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U.S. Environmental Protection Agency
Office of Ecological Processes and Effects Research
Office of Modeling, Monitoring Systems, and Quality Assurance
Office of Research and Development, Washington, DC 20460

Environmental Research Laboratory – Corvallis, OR 97333
Environmental Monitoring Systems Laboratory – Las Vegas, NV 89114
Environmental Research Laboratory – Duluth, MN 55804
Environmental Monitoring Systems Laboratory – Cincinnati, OH 45268
Atmospheric Research and Exposure Assessment Laboratory – Research Triangle Park, NC 27711

NOTICE

This document, which describes the research strategy and completed, ongoing and proposed activities for the Aquatic Effects Research Program (AERP), was prepared for distribution through the AERP Technology Transfer Program. Every effort has been made to ensure that the content of this document is consistent with the current research program plans; the exact content of the descriptions, however, is subject to change as new information is received from AERP Program Managers. Therefore, the information contained herein should not be considered final, and is to be updated on an annual basis to reflect the most current program plans. In addition, because the authors were instructed to limit the length of the summaries to one page, the descriptions do not contain extensive details. The reader is encouraged to contact key individuals (as designated on each research activity summary) for more specific information.

PREFACE

This document has been prepared to provide to scientists and administrators, both within and outside the U.S. Environmental Protection Agency, the most current information on the research strategy in the Aquatic Effects Research Program (AERP) and the projects that contribute to that strategy. The AERP is a matrixed managed program, involving five laboratories within the Office of Ecological Processes and Effects Research (OEPER) and the Office of Modeling, Monitoring Systems, and Quality Assurance, both of which are part of the Environmental Protection Agency's Office of Research and Development. Administration is through OEPER. The AERP also is part of the National Acid Precipitation Assessment Program's Aquatics Task Group, which involves seven federal agencies led by the Environmental Protection Agency.

The materials contained herein summarize AERP research activities funded in FY88 and FY89 and those proposed for funding in FY90. For information on completed or currently funded research, the technical contact indicated on each summary should be consulted For information on activities that are proposed (indicated as such in the "status" category on each description), or on the AERP research strategy, contact:

Daniel McKenzie
Director, Aquatic Effects Research Program
U.S. Environmental Protection Agency
Environmental Research Laboratory - Corvallis
Corvallis, OR 97333
(503) 757-4666

ABSTRACT

The Aquatic Effects Research Program was developed to determine the effects of acidic deposition on surface waters in selected regions of the United States. The program focuses on four policy questions: (1) What is the extent and magnitude of past change attributable to acidic deposition? (2) What change is expected in the future under various deposition scenarios? (3) What is the target loading below which change would not be expected? (4) What is the rate of recovery if deposition decreases? The goal of the program is to characterize and quantify with known certainty the subpopulation of surface waters that will respond chemically to current and changing acidic deposition and to determine the biological significance of observed or predicted changes. The Aquatic Effects Research Program has five major component programs designed to increase understanding of long-term acidification: the National Surface Water Survey, the Direct/Delayed Response Project, Watershed Processes and Manipulations, Long-Term Monitoring, and Indirect Human Health Effects. Short-term acidification is being addressed through the Episodic Response Project, and issues of both chronic and acute acidification are addressed through Biologically Relevant Chemistry. The results of these eight programs are being used collectively in the Synthesis and Integration Program, designed to provide information that allows (1) the policy questions to be addressed quantitatively and (2) the AERP goal to be satisfied.

Critical tasks for the future include (1) contributing to the 1990 goal of the National Acid Precipitation Assessment Program to assess the effects of acidic deposition on surface waters in the United States, (2) implementing research to verify model predictions relating to future effects of acidic deposition on aquatic ecosystems, and (3) establishing a long-term monitoring network capable of detecting biologically significant changes in the chemistry of representative lakes and streams that can be related to known regional populations of aquatic systems.

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SECTION 1

RESEARCH STRATEGY

1.1 INTRODUCTION

In 1980, the U.S. Environmental Protection Agency (EPA) instituted the Aquatic Effects Research Program as a part of the National Acid Precipitation Assessment Program (NAPAP).[1] The Aquatic Effects Research Program is one of many programs within EPA that is addressing the environmental effects of acidic deposition. The Aquatic Effects Research Program is administered through the Office of Ecological Processes and Effects Research within the Office of Research and Development.

Five EPA Laboratories have conducted or presently are conducting research projects within the Aquatic Effects Research Program: the Environmental Research Laboratories in Corvallis, OR, and Duluth, MN; the Environmental Monitoring Systems Laboratories in Las Vegas, NV, and Cincinnati, OH; and the Atmospheric Research and Exposure Assessment Laboratory in Research Triangle Park, NC. The scope, complexity, and policy relevance of the Aquatic Effects Research Program necessitate close coordination and communication among the laboratories, the administrative office, other federal agencies, and state agencies. This document provides such a mechanism by summarizing the fiscal year 1989 research strategy, the projected plan to and beyond 1990, and the research projects funded between fiscal years 1987 and 1989.

1.1.1 Background and Purpose of the Research Program

Four policy questions have guided the design, direction, and focus of the Aquatic Effects Research Program:

1. What is the extent and magnitude of past change attributable to acidic deposition?
2. What change is expected in the future under various deposition scenarios?
3. What is the target loading below which change would not be expected?
4. What is the rate of recovery if deposition decreases?

In light of these policy questions, the primary goal of the Aquatic Effects Research Program is to characterize and quantify with known certainty the subpopulation of surface waters that will respond chemically to current and changing acidic deposition, and to determine the biological

[1]NAPAP was established as a federal, interagency program by Congress through the Acid Precipitation Act of 1980. Activities within NAPAP are collectively funded by the federal agencies. The lead agency for the Aquatic Effects Task Group within NAPAP is EPA. The strategy presented here is applicable only to EPA's program.

significance of observed or predicted changes. The component projects address the effects of both chronic and acute exposure to acidic deposition, i.e., the potential for long-term and short-term acidification. The four major elements of the present program include characterizing the chemical status and quantifying the extent of surface waters at risk, forecasting the future chemical and biological changes in aquatic ecosystems, verifying these forecasts and improving the understanding of controlling mechanisms, and validating these findings through long-term monitoring.

1.1.2 Approach

Providing scientifically sound answers to the four policy questions requires regional-scale data collection efforts and model applications. From 1980 to 1983, however, research on the effects of acidic deposition on aquatic resources was focused primarily on the processes and mechanisms underlying surface water response to acidic inputs. This type of research, which typically requires intensive investigation conducted on a limited number of sites, is essential to refine our understanding of factors controlling acidification. But, because a primary goal of EPA is to provide information that can be used to assess the national-scale risk that acidic deposition poses to aquatic resources, the approach of the Aquatic Effects Research Program was expanded in 1983. The present design was implemented in 1984 upon recognition that current knowledge is limited, not necessarily by the level of understanding of the processes, but by an understanding of the extent, rate, and magnitude of effects. Site-specific research remains essential for advancing and refining our understanding of the mechanisms that control aquatic response to acidic deposition. To avoid drawing conclusions relevant only to specific study sites, however, the Aquatic Effects Research Program now also includes projects designed to characterize surface waters and watersheds on large geographical scales. The data from these projects are being used to test the applicability of hypotheses generated by site-specific research to systems at regional scales. Thus, the Aquatic Effects Research Program continues to pursue both regionally extensive and locally intensive research efforts.

