducting research on acid deposition. (See pp. 12 and 13.)

GAO's December 1984 report, An Analysis of Issues Concerning "Acid Rain," examined available scientific research and presented a series of observations on controlling acid deposition. (See p. 13.)

Results in Brief

Research directed at identifying the adverse effects of acid deposition on lakes and streams included 81 projects as of the end of fiscal year 1985. Initial task force analyses of research results indicate that certain lakes in the eastern states are acidic. Under the task force's present research schedule, it will be a year or more before research determines the condition of other lakes and streams, identifies which lakes have a high potential of becoming acidic in the future, and addresses questions about the extent of damage done to fish and other aquatic life.

Research directed at identifying the adverse effects of acid deposition on forests included 17 projects as of the end of fiscal year 1985. Forests did not emerge as a major research issue until 1983, and research funding for forest effects in fiscal year 1985 tripled the total funding for the three previous fiscal years. The task force estimates that it will be 5 or more years before research defines the extent of forest decline and acid deposition's role in forest change.

Acid deposition research funding increased from $29 million in fiscal year 1984 to $65 million in fiscal year 1985. The fiscal year 1986 proposed budget calls for $85.4 million; about 51 percent of this funding is slated for work on water and forest research.

GAO's Analysis

Status and Results of Aquatic Effects Research

Determining how many of our lakes and streams are or will become acidic and the damage done to fish by acidic waters has been a priority research goal of the Aquatic Effects Task Group since the program's inception. (See pp. 18 and 19.)

The National Surface Water Survey represents the Aquatic Effects Task Group's principal effort to quantify the number of acidic lakes and streams. On the basis of initial analyses of survey data for lakes in the northeast, southeast, and upper midwest, the task group estimates that the number of acidic lakes ranges from about 1 in 25 in the upper midwest to 1 in 5 in the state of Florida. Survey results on the condition of

western lakes and eastern streams are not expected until the fall of 1986. (See pp. 20 to 23.)

Watersheds play a major role in neutralizing acid deposition before it reaches a lake or stream. A major research project began in fiscal year 1985 to identify which eastern watersheds will protect waters from future acidification and which will not. December 1986 is the target completion date for this study. (See pp. 26 to 28.)

Estimates of fish population losses based on existing state agency data show that 400 to 500 Adirondack lakes can no longer sustain certain fish species. However, according to the task group, the full extent of fish losses that can be attributed to acid deposition and the conditions under which such losses occur are not fully known. The second phase of the water survey, to determine the presence or absence of fish in acidic lakes, will begin in the spring of 1986. (See pp. 22, 29, and 30.)

Status and Results of Forest Effects Research

Forests emerged as a major Terrestrial Effects Task Group research issue when concern grew over (1) forest damage in West Germany and the northeastern United States and (2) the role that acid deposition might have in this damage. Two major research projects began in fiscal year 1985 involving forest resources: one to quantify the extent of forest decline and another to determine atmospheric deposition's role in forest change. (See pp. 36 to 38 and 43 to 45.)

Regarding the extent of forest decline, methods and procedures for measuring trees and visually observing and recording their overall physical conditions and symptoms were developed during 1985, and field tests are planned throughout 1986. The actual survey of forest decline is planned for 1987 and 1988 and should be completed in time for the national program's final assessment of acid deposition damage planned for 1989. (See pp. 43 and 44.)

The other project will be conducted to develop an understanding of how different tree species are affected by various types of atmospheric pollution, including acid deposition. These trees include spruce, fir, southern commercial forests, eastern hardwoods, Douglas fir, and Ponderosa pine. (See pp. 44 and 45.)

Research Funding

Task force officials generally believe that acid deposition research funding is adequate and has not curtailed or delayed necessary research.

Only one of the program's nine research categories—Effects on Materials and Cultural Resources—was mentioned as needing additional funding for research. The program official for this research category believes that additional funding is needed, but he also stated that finding federal agencies capable of performing the research is difficult. (See pp. 48 to 50.)

Recommendations

GAO is making no recommendations.

Agency Comments

GAO discussed the acid deposition research with task force officials and has included their comments where appropriate. However, GAO did not obtain the views of program officials, nor did it request official comments from the task force on a draft of this report.

Contents

Abbreviations

CEQ	Council on Environmental Quality
DOD	Department of Defense
DOE	Department of Energy
EPA	Environmental Protection Agency
EPRI	Electric Power Research Institute
FORAST	Forest Response to Anthropogenic Stress
GAO	General Accounting Office
NOAA	National Oceanic and Atmospheric Administration
NSWS	National Surface Water Survey
OMB	Office of Management and Budget
pH	potential of Hydrogen
RCED	Resources, Community, and Economic Development Division (GAO)
TVA	Tennessee Valley Authority
UARG	Utility Air Regulatory Group

Introduction

Acid deposition, generally referred to as "acid rain," continues to be a controversial environmental issue in the United States and other countries. Acid deposition has been linked to (1) declining fish populations in the northeastern United States, southeastern Canada, Sweden, and Norway, (2) withering forests in West Germany and the eastern United States, and (3) eroding buildings.

Acid deposition is formed when sulfur dioxide and nitrogen oxides emitted by coal-fueled power plants, motor vehicles, and other man-made or natural sources enter the atmosphere and return to the earth as acid compounds in rain, snow, and fog (wet deposition) and as particulates and gases (dry deposition). In the United States, the acid deposition issue focuses on sulfur dioxide emissions from older coal-burning power plants in the midwest and their effects on aquatic and forest resources eastward in New York and New England.

The debate continues over the extent to which emissions should be controlled. Environmentalists and certain political leaders, particularly from the northeast, contend that acid deposition has damaged some of the nation's waters and forests, and continue to press for emission reductions to prevent further ecological damage. As of October 31, 1985, at least eight bills were pending in the Congress that would place further reductions on sulfur dioxide and/or nitrogen oxide emissions. Others, including the electrical power industry, maintain that more information on the causes and effects of acid deposition is needed before decisions are made to impose costly emission-reduction requirements that may have minimal or no benefits.

The growing debate over acid deposition has increased demands for more information concerning its causes, extent, and effects. Much of this additional information on acid deposition is expected to come from the research being conducted under the National Acid Precipitation Assessment Program, the federal government's interagency acid deposition research program.

The Federal Acid Deposition Research Program

The National Acid Precipitation Assessment Program (national program) was established by the Acid Precipitation Act of 1980 (Title VII of the Energy Security Act of 1980, Public Law 96-294). The Congress passed the act in June 1980 because of concern over acid deposition and the need for better scientific information concerning its causes and effects. The act established the Acid Precipitation Task Force (task force) and directed it to develop and implement a comprehensive 10-

year national program to research the causes and effects of acid deposition, and actions to limit or reduce its harmful effects.

The task force was formally organized in October 1980 and in June 1982, issued the National Acid Precipitation Assessment Plan—the 10-year research plan mandated by the act. The plan described the state of knowledge and ongoing federal and nonfederal research involving acid deposition, and identified additional informational needs and the program's research objectives. In 1984 the task force issued its first operating research plan which described, in detail, more than 320 research projects that were completed, ongoing, or planned. The task force intends to annually update the operating plan to reflect program changes and future research activities.

Task Force Organization and Responsibilities

The 20-member task force includes senior officials from the National Oceanic and Atmospheric Administration (NOAA); the Environmental Protection Agency (EPA); the Departments of Agriculture, Energy (DOE), the Interior, Commerce, Health and Human Services, and State; the National Aeronautics and Space Administration; the Council on Environmental Quality (CEQ); the National Science Foundation; and the Tennessee Valley Authority (TVA). The remaining eight statutory members are the directors of four DOE national laboratories—Argonne, Brookhaven, Oak Ridge, and Pacific Northwest—and four presidential appointees.

The task force functions as an interagency board of directors that oversees and manages the national program. Its primary responsibilities are to

- establish research goals for the program;
- develop and update research plans;
- coordinate research activities with the private sector and environmental groups, states, and other countries;
- maintain an inventory of federally funded research projects;
- develop an annual interagency budget for program research; and
- assess the implications of research results.

The task force is jointly chaired by a council made up of the agency heads or designees of Agriculture, CEQ, DOE, EPA, NOAA, and Interior. The task force's planning and implementation decisions necessary to run the program are handled by an executive committee made up of other senior officials from each of these agencies except CEQ.

The task force's Program Coordination Office, headed by an executive director, performs the task force's day-to-day administrative activities, which include preparing the budget documents and annual reports and providing information to states, the private sector, environmental groups, and others concerning task force activities.

The task force has 10 working-level task groups: 1 for each of the national program's 9 research categories identified in the program's research plan and 1 for international activities. These groups include program managers and experts from the federal agencies and national laboratories serving on the task force. Each task group is responsible for the detailed planning and implementation of research in its assigned area. A coordinating agency has been identified for each task group to serve as a point of contact and coordination for the work conducted by the task group. Each task group is headed by a task group leader from the coordinating agency. Each task group, its coordinating agency, and a brief description of its program responsibilities are presented in table 1.1.

Table 1.1: Task Group Program Responsibilities

Task group	Coordinating agency	Primary program responsibilities
Natural sources	NOAA	Develop a data base on the extent that natural sources such as lightning, volcanoes, and decaying organic matter contribute sulfur, nitrogen, and other emissions that influence the chemistry of atmospheric deposition, and more reliably measure emissions rates for these substances.
Man-made sources	DOE	Compile a data base that shows past, present, and anticipated sulfur dioxide, nitrogen oxides, and other emissions from man-made sources that influence the chemistry of deposition, and devise methods to estimate the effects and cost of various strategies to control these emissions.
Atmospheric processes	NOAA	Develop (1) a better understanding of the link between atmospheric processes that transport and transform emissions and acid deposition and (2) improved methods for predicting present and future deposition patterns.
Deposition monitoring	Interior	Develop a nationwide program to monitor the chemical composition of wet and dry atmospheric deposition.
Aquatic effects	EPA	Quantify acid deposition's effects on lakes, streams, groundwater, and wetlands, as well as on human health and aquatic life, and develop methods for restoring acidic lakes.
Terrestrial effects	Agriculture	Determine the extent of, and acid deposition's role in, damage to forests and other terrestrial resources—soils, vegetation, and agricultural crops.
Effects on materials and cultural resources	Interior	Determine acid deposition's role in damage to man-made and natural materials and develop methods to protect these materials from further damage.