The present program represents an integrated approach that considers both a broad-scale (top-down) perspective as well as a narrow-scale, individual system (bottom-up) perspective (Figure 1). The top-down approach allows many lakes, streams, or watersheds within many geographic regions to be described on the basis of a few samples collected from a subset of selected systems. The first step in this approach is a synoptic survey, providing a "snapshot" of surface water chemistry or soil characteristics on a regionally significant geographic scale. The approach employs statistically based site selection, standardized sampling procedures and analytical methods, and rigorous quality assurance protocols. The resulting regional characterization provides a frame by which the characteristics of subsets of systems (subpopulations) can be defined. The results of

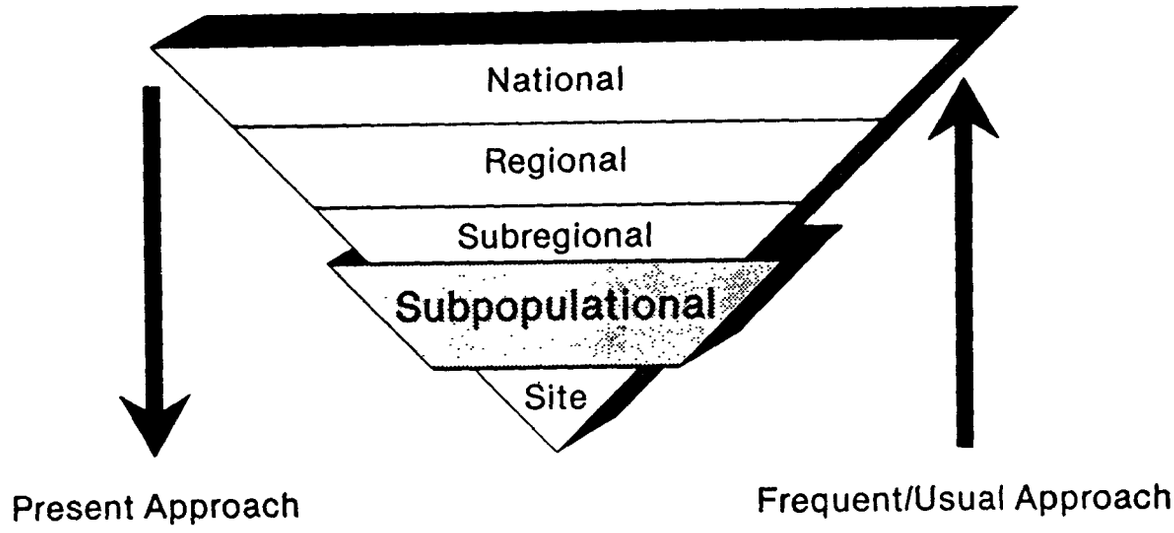


Figure 1. Regionalized classification approach employed in the Aquatic Effects Research Program. This approach focuses on identifying the subpopulation of aquatic systems at risk due to acidic deposition, permitting hypotheses developed from site-level research to be tested at subregional, regional, and national scales. Such testing increases understanding of the extent, magnitude, and rate of effects of acidic deposition.

intensive studies conducted on systems within these subsets can then be scaled to the regional population or to any intermediate subpopulation.

Conversely, inferential analyses resulting from the broad-scale approach may provide important hypotheses that can be tested only in individual systems. The information gained when the two approaches are combined can be used to develop a quantitative evaluation of the regional effects of acidic deposition, as well as the relative importance of processes or mechanisms in particular regions. Ideally, the two approaches should converge at the subpopulation level in order to provide a comprehensive understanding of the regional effects of acidic deposition on lakes and streams identified as sensitive. The Aquatic Effects Research Program's research strategy reflects this goal by coupling the large-scale projects with intensive projects.

The Aquatic Effects Research Program thus evolved from an initial focus (1980-1983) on site-selective, process-oriented research to its focus on regionalization from 1984-1988. As now planned, future research efforts in the program (beyond 1988) primarily will involve testing or verifying acidification hypotheses and developing model forecasts of regional aquatic effects. Through 1990, considerable effort will be focused on integrating the results of the program to allow surface waters to be classified on a regional and subpopulational basis Issues include examining evidence of

historical change and refining estimates of current status and forecasts of future change. This integration and synthesis represents a major contribution to NAPAP's State of Science and Integrated Assessment, both of which are scheduled for completion in 1990. Beyond 1990, the focus will continue to be on verifying existing models and developing new models of acidification (both chronic and episodic) and recovery, assessing the regional importance of episodes, and quantifying biological and chemical change through long-term monitoring.

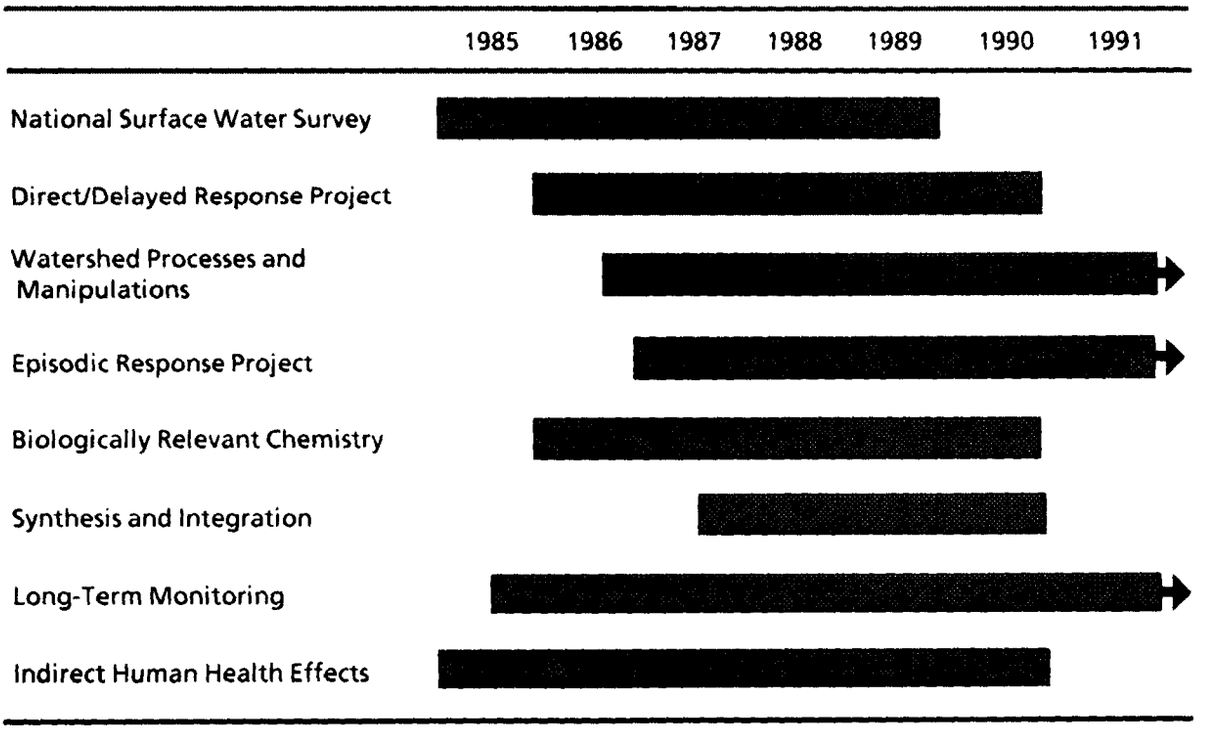
1.2 MAJOR PROGRAMS

The Aquatic Effects Research Program has eight major component programs:

- National Surface Water Survey,
- Direct/Delayed Response Project,
- Watershed Processes and Manipulations,
- Episodic Response Project,
- Biologically Relevant Chemistry,
- Synthesis and Integration,
- Long-Term Monitoring, and
- Indirect Human Health Effects.

The general schedule for completion of these programs is shown in Table 1.

Table 1. General Schedule for the Aquatic Effects Research Program



The National Surface Water Survey, focusing on chronic acidification, is divided into two components: the National Lake Survey and the National Stream Survey. Phase I efforts of both components concentrated on quantifying the current chemical status of lakes and streams. Phase II of the lake survey is designed to quantify seasonal variability in lake chemistry and to investigate the relationship between lake chemistry and fish population status. The Direct/Delayed Response Project is designed to investigate, distinguish, and forecast the time scales over which surface waters are expected to become chronically acidic given various levels of acidic deposition. The Watershed Processes and Manipulations component is a research effort designed to develop and verify hypotheses relevant to the factors and mechanisms under investigation in the Direct/Delayed Response Project. The Episodic Response Project focuses on surface water response resulting from acute or short-term pulses of acidic inputs (as might occur during storms and snowmelt). .The Biologically Relevant Chemistry component is evaluating the extent to which changes in surface water chemistry due to acidic deposition pose a risk to aquatic biota. The Synthesis and Integration component is an integrated analysis and dissemination of results from all research activities in the Aquatic Effects Research Program. The Long-Term Monitoring effort is designed to examine trends in the status of surface waters and to test the validity of conclusions derived from other research activities in the Aquatic Effects Research Program. Indirect Human Health Effects has focused on modification to drinking water supplies by acidic deposition and on bioaccumulation of metals, particularly mercury, in game fish used for human consumption.

1.2.1 National Surface Water Survey

The National Surface Water Survey was implemented to determine the present chemical status of lakes and streams in regions of the United States where the majority of surface waters with low acid neutralizing capacity are expected to occur. The objectives of the survey were to locate surface waters that are acidic or have low acid neutralizing capacity based on an index sampling period and to create a regional data base that would allow surface waters to be classified according to their physical and chemical characteristics.

In Phase I of the National Lake Survey, samples from approximately 2500 lakes were collected for determining a number of physical and chemical variables during fall of 1984 in the northeastern, southeastern, and upper midwestern United States, and during fall of 1985 in the western United States. These data have served to classify lakes so that subsets can be identified for more detailed studies in Phase II of the National Lake Survey and in other programs in the Aquatic Effects Research Program.

Phase II of the National Lake Survey – the Northeastern Seasonal Variability Study – was conducted in 1986. This project was implemented to refine the conclusions of Phase I with respect to

the present chemical status of lakes. Sampling was conducted during the spring, summer, and fall to determine whether lakes found not to be acidic in Phase I during the fall index period are acidic at other times of the year.

The National Stream Survey was implemented in 1985 with a pilot survey of 61 stream sites in the Southern Blue Ridge Province. Phase I was conducted in the spring and summer of 1986 in the Middle Atlantic region with the sampling of approximately 270 stream reaches. Information from the Southeastern Screening Survey (conducted on about 200 stream reaches in concert with the Middle Atlantic sampling) helped prioritize other stream sites for possible future survey activities. The screening covered areas of the Southern Appalachians, the Piedmont, and the Ouachita Mountains, and parts of the Florida Panhandle and Florida Peninsula identified in the National Lake Survey as having a large number of acidic lakes. Results of the National Stream Survey also were or will be used to select systems for analysis in the Direct/Delayed Response Project, Episodic Response Project, and the Temporally Integrated Monitoring of Ecosystems project (part of the Long-Term Monitoring program).

1.2.2 Direct/Delayed Response Project

Forecasting how constant, increasing, or decreasing acidic inputs might affect the chemical and biological status of lakes and streams in the future requires knowledge of the current conditions in surface waters and the primary factors that influence surface water response. Accurate forecasts also require an understanding of complex watershed-mediated processes and mechanisms, as well as the ability to quantify time frames within which responses are expected to occur. The Direct/Delayed Response Project was designed to provide the data needed to classify watersheds based on the time frames during which surface waters would be expected to become acidic (annual average acid neutralizing capacity decreases to zero), at various levels of sulfate deposition. The primary objectives of this research are to (1) characterize the regional variability of soil and watershed characteristics, (2) determine which soil and watershed characteristics are most strongly related to surface water chemistry, (3) estimate the relative importance of key watershed processes across the study regions, and (4) classify a sample of watersheds according to the time frames during which they would reach acidic status and extrapolate these sample results to the study regions.

In the soil survey component of the Direct/Delayed Response Project, a survey was conducted in 1985 in the Northeast on the watersheds of 145 lakes. Eighty-nine percent of these lakes also were selected for the Northeastern Seasonal Variability Study, and all were sampled in Phase I of the Eastern Lake Survey. In 1986, a second soil survey was completed on 35 watersheds in the Southern Blue Ridge Province, selected in conjunction with the pilot stream survey. A third soil survey is being

conducted on a subset of the stream sites in the Mid-Appalachians that also was sampled in the Middle Atlantic Stream Survey.

Three levels of data analyses are being used in the Direct/Delayed Response Project. Level I analyses employ multivariate statistical procedures and steady-state calculations such as sulfur input-output budgets. When integrated with available data, including those from the National Surface Water Survey, the analyses evaluate possible correlations between watershed characteristics and surface water chemistry.

Level II analyses provide order-of-magnitude time estimates of the system response rates to various levels of acidic deposition. These analyses are being used to estimate changes in individual system components considered to be important in controlling surface water acidification, such as sulfate retention and base cation supply.

Level III analyses use dynamic models that integrate key mechanisms controlling surface water chemistry to simulate changes in water chemistry over long periods of acidic deposition. These mechanisms include soil-water interactions (including water contact time), replacement of base cations through mineral weathering, sulfate retention, and base cation buffering. The forecast response times assist in classifying watersheds and estimating the number and geographic distribution of watersheds in each class.

1.2.3 Watershed Processes and Manipulations

Watershed Processes and Manipulations studies focus on testing acidification hypotheses through experimental acidification of aquatic systems and investigations of soil processes. The artificial acidification of a watershed in Maine and a lake in the Upper Midwest are the key manipulation studies in this program. A third manipulation study is being conducted as part of the program on episodic response (Section 1.2.4).

The Watershed Manipulation Project, a component of the Watershed Processes and Manipulations component, was implemented in Bear Brook Watershed in Maine in 1987 to evaluate watershed response to artificial acidification. One watershed receives acid and a second, similar site serves as a control. This project, through a series of laboratory, plot, hillslope, and catchment scale experiments, is designed to (1) assess the quantitative and qualitative response of watershed soils and surface waters to altered deposition; (2) determine the interactions among biogeochemical mechanisms controlling surface water response to acidic deposition; and (3) test the behavior of the Direct/Delayed Response Project models, evaluate model forecasts of manipulation outcomes, and refine model structure to improve the reliability of model forecasts. The Direct/Delayed Response Project models thus serve as a framework for the hypothesis-testing experiments.

The first watershed research site is Bear Brook Watershed in Maine, where pre-manipulation studies began in spring 1987. Manipulation began in 1989 and will continue through 1992. Some activities within the Watershed Manipulation Project and Episodic Response Project have been integrated into the Regional Episodic and Acidic Manipulations Project (see Section 1.2.4).

An integral component of this research area is soil process studies, which complement the Watershed Manipulation Project as well as contribute to the Direct/Delayed Response Project. These studies are investigating soil-related processes hypothesized to be key factors controlling the rate of surface water acidification. The processes include sulfate mobility, sulfate retention and release, cation exchange, cation supply and mineral weathering (including aluminum), organic acids, and nitrate mobility.

The second manipulation study in this program is the experimental acidification of Little Rock Lake in Wisconsin. Before Little Rock Lake was acidified in 1985, a number of hypotheses had been developed regarding the chemical changes and biological responses that might occur in a lake following the addition of acids. One-half of the lake is being acidified to decrease its pH incrementally over a six-year period. The ongoing study is providing direct evidence that will allow the hypotheses to be tested and modified, if necessary, to increase the understanding of potential ecological effects of acidic deposition on an aquatic ecosystem and to develop effective forecasting models.

1.2.4 Episodic Response Project

The Episodic Response Project is a two-phased program designed to investigate the regional response of surface waters to acidic episodes and to provide data on the biological consequences of episodes. The risk to surface waters posed by short-term, acute exposure to acidic inputs will be examined through model-based, regional estimates of the duration, frequency, extent, and magnitude of acidic events, such as those accompanying storms and snowmelt. As a result of the unpredictable nature of snowmelt and rainstorm events, survey approaches for determining episodic response have been marginally successful and are data-limited. Therefore, a more intensive approach is being employed in the Catskills, Northern Appalachian Plateau, and the Adirondacks. Three to five streams in each region are being continuously monitored, and the potential for episodic acidification at each site is being assessed from the resulting data bases. The data will also serve as the basis for regionally applicable models of chemical and biological response that will be applied to the National Surface Water Survey data base.

In addition, as a joint effort with the Watershed Manipulation Project, an experiment is being conducted in Fernow, WV, to examine the influence of altered acidic deposition on chronic and episodic surface water acidification. Data from this project, termed Regional Episodic and Acidic

Manipulations (Figure 2), will be integrated with comparable episodes data to formulate an empirical or conceptual model of episodic acidification that potentially could be applied regionally.

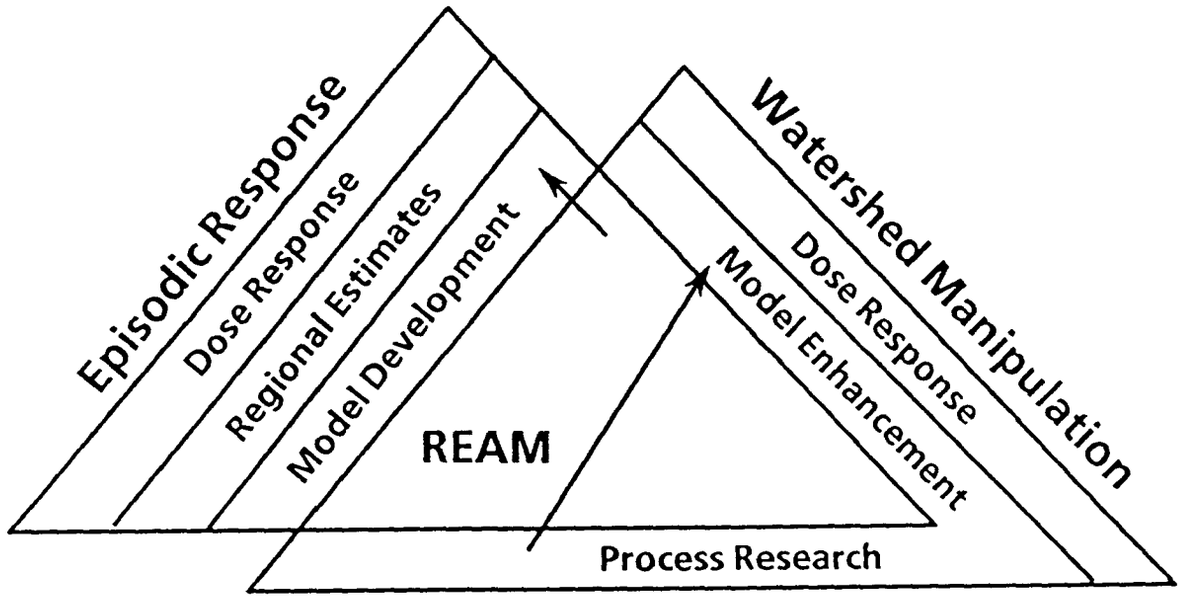


Figure 2. Relationships among the Episodic Response Project, the Watershed Manipulation Project, and the Regional Episodic and Acidic Manipulations (REAM) Project.

1.2.5 Biologically Relevant Chemistry

The goal of the Biologically Relevant Chemistry research area is to provide data that allow regional assessments to be made of the risk to aquatic biota posed by acidic deposition. These regional assessments are based principally on an understanding of the types of chemical conditions that cause adverse biological effects and regional estimates of the extent and duration of such chemical conditions.

The chemical variables instrumental in effecting biotic response are reasonably well-known, but the "critical values" (the concentrations above or below which significant biological effects are expected to occur) of these variables are not well-defined. A study of existing data has therefore been initiated to estimate critical values, identify the associated magnitude and type of biological response, summarize the uncertainty associated with each critical value, and outline the research needed for improved estimates and predictions of biological response.

Two other projects address potential biological effects resulting from short-term and long-term acidification. The goal of the first project, Present Status of the Fishery Resource in the Upper Peninsula of Michigan, is to assess the current status of fish communities and fish populations

in 49 lakes (selected from the Eastern Lake Survey - Phase I frame in the Upper Midwest). Results from these efforts, which include measuring a number of chemical variables in conjunction with fish sampling, provide information on fish species presence/absence and indices of population abundance. Studies in the Indirect Human Health Effects research area (Section 2.9) are also being conducted in conjunction with this project to determine the concentrations and regional distribution of mercury in fish tissues.