Control technologies	EPA	Provide the task force with information on current and emerging technologies that may be used in acid deposition control strategies.
Assessments and policy analysis	EPA	Analyze research results produced by other task groups to determine overall acid deposition damage, develop estimates of the cost and benefits of various control and mitigation measures, and formulate guidance to aid in policy decisions concerning acid deposition.
International activities	State	Encourage and facilitate cooperation between the national program and other nations conducting acid deposition research and monitoring activities.

Agriculture, DOE, EPA, Interior, and NOAA fund virtually all task force research. From fiscal year 1982 through fiscal year 1985, funding for acid deposition research totalled about $133 million. Of the 10 task groups, research in the atmospheric processes category accounted for the largest share of funds through fiscal year 1985—$30.5 million of $133 million. The terrestrial and aquatic effects research categories accounted for the second and third highest shares—$28.1 million and $26.6 million, respectively.

Task force funding is discussed in greater detail in chapter 4 of this report.

Other Acid Deposition Research Efforts

In addition to the task force, various state and private organizations are researching acid deposition. Research by the Electric Power Research Institute (EPRI), the research group sponsored by the electrical industry, totalled about $37.5 million during the period 1976 through 1984. EPRI expects to spend an additional $70 million over the next 5 years. Other acid deposition research efforts include those by states, such as California, Massachusetts, New York, and Wisconsin, and industry groups. The state of California, for example, in 1982 initiated a 5-year acid deposition research program and has been spending about $4 million annually.

In 1985 the forest products industry initiated a multi-year research program to study air quality problems in commercial forests, with $1.3 million being spent in the first year to develop the research approach. Substantial research has also been done by foreign countries, particularly Norway and Sweden, where acid deposition research has been ongoing since the early 1970's.

Prior GAO Report on Acid Deposition

In December 1984 we issued a report summarizing the state of knowledge concerning the causes and effects of acid deposition and examining the issues involved in deciding whether or not actions should be initiated to control it.[1] The report found that although science has determined that man-made emissions cause acid deposition, uncertainties exist concerning the amount and timing of its environmental effects. As a result, the report concluded that available scientific information alone could not be used to determine whether acid deposition control actions should be initiated or should be delayed until a better understanding of the effects could be made. The report noted that given this uncertainty, decision makers must weigh the risks of further, potentially avoidable environmental damage against the risk of economic impacts from acid deposition controls that may ultimately prove to be unwarranted.

Objectives, Scope, and Methodology

By letter dated January 30, 1984, the Chairman, Subcommittee on Oversight and Investigations, House Committee on Energy and Commerce, requested that we review the national program's acid deposition research activities. In a subsequent meeting with the Chairman's office, it was agreed that we would focus our work on (1) determining the status and results of program research to determine acid deposition's effects on our aquatic and forest resources and (2) obtaining information on the adequacy of funds to support required program research, especially in the aquatic and forest effects areas. In the aquatic effects area, we were requested to place particular emphasis on determining the status and results of a national survey funded by EPA to determine the extent of acidic lakes and streams.

We performed work at the Washington, D.C., headquarters of EPA, NOAA, Agriculture, DOE, and Interior, the five federal agencies funding virtually all task force research. Work was also performed at CEQ's Washington,

[1] An Analysis of Issues Concerning "Acid Rain" (GAO/RCED-85-13, Dec. 11, 1984).

D.C., headquarters—the physical location of the task force's administrative staff—and at EPA's Environmental Research Laboratory in Corvallis, Oregon, and North Carolina State University in Raleigh, North Carolina—two locations actively involved in aquatic and forest effects research.

Chapters 2 and 3, respectively, discuss the status and results of the national program's aquatic and forest effects research. These discussions are based on information we developed for 98 projects—81 in aquatic effects and 17 in forest effects—funded by the national program through fiscal year 1985. The 81 projects represent the entire universe of the Aquatic Effects Task Group's work while the 17 projects cover the Terrestrial Effects Task Group's work relating directly or indirectly to forests. Excluded from the latter group are those projects involving agricultural crop research.

Our initial step in developing this information involved reviewing the program's 1984 operating research plan inventory to develop the following profile information for each project: project title; funding agency and funds for fiscal years 1982, 1983, and 1984; the name and agency affiliation of the individual serving as project officer; the name and affiliation of the project's principal researcher; project status; rationale for and objectives of the project; and anticipated or actual research results. Each of the 98 projects was discussed with the project officer having overall responsibility for the project or with the principal researcher performing the work to verify and update the project profile information, and to obtain fiscal year 1985 funding data. These discussions were held primarily during the period December 1984 through March 1985 and involved contacting 40 different project officers and researchers at 21 locations (project officers and researchers were often involved in more than one project).

To supplement this project profile information, we reviewed (1) project records at EPA's Environmental Research Laboratory, at North Carolina State University, at Agriculture's Forest Service headquarters, and at Interior's U.S. Geological Survey headquarters, (2) descriptions of aquatic and forest effects projects accompanying the national program's fiscal year 1986 budget to the Office of Management and Budget (OMB), and (3) research summaries of aquatic and forest effects projects prepared for a November 1984 scientific peer review performed by a panel of experts from this country and abroad.

To determine the status and results of EPA's National Surface Water Survey, an effort involving the sampling of about 2,500 lakes and 580 streams to determine their acidity and other chemical and biological characteristics, we discussed the survey's design, funding, and status with members of the survey management team, including its administrative director, the State University of New York official serving as project officer for the lake portion of the survey, and the Utah State University official serving as project officer for the stream portion. We reviewed various documents associated with the survey, including the April 1984 research plan for the lake portion, the March 1985 draft research plan for the stream portion, and the March 1985 draft environmental assessment statement for western wilderness area lakes included in the survey.

We discussed the national program's aquatic and forest effects research with representatives of the National Forest Products Association, the American Paper Institute, the National Coal Association, and the Utility Air Regulatory Group. Views on the research were also obtained from representatives of various other public and private sector groups having an interest or involvement in acid deposition research, such as the Office of Technology Assessment, the Electric Power Research Institute, and the National Wildlife Federation.

In obtaining information on the adequacy of funding, we reviewed OMB guidance and task force meeting minutes for information on how the program's interagency budgets were developed and funding priorities established. We made a detailed analysis of the task force's fiscal year 1985 budget request data because these data were the most recent and reflected the task force's latest thinking regarding acid deposition research needs. The task force received nearly $65 million in fiscal year 1985, more than double the previous fiscal year's level, but estimated that $74 million to $82 million was needed to perform research it considered essential or desirable to achieve program goals. Specifically, through a review of task force files, we identified the research projects that were cut back, delayed, or cancelled by the reduction in funds and, through discussions with individual task group leaders, attempted to determine the adequacy of funding to perform needed research. We discussed the adequacy of funding with the Chairman of an EPA Science Advisory Board ad hoc panel that evaluated the management, funding, and other aspects of the national program in December 1983, and with the Chief of OMB's Environmental Branch, the section that reviews the national program budgets.

Senior research officials representing the five funding agencies on the task force's executive committee, including the Director, EPA Office of Acid Deposition, Environmental Monitoring, and Quality Assurance, and the Associate Deputy Chief, Forest Service, were interviewed for their views on the program's funding and research activities. Similar discussions were held with the task force executive director and with the aquatic and terrestrial effects task group leaders.

We reviewed a variety of documents for information on the national program, its funding, and the status and results of the aquatic and forest effects research. These include the program's 1982 research assessment plan, the December 1983 EPA Science Advisory Board ad hoc panel report on the program, and our December 1984 acid deposition report.

Our audit work was performed during the period December 1984 through August 1985. During the course of our review, we discussed the research and funding information contained in this report with those agency officials responsible for these activities. In accordance with the Chairman's wishes, we did not discuss nor request official agency comments on a draft of this report. Except as noted above, our work was performed in accordance with generally accepted auditing standards.

National Program Research Continues to Seek Answers to Major Aquatic Effects Questions

Although determining acid deposition's effects on our lakes, streams, and other aquatic resources has been a major goal of the national program since its inception, important questions remain. Initial national program research estimates that the number of acidic[1] lakes ranges from 1 in 25 in the upper midwest to 1 in 5 in the state of Florida. Data to determine the condition of western lakes and eastern streams are not expected until late 1986. Also, research aimed at identifying waters that have a high potential to become acidic is just getting underway, and results are not expected until late 1986. Even more time will be needed before the national program will obtain results from research addressing questions about acidic waters' effects on human health, and methods for restoring acidic waters and protecting waters sensitive to acidification.

Overview of Aquatic Effects Research

Over the years surface waters in certain areas of the country, such as the Adirondack Mountains of the northeast, have been exposed to high levels of acid deposition. Quantifying the effects of acid deposition on our lakes and streams and describing how these effects can be corrected are major goals of the national program's aquatic effects research.

Limited information existed at the time the task force was formed in 1980 concerning the extent of surface water acidification and its impacts on aquatic life. It was generally recognized that about 200 lakes in the Adirondack Mountains were acidic and had experienced loss of fish populations because of acid deposition, but the extent of water acidification and its impacts on aquatic life nation-wide were not known. As a result, the task force adopted the following research goals for its aquatic effects research area.

- Quantify the number of acidic lakes, streams, and other aquatic resources in this country.
- Assess acidic waters' damage to fish and other aquatic life.
- Determine those factors that make water susceptible to acidification and predict sites of future water acidification.
- Develop methods to mitigate the effects of acidification and restore acidic waters.
- Determine the potential impact on human health of acidic waters.

[1]Acidity is expressed in terms of pH (potential of Hydrogen), which is a measure of a solution's acidity based on its hydrogen ion concentration. The pH scale ranges from pH 0 to pH 14, and all values below pH 7 are acidic. The lower the pH, the greater the acidity. Rainfall not contaminated by man-made acid compounds has a pH of about 5 because of acidity from natural sources.

As shown in table 2.1, the task force's aquatic effects research through fiscal year 1985 totalled $44.4 million.

Table 2.1: Number of Projects and Funding for Each of the Aquatic Effects Research Goals

Dollars in millions

Research goal	Number of projects	Funding
Extent of acidic waters	27	$27.8
Water chemistry changes	20	8.1
Damage to aquatic life	25	3.9
Human-health effects	3	.8
Mitigation techniques	6	3.8
Total	**81**	**$44.4**

Four task force agencies—Agriculture, DOE, EPA, and Interior—fund the aquatic effects research. As shown in table 2.2, EPA has provided $27 million, over 60 percent of the total aquatic effects research funding. As table 2.2 also shows, $20.5 million, or 46 percent of all aquatic effects funds, was spent in fiscal year 1985 as the task force continued its efforts to quantify the number of acidic lakes and streams, and to predict likely sites of future water acidification. Interior's funds are provided by the U.S. Geological Survey, the National Park Service, and the Fish and Wildlife Service. Agriculture's funds are provided by its Forest Service.

Table 2.2: Aquatic Effects Research Funding by Agency

Dollars in millions

Agency	Fiscal years 1982-84	Fiscal year 1985	Total	Percent
EPA	$13.7	$13.3	$27.0	61
Interior	6.0	4.0	10.0	23
Agriculture	3.0	3.0	6.0	13
DOE	1.2	.2	1.4	3
Total	**$23.9**	**$20.5**	**$44.4**	**100**

The Aquatic Effects Task Group is responsible for $33.9 million of the aquatic effects research. The remaining $10.5 million represents watershed[2] research and a soil survey under the control of the Terrestrial Effects Task Group.

[2]Watersheds are areas that drain into rivers, streams, lakes, or other bodies of water.

Research to Quantify Extent of Acidic Waters

The first major research goal the task force defined for its aquatic effects research involves determining the extent to which water quality in this country has been affected by acidification. Through fiscal year 1985, 27 projects, hereafter referred to as "extent projects," had received funds totalling about $27.8 million to quantify the extent of water acidification.

The National Surface Water Survey (NSWS), which includes the sampling of lakes and streams to determine their acidity and other chemical characteristics, represents the task force's central effort to quantify the number of acidic lakes and streams. Survey sampling has been completed for lakes in the northeast, southeast, and upper midwest, and EPA's initial analysis estimates that the number of acidic lakes ranges from about 1 in 25 in the upper midwest to 1 in 5 in Florida. NSWS results on the acidity of western lakes and eastern streams are not expected until late 1986. Other extent projects include monitoring to detect long-term trends in water chemistry and studies to determine how precipitation is altered as it passes over watersheds before entering lakes and streams. A discussion of the projects follows.

Mapping Waters Sensitive to Acidification

One of the earlier aquatic effects projects involved determining the susceptibility of surface water to acidification. The work, begun in 1982 and continuing through fiscal year 1985, has produced one national and five draft regional maps depicting the various levels of surface water alkalinity. Alkalinity is a measure of water's capacity to neutralize acids and is generally used as an indicator of its potential susceptibility to acidification. The maps, which are based on alkalinity data for about 2,500 streams and lakes, showed that the northeastern and southeastern states contain the largest portion of waters with low alkalinity. Funding for this project totalled almost $325,000.

National Surface Water Survey to Quantify Surface Water Acidification

While the alkalinity maps showed the locations of surface waters potentially susceptible to acidification, they did not answer the basic question of how many lakes and streams are acidic. Furthermore, other water chemistry data available at the time were incomplete and could not be used to determine the number of acidic lakes and streams. As a result, EPA initiated the NSWS, which is, as its first step, quantifying the number of acidic lakes and streams. The NSWS is being performed in areas of the United States that contain an abundance of low alkalinity waters considered susceptible to acid deposition—the northeast, southeast, upper midwest, and mountainous West.

The NSWS consists of two components—the National Lake Survey and the National Stream Survey. Each component has three phases. Phase I involves the sampling of about 3,100 regionally representative lakes and streams to determine how many are acidic or have low acid-neutralizing capacity. Phase II is designed to be a more intensive look at a small, representative group of phase I lakes and streams to determine (1) the presence or absence of fish in these waters, (2) the chemical characteristics of waters associated with the presence or absence of fish, and (3) the weekly and monthly changes in water chemistry. Phase III is designed to be a long-term monitoring effort involving a smaller group of phase II lakes and streams to quantify future chemical and biological changes that are caused by acid deposition. During fiscal years 1984 and 1985, EPA spent about $12.9 million for NSWS activities.

National Lake Survey

The National Lake Survey involves about 2,500 lakes. With the exception of the mountainous West region, EPA selected lakes of approximately 10 acres or more in size because these make up the vast majority of total lake area in the United States. In the mountainous West region, lakes of about 2 acres or more in size were selected because of their important recreational resources.

Phase I was conducted for 1,619 lakes in the northeast, southeast, and upper midwest regions during the fall of 1984. The sampling was performed during the fall months because the lakes are well mixed and relatively uniform in chemistry. Helicopters were used to gain access to the lakes and to transport the samples for analysis. Sample analysis was done by four laboratories and covered 21 different chemical characteristics, including acidity.

Based on preliminary survey results released in August 1985, EPA estimates that one in five Florida lakes is acidic (pH values of less than 5.5), and about one in eight lakes in the state is highly acidic (pH values of less than 5.0). In the northeast, EPA estimates that 9 percent of the lakes are acidic, with 4 percent of the lakes being highly acidic, while in the upper midwest, 4 percent are acidic, with 2 percent being highly acidic. The survey found no lakes with pH values below 5.5 in the southeast's southern Blue Ridge area, which includes parts of Georgia, North and South Carolina, Tennessee, and Virginia. The survey also measured the lakes' acid neutralizing capacities. Estimates of the number of lakes that do not have good neutralizing capabilities range from 36 percent in the southern Blue Ridge area to 60 percent in the northeast region. EPA is

verifying and validating the data collected during phase I and upon completion will use the data to characterize regional lake chemistry.

Phase I for the 888 lakes in the mountainous West region was deferred until the fall of 1985 so that the issue of gaining access to the 425 lakes located in federally designated wilderness areas administered by the Department of Agriculture's Forest Service could be resolved. Aircraft are prohibited from wilderness areas unless the Forest Service determines that the activity for which they are used is essential to managing the area and cannot be accomplished by nonmechanical means, or for emergencies. Under an agreement reached between EPA and the Forest Service, EPA is sampling about 50 lakes by helicopter while the Forest Service is sampling all the lakes by foot or on horseback. Comparisons will be made of the 50 lake samples obtained by helicopters and those obtained by foot or on horseback to see whether the additional time required to collect samples by foot or on horseback affects sample results. If significant differences exist in the results, NSWS' Technical Director told us that EPA would use the Forest Service samples, but would analyze and report these results separate from the results for the other mountainous West lakes. Preliminary phase I results for the western lakes are expected in the spring of 1986.

Phase II for 150 phase I lakes in the northeastern region is scheduled to begin in the spring of 1986 and to continue through the spring of 1987. According to NSWS' Technical Liaison, a variety of netting and fish-trapping techniques will be used to determine the presence or absence of fish. This official also told us that no decision has been made as to whether phase II work will be expanded to include other aquatic life in the lakes, and that EPA plans to wait for results from phase II in the northeastern region before deciding upon phase II work for the other regions. EPA originally planned that long-term monitoring under phase III would begin in 1987 for the northeast, southeast, and upper midwest regions, and in 1988 for the western region. However, in October 1985, NSWS' Technical Liaison told us that no final decisions have been made concerning the starting dates and the number and location of lakes for phase III.

National Stream Survey

The National Stream Survey is designed to determine the chemical and biological status of a wide range of streams. While the original approach to be used in the stream survey generally paralleled that used in the lake survey, fundamental differences between lakes and streams

required that the stream research approach be modified in several ways. Among these differences are the following.

- Downstream chemistry may be different from upstream chemistry.
- Stream chemistry may change significantly and rapidly during storms and snowmelt.
- Physical access to streams is often much more difficult than access to lakes.

To address these concerns, a phase I pilot survey was initiated in the spring of 1985, with samples being collected from about 60 streams in Georgia, North Carolina, South Carolina, and Tennessee. This area was chosen because it is a geographically compact area that has been studied extensively in the past, and it had been thoroughly surveyed by the team managing the stream survey. Phase I for the eastern half of the country should begin in the spring of 1986, include about 580 streams, and be completed in the fall of 1986. Phase I for streams in the West is tentatively scheduled to begin in early 1988. Phase II for streams is scheduled to begin in the spring of 1987, but the number and location of streams that will be included in phase II will be determined after phase I has been completed. Also, no decisions have been made concerning the starting date for phase III, and there are preliminary discussions about combining phases II and III.

Monitoring to Determine Changes in Water Chemistry

The NSWS is providing information on the acidity of lakes and streams, which can change as changes occur in acid deposition. EPA initiated a monitoring effort to detect and measure future trends in water chemistry and to compare how these changes differ in regions with similar or varying deposition rates. Eight monitoring projects, totalling $700,500, and involving 126 monitoring sites (91 lakes, 23 streams, and 12 reservoirs) in 12 states have been funded. Areas covered by the projects include the northern Rocky Mountains and portions of the upper midwest, the northeast, and the southeast. The 126 sites were chosen because of their low alkalinity waters and their presumed susceptibility to acid deposition. Measurements taken at each site include acidity, alkalinity, color, temperature, and various other chemistry components, such as aluminum, calcium, and magnesium. The chemistry of deposition falling in the area is being provided by monitoring sites located in close proximity to the monitored waters.

At the time of our review, the eight projects had been operating about 3 years, which is not sufficient time to establish trends concerning

changes in water chemistry. The EPA research biologist, who is program manager for research aimed at determining the extent of acidification, told us that about 10 years of data are needed before trends begin to emerge. He also anticipates that much of the work being done under these eight projects will be incorporated into the long-term monitoring to be done under phase III of the NSWS.