The Biological Effects of Acidic Episodes study, designed as part of the Episodic Response Project, deals with the effects of episodic acidification on fish populations in streams. Fish transplant experiments in conjunction with detailed chemical monitoring are being used to evaluate the degree to which episodes may influence fish movement and mortality rates. A principal aspect of the study is the identification of key characteristics of episodes that control the severity and nature of effects on fish populations.

1.2.6 Synthesis and Integration

Three key activities within the Aquatic Effects Research Program are targeted at synthesizing, integrating, and disseminating program results. First, the Regional Case Studies project is using data from many sources, including the National Surface Water Survey, to provide an integrated evaluation of the potential and measured effects of acidic deposition on surface waters with low acid neutralizing capacity. Past chemical and biological status are being examined, and current chemical, physical, and biological characteristics of surface waters are being compared on a subregional basis to identify the key determinants of surface water chemistry. The focused, specific activities in the Regional Case Studies will help refine current understanding of the relationships between acidic deposition and surface water chemistry and biology.

The second activity is the preparation of a series of seven State-of-Science/Technology Reports that will contribute to Part I of a two-part comprehensive assessment of acidic deposition and its effects, to be published by the National Acid Precipitation Assessment Program. Part II, the 1990 NAPAP Assessment, will contain the integrated results, conclusions, and uncertainty estimates generated from application of the procedures described in the State-of-Science/Technology Reports. The seven related reports will present the current state of knowledge regarding the chronic and episodic effects of acidic deposition on aquatic resources. Historical status and methods for forecasting future change in status also will be addressed.

The first report in the series will summarize the current chemical status of surface waters in five regions of the United States, evaluate the spatial distribution of their chemical characteristics, and examine the associations of surface water chemistry with watershed characteristics and wet

deposition chemistry. Results for the United States will be compared with those for Canada, Norway, and other nations having temperate climates.

The second report will focus on what is known about natural watershed processes, both aquatic and terrestrial, that affect chronic acid-base chemistry in lakes and streams. Processes related to hydrology and biogeochemistry in watersheds and in lakes and streams, and those associated with changes in land use will be examined. How acidic deposition interacts with these natural processes, and the implications for surface water and soil acidification or recovery, will be presented. Results from case studies of soil and water acidification, conducted internationally and in the United States, will be compared for natural systems with and without acidic deposition and for a number of experimentally acidified systems.

The third report will be an overview of the state of knowledge regarding natural and anthropogenic factors that influence the acid-base chemistry of surface waters and how these factors might influence the occurrence and detection of historical change. Methods for investigating historical change (historical water chemistry measurements, paleolimnological reconstructions, comparisons between high and low deposition areas, and models) and their associated uncertainties will be discussed. Results from several distinct lines of investigation will be integrated to provide historical estimates of change for lakes in the Adirondacks, and possibly for drainage lakes in the Northeast and Upper Midwest and for seepage lakes in Florida.

The current understanding of episodic acidification of surface waters will be summarized in the fourth report. The relationships of episodes to chronic acidification and the hydrologic cycle, their chemical characteristics and biological significance, and the processes that control them will be discussed. The extent and severity of episodic acidification will be presented, with data limitations clearly identified, for the United States, and compared when appropriate with European and Canadian information. Modeling approaches for estimating the regional magnitude, duration, frequency, and extent of episodes (and associated uncertainties) are presented and evaluated. The report concludes with a discussion of the relative contributions of natural and anthropogenic factors to episodic acidification.

The fifth report will identify the chemical parameters that influence the effects of changes in acid-base chemistry on biological communities and processes. Methods for quantitatively evaluating the relationship between changes in acid-base chemistry and regional effects on fish populations will be presented, along with associated uncertainties. Qualitative discussions will include the effects of surface water acidification on aquatic organisms other than fish, e.g., benthic invertebrates, amphibians, waterfowl, and mammals.

Methods for forecasting changes in acid-base chemistry and surface waters and their associated uncertainties will be presented in the sixth report. Three general types of models – steady-state, empirical time-varying, and dynamic system models – will be evaluated. Prior model applications in the United States, other North American regions, and Europe will be summarized. Each model will be discussed with regard to its structure, assumptions and limitations, sensitivity and behavioral analyses, and verification/validation studies. Error analyses, linkages to deposition estimates and inputs to biological models, and procedures for extrapolation to obtain regional estimates will be discussed.

The last report on aquatic effects will be an evaluation of the mitigative (surface water acid neutralization) approaches to restore and protect surface waters from acidification. This report will include a description of previously applied mitigative strategies and the effects of these mitigative techniques on ecosystem structure and function for acidic surface waters.

The third activity in this program is the Technology Transfer project, which distributes products of the Aquatic Effects Research Program to interested parties such as state agencies, federal agencies, and universities. These products include a quarterly program status report that provides periodic updates on program activities; supporting documents produced in conjunction with major reports, such as quality assurance and field operations reports; data base packages that include major survey data bases on magnetic media and instructions on their use; users' handbooks, such as analytical methods manuals; and a biennial journal that lists program publications and presentations. The goal of this project is to inform a wide audience about activities in the Aquatic Effects Research Program on a regular basis.

1.2.7 Long-Term Monitoring

Forecasts of surface water response to future changes in acidic loadings can be confirmed only through the long-term collection and analysis of chemical and biological data. To this end, long-term monitoring efforts are being designed to quantify, with known certainty for defined subpopulations of lakes and streams, the rate at which changes in surface water chemistry are occurring and the characteristics and subregional extent of these affected lakes and/or streams.

Long-Term Monitoring has two program elements - Site-Specific Long-Term Monitoring and Temporally Integrated Monitoring of Ecosystems. The Site-Specific Long-Term Monitoring program element involves individual monitoring sites that are part of the NAPAP's surface water monitoring effort. This continuation of data collection and analysis for 90 low acid-neutralizing capacity (ANC) systems is providing information on natural variability of these systems over a range of annual hydrological cycles, as well as preliminary insights into whether and where trends in acidification or recovery are occurring.

The Temporally Integrated Monitoring of Ecosystem program element will build on the information from the Site-Specific Long-Term Monitoring element as well as the data collected through the National Lake and Stream Surveys to design a chemical and biological monitoring network that will enable quantitative estimates of change in particular subpopulations of interest to be made with known confidence.

The Temporally Integrated Monitoring of Ecosystems program element, as now planned, has four principal objectives: (1) to provide early-warning signals of surface water acidification or recovery in the selected study regions; (2) to provide an ongoing assessment of regional patterns or trends in surface water acidification or recovery; (3) to assess the extent to which observed patterns and trends in surface water chemistry correspond with model forecasts of surface water chemistry changes, e.g., from the Direct/Delayed Response Project; and (4) to assess the relationships between the observed patterns and trends in aquatic ecosystems and patterns and trends in atmospheric deposition. This study is proposed as an integrated monitoring effort, employing standardized sampling and analytical methods and rigorous quality assurance protocols. The original study design was conceived as a hierarchical frame comprised of four tiers, with each tier representing a specific monitoring approach, according to the degree of detail needed to assess trends in regional-scale change (see Figure 3 of Research Activity Descriptors, FY88, EPA/600/9-88/006). This original concept has been refined to emphasize the early warning or anticipatory objective of the program as well as to make maximum use of past or ongoing elements in the Aquatic Effects Research Program. Conceptually, the current design can be represented by the "wheel and axle" configuration shown for the Northeast in Figure 3.