Watershed Research

Watersheds, which are the areas that drain into a lake, stream, or other body of water, represent a critical link between acid deposition and water acidification because deposition entering waters from the watershed has the greatest impact on water chemistry. In certain cases, watersheds can buffer and neutralize the acidity of deposition while in other cases, they may have limited or no effect on deposition acidity. The task force research includes 11 watershed projects that are studying how the chemistry of deposition changes as it passes through the trees, leaf debris, soil, and bedrock of watersheds. Funding, totalling about $12 million, is provided by the Forest Service, the Geological Survey, the National Park Service, and EPA.

Forest Service Research

The Forest Service's eight watershed projects, totalling $6 million through fiscal year 1985, are examining how different forest management practices, in combination with acid deposition, affect water chemistry. The work is being done by the Forest Service's Northeastern, North Central, Southeastern, Rocky Mountain, and Pacific Northwest Forest Experimental Stations in 13 states. In May 1985 the Terrestrial Effects Task Group leader told us that three of the watershed projects were just getting underway. Major results from the other projects include the following.

- Research at the Hubbard Brook Experimental Forest in New England has shown that soils in the New England area are poor buffers of acid deposition.
- Research at the Fernow Experimental Forest in West Virginia and bordering states has shown that the soils and bedrock in that area effectively neutralize acid deposition, and that water leaving the watershed has an average pH of 5.9. Precipitation in the area is very acidic, with an annual average pH of 4.2.

- Work in the southern Appalachian and Piedmont regions has shown that watershed soils have provided a good buffer against and delayed the effects of acid precipitation on streams.

U.S. Geological Survey Research

The one Geological Survey watershed project, involving a number of sites ranging in size from about one-half of a kilometer to five square kilometers, is specifically designed to develop information on how soil and bedrock characteristics affect stream water chemistry. Sites were selected where a stream flows over a single type of bedrock, so that changes in water chemistry could be attributed to a particular bedrock and effects projected to similar stream types on like bedrock. The Geological Survey hopes that the research will allow researchers to eventually separate changes in water chemistry caused by natural occurrences from those caused by man-made activities. Through fiscal year 1985 the Geological Survey spent about $2.9 million on watershed research.

National Park Service Research

The National Park Service's one watershed project is studying the effects of acid deposition on natural remote areas in four of its national parks—Isle Royale, Rocky Mountain, Sequoia, and Olympia National Parks. The work includes developing information on the chemistry of rainfall, snowfall, dry deposition, and waters in each area; compiling data on plants and animals potentially sensitive to acid deposition; and measuring the changes in deposition chemistry as it passes through the watershed. The National Park Service plans to develop baseline data to identify normal conditions at these sites. Researchers plan to monitor for changes and to initiate studies to determine the cause for any changes. The National Park Service estimates that it has spent $1.7 million on research in these four national parks through fiscal year 1985. Research results indicate that bedrock, soils, and surface waters in the high elevations of the Rocky Mountain National Park have almost no acid-buffering capacity and that, although atmospheric deposition is not acidic at this time, there is potential for damage if deposition becomes acidic. At Isle Royale, research indicates that ecological effects on aquatic resources will apparently be subtle and long-term rather than immediate because of the combined acid buffering provided by trees and soils in the region. At the Sequoia National Park, where research is being done at three lakes spanning the park's varying elevations, research has shown that the watershed surrounding the highest lake has a low acid-buffering capacity and that the lake has the potential to become acidic from acid deposition. The Olympia National Park research

site was established in 1984, and research was in its preliminary phase when we contacted the project officer in early 1985.

EPA Watershed Research

In fiscal year 1985 EPA initiated a research program to examine how watersheds affect acid deposition. During fiscal year 1985 EPA spent $1.3 million to begin the first phase of this work, which involves selecting four or five watershed sites where soil processes and other watershed activities will be studied to develop a better understanding of how they work and how they interact to affect water chemistry. During fiscal year 1986, EPA plans to increase the number of watersheds to anywhere from 8 to 20 sites and to carry out an intensive long-term monitoring program. Soils, vegetation, and water will be monitored at each site to determine what changes occur as the acidity of deposition increases or decreases. Deposition monitoring will be conducted at each site so that researchers can correlate observed changes with acid deposition levels.

Other Extent Area Research

Six other extent area research projects, funded at $1.9 million, include two projects which inventoried and evaluated water quality data in existence as of 1982, two projects that analyzed lake sediment to determine past deposition trends, one project that studied how industrial plants affect air and water quality on Alaska's Kenai Peninsula, and one project that studied how water chemistry changed in southeastern streams following storms.

Research to Predict Future Water Chemistry Changes

In addition to projects aimed at quantifying the extent of acidification that has already occurred in our lakes and streams, a second, major goal of the aquatic effects research is directed at identifying those factors that control the susceptibility of waters to acidification and, ultimately, developing the capability to predict likely sites of future water acidification.

Through fiscal year 1985, 20 water chemistry projects, totalling about $8.1 million had been funded. Watersheds play a major role in neutralizing acid deposition. In fiscal year 1985, a major research initiative referred to as the direct/delayed response project was funded to develop information on the acid-neutralizing capabilities of eastern watersheds and to determine whether and at what rate future water acidification might occur. Results from the project are not anticipated until December 1986. Other water chemistry work includes 10 projects that relate to the

development of water chemistry models and 8 projects involving research of soil processes, storms, and snowmelts to determine their contributions to water acidification. The remaining project is a $405,000 administrative account funded by EPA to cover the salary and related expenses of the program manager for water chemistry research.

Direct/Delayed Response Project

Watersheds can have a major effect on the degree and rate of water acidification. In some cases, the capabilities of watersheds to neutralize acid deposition before it enters surface waters may be limited or exhausted. Consequently, waters surrounded by these watersheds may respond relatively quickly to acid deposition, becoming acidic in a period of a decade or less. These systems are characterized as "direct response" systems. In other cases, certain watersheds may have a much greater capacity for neutralizing acid deposition, and it may take centuries before waters in these areas become acidic. These systems are characterized as "delayed response" systems.

Direct/delayed is a relatively new national program concept. It gained momentum after a March 1984 panel discussion on lake acidification conducted by the National Research Council, which concluded that the lack of information on watersheds' capability to neutralize acids was limiting the ability to predict acidification rates for individual lakes and streams. As a result, the Aquatic Effects Task Group initiated a research project that would by December 1986,

- estimate the current geographic extent of direct/delayed response systems in the East where clear water streams and lakes with low alkalinity are receiving the greatest levels of acid deposition and
- predict the time of responses of systems to acid inputs in four selected subregions—the Adirondacks, a portion of the Appalachian Plateau, the Shenandoah National Park, and portions of the southern Blue Ridge Mountains.

Knowing whether systems are direct versus delayed response is important in predicting whether water acidification may be a future problem. In the case of direct response systems, the theory is that water acidification that has occurred at these sites is all that will occur unless future acid deposition levels increase. In the case of delayed response systems, the theory is that water acidification is long-term in nature. Consequently, at present acid deposition levels, water acidification may occur because accumulated deposition over the years will eventually deplete the watershed's neutralizing capacity, allowing more and more acids to

flow unneutralized into the lake or stream and causing rapid acidification.

One primary component of the direct/delayed work involves gathering, analyzing, and depicting surface water and soil chemistry characteristics. EPA plans to rely on the NSWS for the water chemistry data and, in fiscal year 1985, initiated a National Soil Survey to develop information on sulfate absorption and other soil chemical characteristics considered key in determining a soil's ability to neutralize acid deposition. A three-month pilot program initiated in September 1984 developed and tested the organizational structure, field procedures, and laboratory capability required to carry out the survey and gathered soil samples from 25 watershed sites in Maine and from 32 sites in New York. According to the EPA project officer for the National Soil Survey, soil survey work began in April 1985 at 150 northeast watershed sites and in October 1985 at 66 southeast watershed sites. Work at the northeast sites is scheduled to be completed in November 1985, while work at the southeast sites is expected to continue through June 1986.

Fiscal year 1985 funding for the direct/delayed response project, including the National Soil Survey, totalled about $4.5 million.

Modeling Research

The crux of the water chemistry objective is to develop the capability to predict, through computer modeling, how water chemistry will change at various levels of acid deposition. Ten projects, funded by EPA for $1.6 million, involve modeling work, including a workshop held in the summer of 1983 to discuss the problems associated with predictive modeling. Work on two projects, totalling $200,000 and designed to develop models for predicting water chemistry changes during storms and snowmelts, was just getting underway at the time of our review. The following summarizes three of the six remaining water chemistry modeling projects.

- An $85,500 project with the University of Iowa developed a model that predicts water chemistry at various levels of acid deposition. The model has been used to predict changes in acidity and alkalinity for Adirondack lakes under three different acid deposition scenarios—present acid deposition level, double the present level, and half the present level. Although the model predicts final chemistry at a given acid deposition level, it is not able to predict how long it will take for the water chemistry change to occur. Also, at the time of our review, the model had not been applied outside the Adirondacks.

- An ongoing project, funded for $57,000, is developing a model that will predict for upper midwest seepage lakes (those with no permanent surface inlets or outlets) how long it will take for a change in deposition to cause a change in surface water chemistry. At the time we completed our work, the model had been developed but had not been field tested.
- An $827,500 completed study of acidification in the upper midwest showed that very few lakes are presently acidic, but that this situation could change in the future if the acidity of deposition increases. A model developed as part of the project predicts that when using an acidity concentration of pH 4.1 (as found in the Adirondacks), about 30 percent of the upper midwest lakes would become acidic.

Process and Event Studies to Understand Acidification Process

An improved understanding of storms, snowmelts, and soil processes is needed to develop accurate models for predicting water chemistry change. Eight water chemistry projects—six funded by EPA and two by Interior—totalling about $1.6 million, involve research in this area. Five projects are studying the various processes that occur between the time acid deposition falls on a watershed and the eventual change in surface water chemistry. The projects are examining how soils interact with and change acid deposition and how aluminum reacts chemically to changes in water acidity. Elevated levels of aluminum, which have been observed in acidic waters, can be toxic to fish. Funding for these projects totalled $928,300.

The remaining three projects, funded at a combined amount of $630,000, are monitoring the levels of acidity that enter and leave watersheds during various times of the year, especially during storms and snowmelts, to better understand the mechanisms that transport acidity to surface water.

Research to Determine Acidic Waters' Effects on Fish and Other Aquatic Life

In addition to determining the extent of water acidification that has already occurred, and identifying those characteristics that will make certain lakes and streams susceptible to future acidification, the national program is also researching water acidity's effects on fish and other aquatic life. The task force's ultimate goals are to determine (1) the number and location of fish populations lost or likely to be lost due to water acidification and (2) the overall effects of water acidification on the aquatic community.

Through fiscal year 1985, 25 projects, totalling about $3.9 million had been funded by EPA and Interior in this area. The projects cover a variety of activities, including models to predict fish presence or absence based on water acidity and other chemical characteristics, and the acidification of a lake to study how fish are affected by acidification.

The research has produced some estimates of fish losses for the Adirondacks based on existing state agency data, but little progress has been made in quantifying the numbers of fish populations lost in other regions or currently at risk. In addition, questions remain concerning how acidification affects lakes. The NSWS phase II work at 150 northeastern lakes, scheduled for completion in the spring of 1987, as well as the acidification of Little Rock Lake in Wisconsin over the next 4 years are expected to provide more information about the effects acidity has on fish and lakes.

Modeling and Fish Loss Estimates

Nine projects—seven funded by EPA and two by Interior, for $633,900—address fish losses from water acidification in the Adirondacks and other areas of the northeastern United States. One project, funded by EPA for $141,000, involves a model that predicts the presence or absence of fish on the basis of the acidity, alkalinity, and other chemical characteristics of lakes. At the time we completed our review, the model could be used for only one region (the Adirondacks) and one species of fish (brook trout). However, work was underway to modify the model so that it could be applied to other fish species and to two other regions—Maine and Ontario, Canada.

Two projects, conducted by North Carolina State University at a cost of almost $87,500, compiled and critiqued existing state agency data on fish populations in the northeast. The research estimated that 20 to 28 percent of the 2,760 lakes in the Adirondacks was acidic, with pH levels less than 5.0, and that 400 to 500 Adirondack lakes could not sustain certain fish populations.

Six projects totalling $405,800, involve small-scale surveys designed to collect information on the chemistry and fish populations of lakes and streams altered by acid deposition. The work, performed in Maine, Vermont, other sensitive northeast regions, and the southern Blue Ridge Mountains, attempted to develop information on water chemistry and fish populations against which future data may be compared to determine changes.

Laboratory and Field Studies

Six laboratory and field studies, totalling about $1.2 million, have been funded to better understand and describe the process of acidification and to provide input for modeling acid deposition's impacts on fish. The largest of these laboratory and field studies involves a $713,500 project funded by Interior's Fish and Wildlife Service to develop a biological indicator for the early detection of fish damage from water acidification. Preliminary results indicate that enzyme activity and bone development in fish seemed to be altered by acidification prior to more pronounced effects of altered growth and eventual death and, therefore, may be a biological indicator that water acidification is affecting fish. Work on this project is expected to be completed by March 1986.

Two other projects, funded by EPA for about $147,000, are studying the effects of water acidification and aluminum on young and adult fish. Results from one project, where adult trout were exposed to high acidity levels to observe effects on offspring, supported the hypothesis that the most critical stage for exposure to acidification is during early life. The other project indicates that while acidity can be toxic to younger fish, aluminum can be toxic to older fish.

In addition, two laboratory studies, funded by EPA for $155,000, are examining how certain game fish, such as smallmouth bass, are affected by increased acidity that occurs during storms and snowmelts. One of the projects has been completed, but at the time we conducted our review, the program manager had not received the final report and was reluctant to discuss any specific results. For the other project, the program manager told us that research showed that different life stages of fish exhibit differing responses to aluminum and acidity.

The last project, funded by Interior's Fish and Wildlife Service for $152,000, involved a field study that established, through observations of acidic and neutralized lakes, that lakes with higher acidity generally had fewer fish than lakes with lower acidity levels.

Acidification of a Lake

A key project examining the critical issue of how fish respond to acidification involves the acidification of Little Rock Lake in Wisconsin to determine what changes acidification causes in nontrout, warm-water fish and the reasons why. Little Rock Lake is one of Wisconsin's sensitive lakes that is currently not experiencing adverse effects from acidification. As a result, researchers will be able to study how the lake changes as it becomes acidic, starting with the early, most subtle changes. Also, because Little Rock Lake is representative of many upper

midwest lakes and lakes in other parts of the country with warm-water fish, the results will enable researchers to predict changes in other lakes. The project, funded by EPA for $940,000 through fiscal year 1985, involves placing a plastic barrier to divide the lake in half. A year was spent in developing chemical and biological data on both halves of the lake. In May 1985 scientists began acidifying one-half of the lake while allowing the other half to remain in its natural state. During the acidification process, which will take about 4 years and will eventually lower the water to a pH level of about 4.5, the researchers plan to observe the changes that occur to fish, other habitat, and the food chain in the acidic portion, and to compare these changes to occurrences in the non-acidic portion.

A second project was funded by EPA for $35,100 to select a site for a second lake acidification experiment. The work resulted in the selection of a site in Maine; however, the actual acidification project was not funded because EPA reprogrammed the funds to other research.

Other Aquatic Life Studies Supplement Objective

Seven other projects, funded by Interior's Fish and Wildlife Service for about $950,000, are examining how acidic water affects the birth, growth rate, and feeding behavior of waterfowls and amphibians; whether microorganisms living on stream bottoms can be used as indicators of acid deposition stress on fish and acquatic life; and how water acidity affects phosphorous, an important nutrient in the water. The remaining project is an administrative account funded by EPA to cover salary and travel expenses of the program manager. Administrative costs through fiscal year 1985 totalled about $145,500.

Research to Determine Acidic Waters' Effects on Human Health

In addition to fish and other aquatic life, acid deposition may affect humans through the water they drink and the fish they eat. Determining the potential effects of freshwater acidification on human health from exposure to toxic metals, such as lead and mercury through drinking water and fish consumed from acidic lakes, is the focus of the task force's human health effects research. Overall, research has shown that elements, such as lead and copper, may increase in drinking water under acidic conditions, and that mercury contamination of fish may be of concern if affected fish are regularly consumed. Ingestion of mercury can, depending on the levels, cause central nervous system and kidney damage.

The task force's human health effects research has been limited to three projects, totalling $786,900. The largest involved an EPA project, completed in January 1984 at a cost of $201,900, that sampled the waters of 270 water supply systems to determine if excessive levels of lead, copper, and other metals were occurring in drinking water because of acid deposition. The research showed that the metal levels in raw drinking water (water not yet treated by the water supply systems) were generally below maximum federal levels. At the same time, analyses of 43 sets of samples of water left standing overnight in residential plumbing showed that the maximum federal levels for copper and lead were exceeded in 42 percent and 8 percent, respectively, of the samples. The EPA program manager for human-health effects research told us that the research did not demonstrate that water acidity was the cause of the high metal levels.

Two projects, totalling $585,000, are studying the accumulation of toxics in fish. A DOE project, funded for $575,000, is examining the threat that mercury, lead, and other toxic substances present in edible fish pose to human health. According to DOE's principal researcher on the project, results show that higher levels of metals, including mercury and cadmium, exist in fish in acidic waters, but that for the most part, these levels are below guidelines established by the Food and Drug Administration. An ongoing $10,000 EPA project, which had not started at the time of our review, will attempt to establish a link between mercury in game fish and acid deposition.

Additional research in the human-health effects area is planned to further study the issue of increased toxic contaminants in drinking water and the association between acid deposition and mercury accumulation in fish. According to a draft research plan published in late 1984, such research is anticipated to continue into the late 1980's and possibly into the early 1990's.

Research to Develop Methods of Restoring Acidic Waters

Developing methods to restore waters that have become acidic is one means of mitigating the effects of water acidification. Liming, the application of lime or other alkaline materials to a lake or stream to neutralize acidity and increase alkalinity, is probably the most effective means of mitigating water acidification. But questions remain concerning its long-term ecological effects, costs, and application techniques.

Through fiscal year 1985, EPA and Interior funded six projects, totalling about $3.8 million, to develop information on the problems and benefits

of liming. The largest project, totalling over $2.3 million, is specifically designed to study the effectiveness and consequences of lake liming in five states—Maine, Minnesota, New York, Tennessee, and West Virginia. The task force anticipates that these state programs will last for 5 years so that the long-term consequences of liming can be studied. Earlier work under this project developed reference material to aid in implementing liming programs.

A second project, funded for $702,400, tested the effectiveness of limestone gravel emplacements in the spawning area of brook trout in improving their survival in acidic waters. The research showed that liming only the spawning area was not fully successful in improving the overall survival rates, and that additional liming is needed to sustain fish as they migrate from the spawning area into untreated portions of the lake.

The remaining mitigation research included a $319,000 project that served as a pilot lake-liming experiment to support the 5-year lake-liming effort and a $148,000 project that showed that limestone contactors (water treatment devices containing crushed limestone through which water flows) represent a viable technique for small water supply systems and individual households to reduce the acidity of drinking water. The two other projects, totalling $299,000, basically developed information on the state of knowledge and additional research needed in the mitigation area.

Research Has Not Determined Acid Deposition's Role in Forest Damage

Acid deposition's effects on forests emerged as a major issue with the national program in 1983, after an alarming increase in the extent of forest damage in West Germany thought to be caused by acid deposition and indications of similar damage in the northeastern United States. At about the same time, the task force realized that improvements were needed in its research program to determine the effects that acid deposition may have on forests and developed two new efforts to quantify the extent of forest damage and determine the role of air pollution in forest damage and decline. Both projects were initiated in fiscal year 1985, but results on the extent of forest damage are not anticipated until 1989, and results on the role of acid deposition in contributing to forest damage are not anticipated until 1990 or later.