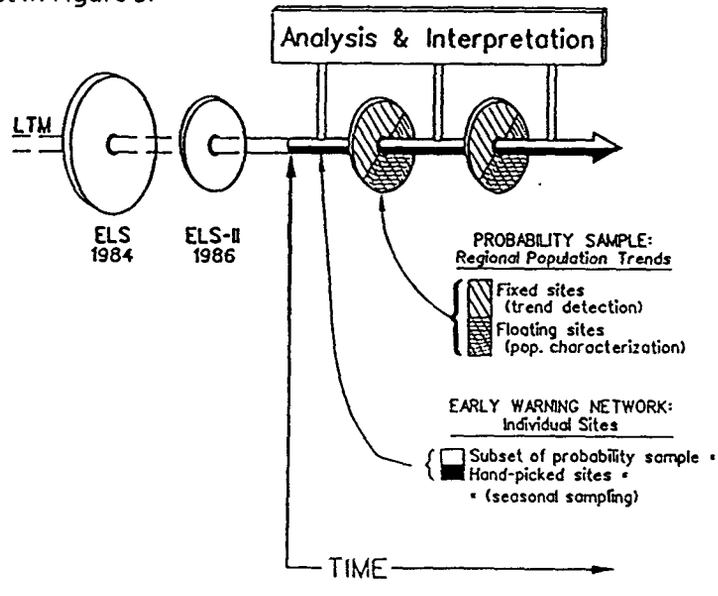


Figure 3. The conceptual "wheel and axle" design frame for Temporally Integrated Monitoring of Ecosystems (TIME) in the Northeast, with relevant Aquatic Effects Research Program elements.

The axle is comprised of specific sites selected for temporally intensive long-term monitoring. The wheels represent regionally extensive synoptic surveys of sites selected within a probability sampling frame that allows regional extrapolation of results. Prior to its planned implementation in 1991, project analyses will focus on data from completed or ongoing component surveys of the National Surface Water Survey and from the Site-Specific Long-Term Monitoring Program. The results of these analyses will be used to select rapid response (axle) sites and to design and conduct periodic resurveys (wheels) for post-1991 implementation.

The sampling network for the core program will include a subset of a regional probability sample and a set of rapid response sites selected from a pool of candidate sites that focus on previously identified subpopulations of interest, fulfill rapid response criteria, span gradients of atmospheric deposition, and have prior monitoring/watershed data. The probability sample subset will be chosen to represent classes or types of systems, and the "hand-selected" samples will serve as rapid response sites. Both sets of sites will be sampled at least seasonally.

The periodic surveys will be conducted on two types of systems: fixed sites (intended for trends detection) and floating sites (intended for regional characterization of surface water populations). Once implemented, the fixed sites will not vary and thus will serve to address the issue of long-term trends. The floating sites will vary from survey to survey to ensure ongoing regional characterization.

1.2.8 Indirect Human Health Effects

Research on the indirect human health effects of acidic deposition has had two main areas of focus. One is the alteration of drinking water supplies as a result of acidic inputs. The second is the accumulation of mercury and other potentially toxic metals in the muscle tissues of edible fish.

Drinking water studies examined existing data to determine the potential modification of drinking water quality by acidic deposition, emphasizing precipitation-dominated systems. These activities will continue as part of the effort for NAPAP's State-of-Science Reports on direct and indirect human health effects.

Mercury bioaccumulation is being examined in conjunction with the fishery survey in the Upper Peninsula of Michigan. The objectives of this study are to determine (1) if fish in acidic lakes have higher tissue concentrations of mercury than do fish in otherwise similar, nonacidic lakes and (2) the association between physicochemical lake characteristics and fish tissue mercury concentrations. Analysis of the extent to which mercury bioaccumulation in fish occurs in the Upper Peninsula of Michigan and the extent to which dissolved mercury is related to lake water pH is ongoing.

1.3 PROGRAM COORDINATION AND LINKAGE

The designs, goals, and objectives of the projects within the Aquatic Effects Research Program reflect the need to classify systems to (1) further scientific understanding and (2) assess on a regional scale the risk of aquatic resources to acidic deposition. The degree of confidence in answering policy, assessment, and scientific questions about surface water acidification is enhanced by a common approach employed throughout Aquatic Effects Research Program projects (Figure 4) for the collective program goal of regionalization.

When a project is initiated, its goals are evaluated from the perspective of their relevance to one of the four policy questions (Section 1.1.1). Peer-review workshops are held to assist in refining project plans and to ensure that the approach is scientifically sound and the objectives are relevant to the project goal. Within each project, the design, analysis, and interpretive phases are completed under a system of internal reviews, emphasizing quality assurance, regional classification, and scientific validity. External review of products ensures that conclusions are scientifically sound, leading to a refined understanding of acidification issues, upon which regional assessments with known certainty bounds can be based. Sound policy decisions, in turn, then can be formulated.

The integrated structure of the Aquatic Effects Research Program also emphasizes regionalization. Statistically based site selection procedures and standardized protocols improve efficiency of data collection and ensure data comparability. The regional population estimates generated by the National Surface Water Survey serve as the statistical frame for other geographically extensive projects and provide the basis for classifying discrete subpopulations of surface waters upon which more intensive investigations can be focused. The identification of subpopulations at risk within the regional frame, coupled with integrated chemical, biological, and soil surveys, enhances the ability to extrapolate results of watershed studies to regional scales (Figure 5). The integrated program structure allows an assessment of the geographical extent of aquatic resources at risk and permits the results of watershed-level, process research to be evaluated on regional scales.