Overview of Forest Effects Research

During the early years of the national program, attention focused on acid deposition's effects on water rather than on forests. According to the national program's 1983 annual report, initial forest productivity studies indicated that forests were not expected to be threatened by acid deposition and in fact, some thought that the nitrogen in acid deposition might help forest growth. Consequently, the Terrestrial Effects Task Group research concentrated on the role of forests and soils in water acidification and on acid deposition's effects on crops.

In 1983 acid deposition's effects on forests began to emerge as a major research issue with the national program. Results of a survey conducted in West Germany in 1983 found that 34 percent of the trees showed damage—a dramatic increase from the 8 percent reported in 1982. This, together with increasing evidence of growth decline and dieback[1] of several tree species in this country, especially red spruce in the higher elevations of eastern United States, raised concern about the relationship between acid deposition and forest damage.

The Terrestrial Effects Task Group realized that improvements were needed in its research efforts to determine the effects of acid deposition on forests. The task group stated that forests had become one of the major issues related to acid deposition, but that critical questions remained unanswered about the role of acid deposition in forest decline, and that knowledge about forest effects was well behind that relative to other national program research areas.

[1]A condition in plants in which the branches or shoots die from the tip inward, caused by any of several parasites, environmental conditions, or other factors.

Through fiscal year 1985 the task force's Terrestrial Effects Task Group had funded 17 projects, totalling $11.2 million, to determine how acid deposition and other air pollutants may affect forests.[2] The projects include:

- eight tree growth projects, totalling $2.8 million, designed to examine acid deposition's impact on mature trees and tree seedlings;
- seven soil process projects, totalling $919,000, designed to determine how acid deposition changes soil chemistry;
- a National Vegetation Survey, totalling $2.5 million, designed to determine the extent of forest damage and decline in the northeast; and
- one project, referred to by the task force as its Mechanistic Studies project, totalling $5 million, designed to determine the processes and mechanisms involved in forest decline and damage, and the role that air pollution has in forest changes.

The eight tree growth and seven soil process projects were initially funded prior to fiscal year 1985 before forests became a priority research effort. In general, the projects represent small laboratory experiments, designed to explore the impact that acid deposition may have on mature trees, tree seedlings, and nutrients in the soils. With the exception of one of the tree growth studies, none of the research was designed to quantify forest damage or, more importantly, to determine acid deposition's role in forest damage and decline. The one project which attempted to do so failed because of problems with its design. With the exception of two tree growth studies, all research funded prior to fiscal year 1985 terminated as of September 30, 1985, and future tree growth and soil process work relating to forests will be performed under the task force's newly developed Mechanistic Studies project.

The National Vegetation Survey and the Mechanistic Studies project, new initiatives funded in fiscal year 1985, are designed specifically to quantify forest damage and decline, and to determine how acid deposition and other air pollutants affect forests. The vegetation survey will, through tree measurements and visual observations of forest conditions, develop estimates of forest growth decline and damage. The Mechanistic Studies project will combine soil process, deposition monitoring, and tree growth work to determine how and to what extent acid deposition and other air pollutants affect major forest types, such as spruce and fir.

[2]The Terrestrial Effects Task Group also provided about $9 million for 12 watershed research projects and $1.5 million for a National Soil Survey. These projects primarily involve aquatic effects research and, consequently, were discussed in chapter 2.

eastern hardwoods, including oak, hickory, and maple; and southern commercial forests.

As shown in table 3.1, EPA and Agriculture have funded virtually all forest effects research, providing $11 million of the $11.2 million in funds through fiscal year 1985. DOE provided the remaining $0.2 millio As also shown in table 3.1, only about $2.9 million of the total funds were provided prior to fiscal year 1985. The bulk of forest effects research funding came in fiscal year 1985 with the initiation of the National Vegetation Survey and the Mechanistic Studies project.

Table 3.1: Forest Effects Research Funding by Agency

Dollars in millions

Agency	Fiscal years 1982-84	Fiscal year 1985	Tot
Agriculture	$1.0	$4.6	$5
EPA	1.7	3.7	5
DOE	.2	0	
Total	$2.9	$8.3	$11

The remainder of the chapter is devoted to a discussion of the funding and results of the eight tree growth and seven soil chemistry projects initiated prior to fiscal year 1985, and the two new forest effects initiatives—the National Vegetation Survey and the Mechanistic Studies project—initiated in fiscal year 1985.

Projects That Address Acid Deposition's Effects on Tree Growth

Eight projects, funded by EPA, DOE, and Agriculture, totalling $2.8 million, involve studies of how acid deposition affects tree growth. Three of the studies involved mature trees, including one—Forest Response to Anthropogenic[3] Stress (FORAST)—which attempted to quantify forest decline and correlate it with acid deposition. The second mature tree study, an EPA project completed in 1983 at a cost of $150,000, gathered data on sulfur dioxide levels in eastern Tennessee forests. The third, a multi-year project funded by Agriculture's Cooperative State Research Service for $700,000, was just getting underway at the time of our review and involves a variety of issues, including the interaction of acid deposition and disease in red spruce decline and the impacts of acid deposition and ozone on trees in California.

[3]Man-made.

The five remaining projects primarily involved laboratory experiments of acid deposition's effects on tree seedlings. Overall, the results showed that seedling roots and other organisms aiding in providing nutrients to trees may be damaged by high acidity levels. But acid deposition's effects on tree seedling growth were inconclusive, as some seedlings increased in growth at high acidity levels, while others decreased in growth.

The FORAST Study

EPA initiated the FORAST study in 1982 to quantify growth changes in forests in the eastern United States and to determine the relative contribution of acid deposition and other atmospheric pollutants in observed changes in forest growth. The project, performed by the Oak Ridge National Laboratory and others at a total cost of $700,000, involved analyzing two different tree cores collected from 7,000 trees in 15 eastern states to determine the extent of tree growth changes over the past 50 years. Changes in growth rates were determined by measuring the width of tree rings on the tree cores (tree-core analysis). The changes were then compared with variables such as climate, soil fertility, and sulfur dioxide and nitrogen oxide emissions data to determine what correlations, if any, existed between the changes and the variables.

In August 1984 a preliminary report was prepared summarizing the research results. Overall, the report stated that the tree-coring analyses indicated a slowing of tree growth beginning around 1960 throughout the entire Appalachian region, ranging from an abrupt change in the growth rate of certain species of spruce, fir, and pine, to a more subtle change for other hardwood and softwood trees in the region. The report also stated that atmospheric pollution may be an important factor in the observed changes because

- the observed changes were largest in areas where the atmospheric deposition of pollutants was the highest—the northeastern United States and at higher elevations;
- the observed changes intensified during a time period when sulfur dioxide and nitrogen oxide emissions were strongly increasing across the region; and
- at several sites analyzed, the growth rate changes corresponded well to changes in sulfur dioxide emissions in those regions.

In September 1984 an independent scientific panel comprised of forest science experts and a statistician reviewed the FORAST draft report and raised serious questions about the study's design and methodology, and

whether the data supported forest decline much less tied forest decline to acid deposition. Specifically, the reviewers noted that

- the FORAST study did not scientifically establish that an abnormal decline in tree-ring growth had occurred (that is, the decline in tree-ring growth could be due to natural factors, such as climate or disease, or to forest management practices);
- the lack of reliable or convincing proof of a larger-than-expected reduction in tree growth made it impossible to attribute man-made pollution as the cause of the decline; and
- inadequacies in the design and extent of sampling provided only case study information on the specific tree plots studied and prevented projecting growth trends away from the test sites.

Because of these design shortcomings, the panel recommended that the FORAST data not be published.

In December 1984 representatives from EPA, the FORAST principal researcher, and several of the reviewers met to decide the future course of action in view of the panel's comments. These officials decided to consolidate the data from the states into a single data base so that others could use and analyze the information. The group also decided to perform additional analyses of the red spruce data to see if these data could be used to demonstrate decline. The red spruce data were selected because they contained the most complete information on the conditions of the trees from which the cores were taken. According to the FORAST project officer, these tasks are expected to be completed by January 1986.

The task force originally planned to use the FORAST data as an integral part of its 1985 assessment of the physical and economic damage caused by acid deposition. Our review of the August 1984 draft outline pertaining to the forest segment of the assessment, and discussions with the member of EPA's Acid Deposition Assessment Staff responsible for the terrestrial section of the assessment, showed that the FORAST data would be used to quantify forest decline on a regional basis and to correlate the decline to acid deposition. However, in March 1985, the EPA staff member told us that because of the criticisms raised by the review panel, the FORAST data would be included in the assessment to describe the types of information available on forest damage and decline, but would not be used, as originally planned, to quantify forest decline or to relate acid deposition to forest decline.

Tree Seedling Research

Five projects—three funded by EPA and one each by Agriculture and DOE—totalling about $1.3 million, involved studies of how acid deposition affects tree seedlings.

The three EPA projects involved the application of simulated acid deposition to tree seedlings to observe effects on seedlings, their roots, and other organisms aiding in the tree nutrient process. Results from the three projects were inconclusive as to how increased acidity affects tree seedlings. For example, one of the studies, completed in 1983 at a cost of $30,000, found that acidity levels of pH 4.0 reduced the height but increased the diameter of loblolly pine seedlings. Another study, completed in March 1985 at a cost of $85,000, showed that white oak and loblolly pine seedling growth decreased but that red spruce and green ash seedling growth increased. It also found that damage to lichen—a fungus/algae which grows on trees and rocks—occurred at pH levels between 2.6 and 4.2. The third EPA project, completed in February 1984 at a cost of $85,300, found that high levels of acid precipitation caused reduced root length in short leaf and loblolly pine.

The DOE project, initiated in fiscal year 1982, attempted to design three experimental plots within an existing forest to determine the effects of different acid deposition levels on forest growth. Researchers attempted to design the plots in such a way that they could control the deposition reaching the tree seedlings but allow the seedlings to experience all other natural forest occurrences. However, after spending about $165,000 on the project, DOE terminated it in early fiscal year 1985 because of continuing problems in designing the research plots.

The last tree seedling project is an ongoing Agriculture effort to assess and quantify the beneficial and injurious effects of acid deposition on forests. The work will be performed by the Forest Service's Northeastern Forest Experimental Station in Ohio as part of its continuing research work. It will involve laboratory and other controlled environment experiments in which hardwood tree seedlings, such as elm, yellow poplar, and black cherry, will be exposed to acid deposition and other air pollutants to better understand how these pollutants affect tree growth, structure, and productivity. Earlier work under this project included studies of ozone's effects on forests in the Blue Ridge and southern Appalachian mountains of Virginia, which showed that ozone from distant industrial complexes in the northwest and northeast is responsible for reduced tree growth in this region. Funding for this project, including the hardwood tree seedling work, totals about $950,000.

Projects That Address Acid Deposition's Effects on Soil Chemistry

In addition to direct effects of acid deposition on trees, scientists are concerned with its possible indirect effects on forest soils. One concern involves the accelerated loss of essential plant nutrients by acid deposition. Forest soils contain limited nutrient supplies, and nutrient depletion may occur to the point where forest growth is affected. Another concern involves the accelerated release of toxic materials, such as aluminum. Aluminum is relatively abundant in soils and when released, eventually enters surface waters where it may be toxic to fish.

Seven projects, funded by EPA for $918,900, involve studies of how acid deposition affects soil chemistry as it passes through the soil. Overall, the research has shown that as the acidity of water entering the soil increases, the amount of nutrients released from the soil also increases. The amount of nutrients released depends on the soil type and other soil characteristics, such as air spaces in the soil and its moisture content. The following are results from three of EPA's soil process research projects.

- A $315,000 research project by the Oak Ridge National Laboratory studied how acid deposition affected nutrients in the soils in one western and four eastern states. The researchers found that acid deposition increased the rate by which nutrients were leached from the soil at study sites in the eastern states from 50 to 100 percent. In the one western state, however, nutrient leaching increased by only 1 to 2 percent primarily because of the high level of acids naturally produced by western soils.
- A $79,000 project by the University of Florida studied how acid deposition affected nutrient leaching for three types of soils in South Carolina and Florida. The research showed that nutrient loss due to leaching was proportional to the acidity of the infiltrating waters, that is, the more acidic the water going through the soil, the greater the nutrient loss.
- An $80,000 project by Clemson University studied how acid deposition affected the release of aluminum from southern Piedmont area soils. The research showed that an acidity level of pH 4 had a negligible effect on the release of aluminum, but at a pH 3 level, aluminum was rapidly released and large scale breakdowns of clay in the soils occurred.

The soil chemistry projects terminated in August 1985, and future soil chemistry research will be conducted as part of watershed research or the newly initiated forest effects research.

New Forest Effects Research Initiatives

Realizing that critical questions remained unanswered about the extent of acid deposition's role in forest decline, the Terrestrial Effects Task Group initiated, in fiscal year 1985, a National Vegetation Survey to develop information on the nature, extent, and severity of forest decline and damage in this country. The task group also initiated a Mechanistic Studies project to determine the mechanisms involved in forest decline and damage and air pollution's role in forest change. Several years will expire before this information is available because results on the extent of damage from the National Vegetation Survey are not anticipated until 1989, and the cause/effect relationship from the Mechanistic Studies work until 1990 or later.

National Vegetation Survey

Despite evidence of damage and decline in forests, no scientific data are available on the nature, extent, or severity of forest damage or decline in this country. The National Vegetation Survey is designed to fill this knowledge gap. Its primary objective is to provide—through actual tree measurements and visual observations—geographic estimates of forests in the eastern United States showing unexplained damage to tree foliage or unexplained reductions in tree growth.

The survey consists of three phases. The first phase involved developing methods and procedures for measuring the radii of trees, and criteria for visually observing and recording their overall conditions. The Forest Service official serving as program manager for the survey told us that work to test and refine the procedures and criteria is ongoing and should be completed by the end of December 1985.

The second phase will be the actual survey of forest damage and decline. A pilot survey is scheduled to begin in February 1986 and continue throughout 1986 that will further refine the survey procedures and criteria as well as develop survey data for two sites in the eastern part of the country. The actual survey of forests in the eastern portion of the country is scheduled for 1987 and 1988. The Forest Service program manager for the survey told us that the sites to be surveyed will be selected from the nearly 100,000 plots the Forest Service uses to regularly collect forest inventory data as part of its Forest Inventory and Analysis Program. A combination of random and preselected sites will be selected. The task force plans to have the survey completed and the results available for the national program's final assessment in 1989.

The third phase involves a long-term monitoring effort to detect changes in forest conditions as air pollution emissions increase or decrease.

According to the survey program manager, the third phase, if implemented, will not begin until the early 1990's.

Funding for the survey in fiscal year 1985 totalled $2.5 million; $2.3 million came from the Forest Service and $200,000 came from EPA.

Mechanistic Studies Project

According to the task force, sulfur compounds, the predominant cause of acid deposition in the eastern United States, is no longer considered the only air pollutant that may affect forests. Nitrogen compounds, oxidants, and other air pollutants also appear to cause forest damage. The Mechanistic Studies project, initiated in fiscal year 1985, is designed to clarify how and in what ways air pollution damages our forests and the role of each pollutant in forest change.

The central theme of the Mechanistic Studies project is the use of a single body of scientists, referred to as a Research Cooperative, to develop an understanding of how a particular forest type in a particular region responds to atmospheric deposition. Four cooperatives have been established: spruce and fir; southern commercial forests; eastern hardwoods, including oak, hickory, maple, beech, and birch; and Douglas fir and Ponderosa pine. The forest types to be studied by the cooperatives were selected because of their economic importance and/or evidence of unexplained damage or dieback.

According to the Mechanistic Studies' December 1984 draft research plan, a number of theories exist concerning the actual mechanisms involved in forest decline. One theory is that atmospheric deposition may diminish a tree's ability to take up water or to control water loss from leaves, and thus increases its susceptibility to moisture stress. Another is that deposition may alter the tree's uptake of nutrients and result in a nutrient imbalance. A third is that atmospheric deposition may make trees more susceptible to attack by insects and disease. The research plan states that these and other hypotheses of how forests may be affected by atmospheric deposition will be explored and their significance determined by the Mechanistic Studies work.

The task force plans that by 1987, the Mechanistic Studies will provide (1) an estimate of the effects of sulfur dioxide, nitrogen oxide, and oxidants in forest damage, (2) a list of hypotheses of how damage may occur, (3) a preliminary model of how forests will respond to various levels of atmospheric deposition, and (4) a listing of tree species sensitive to or likely to be affected by deposition. By 1989 the task force

hopes that the Mechanistic Studies work will provide information concerning the specific effects various levels of a single pollutant or a combination of pollutants have on forests, and develop the ability to predict how forests will respond to various levels of air pollution.

Fiscal year 1985 funding for the Mechanistic Studies totalled $5 million: EPA contributed $3.3 million and the Forest Service contributed $1.7 million. These funds were used to purchase equipment and to support research by the spruce/fir and southern commercial forests cooperatives. The eastern hardwoods and the Ponderosa pine/Douglas fir cooperatives are scheduled to begin research in fiscal year 1986. Once underway, the task group expects each of these cooperatives to operate on an annual budget of approximately $1.5 million.

Information on Acid Deposition Research Funding

Funding for acid deposition research has steadily increased since fisc year 1982 and more than doubled from $29 million in fiscal year 1984 $65 million in fiscal year 1985. Although the fiscal year 1985 funding totalled about $10 million less than requested, task force officials gen ally considered the fiscal year 1985 funding sufficient to carry out essential research. Public and private groups outside the task force might emphasize different research priorities, but none indicated that acid deposition funding was not adequate.

Overview of National Program Budget Process and Funding

As noted in chapter 1, the task force is responsible for developing the annual task force research budget for the national program. The task force generally receives guidance from OMB that establishes funding levels for task force budget requests. This guidance is passed on to the individual task groups, who decide which research projects will be funded and which agency will fund the projects. Individual task group budgets are prepared and once approved by the task force are combine into the task force budget and forwarded to OMB for review, approval, and eventual inclusion in the President's budget to the Congress.

The task force budget identifies the funding proposed for each of the nine research categories and for international activities. The budget als identifies the amount of funds each agency will provide to support the research because the task force does not receive appropriations as a sep arate entity. Rather, funding for the task force is appropriated to each agency through its normal budget process.

Five agencies—EPA, Agriculture, DOE, Interior, and NOAA—fund virtually all the research. As shown in table 4.1, EPA has provided nearly $70 million, or about 53 percent, of the $133 million in total research funds provided through fiscal year 1985. According to the Director, EPA Office of Acid Deposition, Environmental Monitoring, and Quality Assurance, EPA is responsible for determining and developing policy issues relating to acid deposition, and the funding reflects the high priority EPA has given acid deposition and its desire to ensure that all the necessary research for making policy decisions is performed.

Table 4.1: Total Acid Deposition Research Funding by Agency Through Fiscal Year 1985

Dollars in thousands

Agency	FY82	FY83	FY84	FY85	Total
EPA	$ 9,125	$11,436	$14,608	$34,512	$ 69,681
Interior	2,110	3,567	4,995	8,396	19,068
DOE	2,544	2,060	3,929	8,736	17,269
Agriculture	1,349	2,963	2,808	9,100	16,220
NOAA	1,900	2,250	2,336	4,148	10,634
TVA	325	•	•	•	325
Total	**$17,353**	**$22,276**	**$28,676**	**$64,892**	**$133,197**

Research funding among the task force's 10 task groups varies considerably. The two task groups that are the focus of this report—aquatic effects and terrestrial effects—account for $54.7 million, or 41 percent, of total research funds through fiscal year 1985. Funding for each of the task groups through fiscal year 1985 is shown in table 4.2.