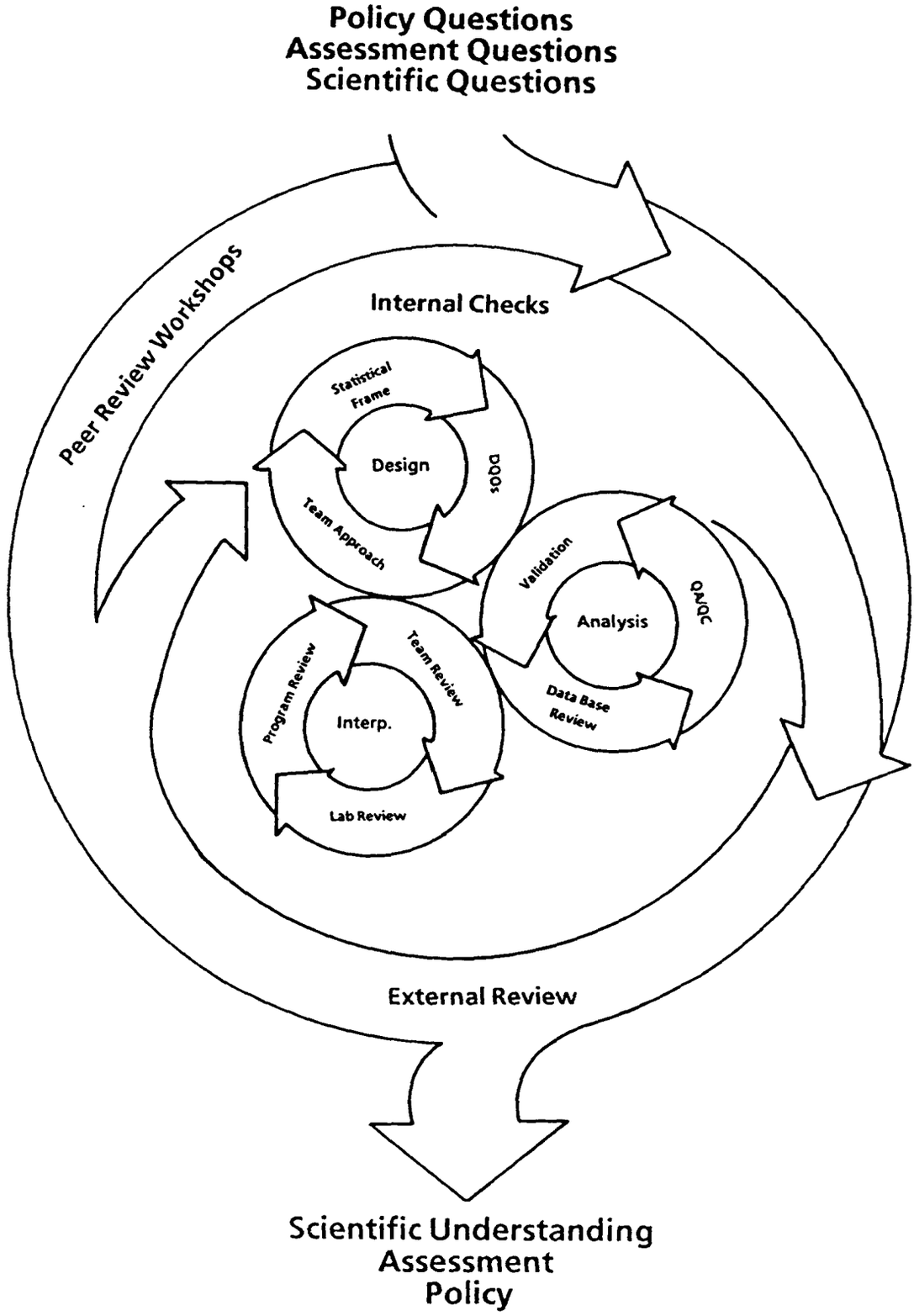


Figure 4. Internal and external checks to ensure that the projects within the Aquatic Effects Research Program provide quantitative answers with known certainty bounds to policy, assessment, and scientific questions.

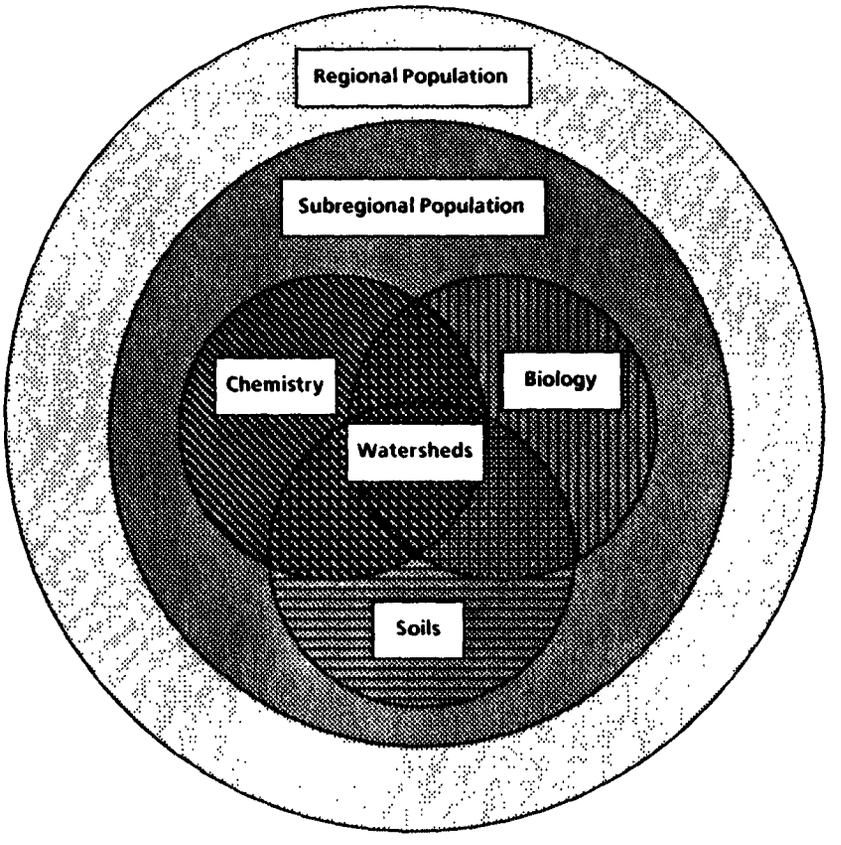


Figure 5. **Integration of projects within the Aquatic Effects Research Program. Geographically extensive surveys of soils and surface water chemistry and biology are integrated through the use of standardized methods of data collection and common study sites. This integration permits the understanding of effects at the watershed level to be extrapolated to regional scales.**

1.4 FUTURE PLANS TO 1990

1.4.1 Overview of Research Program Integration

The research strategy for the Aquatic Effects Research Program, designed in 1983 and implemented in 1984, lays the foundation for answering, on a regional scale, the four policy questions listed in Section 1.1.1 with known confidence. The focus in 1989 and 1990 is to advance, through synthesis and integration of results from the various research activities, the primary goal of the program:

> *Characterize and quantify with known certainty the subpopulation of surface waters that will respond chemically to current and changing acidic deposition, and determine the biological significance of observed changes.*

Identifying the subpopulation that is likely to change chemically in response to various acid loadings is primarily a classification procedure (Figure 6) The statistical frame and the standardized protocols applied in the National Surface Water Survey permit regional (based on geography) and subpopulational (based on physical and chemical attributes) characteristics to be quantified with known certainty. More intensive studies that address a specific question beyond the scope of the original survey goals (but within the frame and design criteria of the survey) then can be focused in a particular geographical area, e g , the Sierra Nevada, or on a particular type of system, e.g , seepage lakes or those with conductance ≤ 10 µS/cm.