Table 4.2: Funding Provided to Task Groups Through Fiscal Year 1985

Dollars in thousands

Task group	FY82	FY83	FY84	FY85	Total
Natural sources	$ 600	$ 700	$ 847	$ 1,155	$ 3,302
Man-made sources	1,170	1,350	2,100	2,335	6,955
Atmospheric processes	4,854	5,232	6,392	14,019	30,497
Deposition monitoring	3,034	4,409	5,991	8,501	21,935
Aquatic effects	3,052	3,363	4,290	15,895	26,600
Terrestrial effects	2,850	4,437	4,507	16,346	28,140
Effects on materials and cultural resources	428	995	1,495	1,984	4,902
Control technologies	•	•	•	625	625
Assessments and policy analysis	1,365	1,790	3,054	4,032	10,241
International activities	•	•	•	•	•
Total	**$17,353**	**$22,276**	**$28,676**	**$64,892**	**$133,197**

As table 4.2 shows, funding for the aquatic effects and terrestrial effects task groups more than tripled in fiscal year 1985 from the fiscal year 1984 level as ongoing task force efforts were continued and new ones were initiated to determine acid deposition's effects on our lakes, streams, and forests. As discussed in chapters 2 and 3, the task force is emphasizing broad-based, multi-million dollar research efforts, such as (1) the National Surface Water Survey to quantify surface water acidification, (2) the direct/delayed response project to determine which watershed soils delay surface water acidification and which do not, and

(3) the Mechanistic Studies project to determine how, and to what extent, atmospheric deposition affects forests.

Task Force Views on Fiscal Year 1985 Funding Adequacy

In fiscal year 1985, the task force requested more research funds than eventually received. Based on OMB guidance, the task force in October 1983 requested $35 million for fiscal year 1985. However, in its budget request to OMB, the task force expressed concern that $35 million was inadequate to conduct the research needed to address important acid deposition issues. Consequently, later in the same month, the task force submitted a second fiscal year 1985 budget to OMB requesting $82 million. The task force stated that this level of funding was desired to speed up the research and to provide greater confidence in its results. The task force stated that as a minimum, $74 million was needed to perform research that the task force considered essential to the program. An EPA Science Advisory Board ad hoc panel that had reviewed the national program recommended that task force funding for fiscal year 1985 should be, at most, $55 million, or approximately double the fiscal year 1984 funding. OMB adopted the panel's recommendation and approved a $55.5 million acid deposition research budget for fiscal year 1985. The Congress, in acting on the individual budget requests of the agencies funding acid deposition research, appropriated $64.9 million for fiscal year 1985.

In discussing the program's funding before the Senate Committee on Environment and Natural Resources in April 1984, the task force's executive director noted that while it is desirable to put as much effort into research as possible, the ad hoc panel that reviewed the national program advised that $55 million for fiscal year 1985 was the most funds the program could effectively spend. The Director of EPA's Office of Acid Deposition, Environmental Monitoring, and Quality Assurance, who serves as EPA's representative on the task force's executive committee, told us that while the research projects in the task force's fiscal year 1985 budget request for $82 million were worthwhile, the task force had not fully developed or planned many of these projects and could not have effectively used the entire $82 million in fiscal year 1985 had it received that amount.

Of the nine research task groups funded in fiscal year 1985, only the task group leader for the Effects on Materials and Cultural Resources research category believed that his area could use more funds. The Effects on Materials and Cultural Resources category involves research

to determine how acid deposition affects various man-made and natural materials, such as metals, paints, stone, concrete, and marble.

Our analysis of the fiscal year 1985 budget request showed that the task force requested about $3.6 million for the Effects on Materials and Cultural Resources area to do new or expand ongoing work, such as field exposure studies of man-made materials, concrete damage research, and historic site damage monitoring. However, the task group received a total of $2 million—$1.6 million less than requested but an increase of about $500,000 above the fiscal year 1984 level.

The task group leader told us that Effects on Materials and Cultural Resources research has not received priority funding in relation to other task force research. As an example of the importance of this area, we were referred to a national program draft study released in July 1985, which estimates that in a 17-state region, acid deposition annually causes about $5 billion in damage to buildings and other structures. The task group leader noted that these results are very preliminary because of the limited field work done in conjunction with the study. Nevertheless, he believed that the study points out the impact that acid deposition appears to have on our materials and cultural resources, and highlights the need for additional research in this area.

The Effects on Materials and Cultural Resources Task Group currently has five permanent sites—one each in Washington, D.C., New Jersey, New York, North Carolina, and Ohio—where tests are performed regarding air pollution's effects on metals, limestone, and marble. The task group leader told us that the Effects on Materials and Cultural Resources Task Group could use major funding increases to

- expand field monitoring work beyond the current five sites,
- initiate research involving concrete and paint damage, and
- intensify laboratory work to correlate damage to materials with specific air pollutants.

In February 1984, a panel reviewing Effects on Materials and Cultural Resources research concluded that funding in this area was very low relative to its importance to the overall acid deposition issue. At the time of the review, funding for Effects on Materials and Cultural Resources totalled about $1.5 million, or about 5 percent of the $28.7 million in research funding for fiscal year 1984. The reviewers recommended that the task force provide greater funding to support the

effects on materials area, but did not specify how much of an increase i funding should be provided.

In February 1985 the task force's executive director acknowledged that the task force had placed a lower priority on material effects research, but stated that the task force planned to give this area more attention. Proposed fiscal year 1986 funding for the Effects on Materials and Cultural Resources research category totals about $2.1 million—a $127,00(increase over fiscal year 1985. This increase represents less than 1 percent of the total increase in national program funds between fiscal year 1985 and 1986.

The task group leader for the Effects on Materials and Cultural Resources research category told us that in his opinion, about twice the fiscal year 1986 proposed funding level would be a reasonable figure to perform needed research in this area. At the same time, he said that it would be difficult to find federal agencies that are willing and whose laboratories are equipped to perform research involving acid deposition's effects on man-made materials and cultural resources. He said that none of the national program agencies have materials and cultural resources as their primary mission, and that the Department of Defense (DOD) would be the ideal agency to perform such research because of the work it does in testing how weather and other elements affect military equipment and hardware. He noted, however, that DOD is not a part of the national program effort.

Fiscal Year 1986 Research Funding

The President's budget for fiscal year 1986 requested about $85.4 million for acid deposition research, a $20.5 million increase over the fiscal year 1985 level. As shown in table 4.3, the terrestrial effects and the aquatic effects areas represent the largest and second largest research categories and together account for 51 percent of the funds requested for fiscal year 1986. The $23.1 million proposed for terrestrial effects represents a $6.8 million increase over fiscal year 1985, while the $20.6 million proposed for aquatic effects represents an increase of about $4.7 million.

Table 4.3: Proposed Fiscal Year 1986 Task Group Funding

Dollars in thousands

Task group	Fiscal year 1986
Natural sources	$ 1,155
Man-made sources	4,113
Atmospheric processes	18,796
Deposition monitoring	10,994
Aquatic effects	20,569
Terrestrial effects	23,105
Effects on materials and cultural resources	2,111
Control technologies	623
Assessments and policy analysis	3,931
International activities	0
Total	**$85,397**

Six agencies—EPA, Agriculture, DOE, Interior, NOAA, and TVA—have proposed research funds for fiscal year 1986. As shown in table 4.4, EPA proposes funding $60.5 million, or about 71 percent of the total acid deposition research funding for fiscal year 1986. The $60.5 million represents a $25.5 million increase over the $35 million that EPA provided in fiscal year 1985. While EPA is planning to substantially increase its funding, the other agencies generally are funding at or below their fiscal year 1985 levels. NOAA's $4.15 million level for fiscal year 1986 equals its fiscal year 1985 level, while Agriculture, Interior, and DOE's fiscal year 1986 levels are about $3.8 million, $2 million, and $114,000, respectively, less than their fiscal year 1985 levels. The $400,000 to be provided by TVA represents the first funds provided for acid deposition research by the agency since fiscal year 1982.

Table 4.4: Proposed Fiscal Year 1986 Research Funding by Agency

Dollars in thousands

Agency	Fiscal year 1986
EPA	$60,507
NOAA	4,148
Agriculture	5,333
DOE	8,622
Interior	6,387
TVA	400
Total	**$85,397**

Views of Outside Organizations on National Program Funding

Our discussions with representatives of public and private sector groups having an interest or involvement in acid deposition research showed that while some might emphasize different aspects of research than those reflected in the priorities set by the task force, no one indicated that the program was not adequately funded.

The chairman of the ad hoc panel that reviewed the national program and recommended the $55 million budget for fiscal year 1985 considered the funding to be adequate. He told us that the panel anticipated that the national program would grow and eventually stabilize at $100 million a year, but that the $55 million budget was the most funding the national program could effectively absorb at that time. He also told us that how soon the program reaches the $100 million figure would depend on the rate and success of the ongoing research.

The Utility Air Regulatory Group (UARG) is a national consortium of utilities whose membership includes the Edison Electric Institute, the National Rural Electric Cooperative Association, the American Public Power Association, and 75 electrical utilities. The Chairman of UARG's Acid Deposition Committee on the national program told us that the basic question is not whether additional funds are needed, but whether or not the national program can effectively manage additional funds. He noted that the national program's $55 million budget for fiscal year 1985 was recommended by an ad hoc panel that had performed an exhaustive review of the national program and which concluded that this level of funding was the most the program could effectively absorb.

A representative of the National Wildlife Federation told us that it is not a question of more funds, but how existing funds are used. He told us that his organization believes there is sufficient evidence to show that acid deposition has and is damaging our lakes and streams, and that the national program should place more emphasis on research of methods for reducing sulfur dioxide emissions. Similar views were expressed by a representative of another conservation organization, the Izaak Walton League, who told us that the national program should focus more research efforts on nitrogen oxide reduction strategies and technologies because of its possible role in forest decline.

OMB's Environmental Branch is responsible for reviewing the national program budgets. The branch chief and the OMB budget examiner responsible for the national program budget believed that funding was adequate. They told us that OMB's decision to limit the program to about $55 million in fiscal year 1985 was heavily influenced by the ad hoc

panel's recommendation that funding should not exceed this amount for fiscal year 1985.

Observations

The question of whether or not national program funds for acid deposition research are adequate to perform necessary research is one often asked of research programs. With the possible exception of the Effects on Materials and Cultural Resources category, national program officials and representatives of interested public and private organizations believe that funds are adequate. Moreover, the issue appears not to be whether the national program should be given additional funds but whether it could have made effective use of increased funds. The comments from several national program officials, as well as several individuals outside the national program, indicate that at least during fiscal year 1985, substantial increases in funds could not have been effectively used.

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