The extent to which chemistry of surface waters has changed historically also can be qualitatively evaluated using the National Surface Water Survey data and framework. Using current chemical status and empirical models that hindcast changes in acid neutralizing capacity or pH, for example, it is possible to examine the response of surface waters to increases in sulfate concentrations. Developing relationships between the increases of surface water sulfate concentrations and atmospheric sulfur deposition would permit an evaluation of the extent of chronically acidic systems and their association with regional patterns of sulfate deposition. Additionally, applying paleoecological techniques to reconstruct historical pH and acid neutralizing capacity to lakes in the National Surface Water Survey frame can provide a population-based estimate to the number and proportion of lakes that were naturally acidic prior to 1850 and an assessment of the number and proportion that have acidified since the onset of acidic deposition. Correlation analyses of these estimates with other data, such as sulfate deposition levels and lake water sulfate concentrations, might reveal patterns between surface water acidification and anthropogenic atmospheric deposition.

The Direct/Delayed Response Project, like the National Surface Water Survey, also focuses on classifying the subpopulation at risk, but enhances or refines the classification by considering the time frames over which surface water chemistry might change as well as the characteristics of the watersheds in which the systems are located Primarily employing various models for forecasts of future status, the Direct/Delayed Response Project benefits from the Watershed Manipulation Project, which seeks to verify the dynamic, as well as the more simplistic, empirical surface water acidification models through controlled acidification experiments. Results of the studies on subpopulations of special interest also are useful in modifying existing models or developing new models if the results of the model verification studies indicate that the processes represented in the models or the input parameters are inaccurate.

How surface waters might respond to increased or decreased acidic loadings can be addressed using an approach similar to that for current acidic loadings The subpopulations classified as responding to current loads can be re-examined to project whether they might recover if acidic deposition were decreased Conversely, those forecast as not responding at current loads could be re-examined to determine whether they might acidify if deposition increased.

This stepwise, integrative analysis leads to completion of the primary output of the Aquatic Effects Research Program – data that allow a definition, on a region-specific basis, of the expected

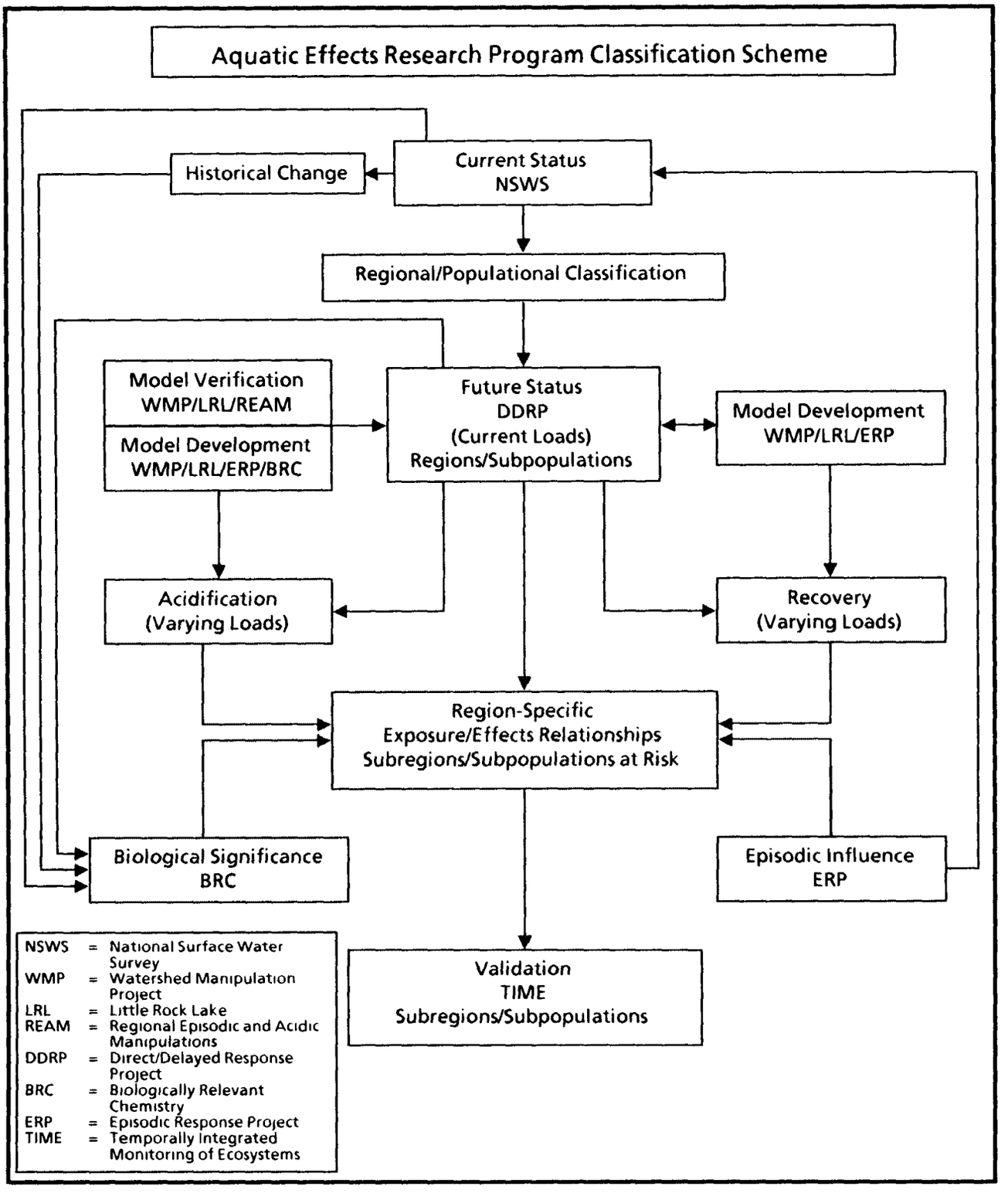


Figure 6. Classification approach to lead to the identification of regional exposure/effects relationships between chemical and biological status and atmospheric deposition and corroboration of these relationships through long-term monitoring.

chemical response of surface waters and the biological implications of that response for various increases and decreases in levels of acidic deposition.

From its inception, the major emphasis of the program has been on sulfate and its role in long-term acidification, but nitrate and its role in episodic acidification has become increasingly important in understanding the effects of acidic deposition on surface waters. Consequently, a major focus of the Aquatic Effects Research Program, begun in 1988 and planned for continuation beyond 1990, is to refine the understanding of the role of episodes in altering surface water chemical status. Evaluating the regional-scale importance of episodes requires not only field studies that foster a better understanding of the factors and processes controlling their frequency, duration, and magnitude, but also the development and refinement of regionally applicable models that can be used to project their geographic extent. The Episodic Response Project contributes to refining the current status of surface water chemistry by accounting for estimates of lakes and streams that are acidic during times other than those identified in the National Surface Water Survey Model development as part of the Episodic Response Project both contributes to and benefits from the subpopulational response classifications identified from projections of future chemical status. Finally, comprehensive, integrative analyses of the regional importance of episodes contributes to the development of regional relationships between surface water response and acidic deposition

All Aquatic Effects Research Program activities contribute to the development of a framework that allows biological implications of the findings and conclusions to be evaluated. For example, analyses of historical change must consider the relevance to biological effects, i.e., an inferred change in pH from a historical value of 6 0 to a current value of 5 0 might be significant from a biological perspective, whereas a similar 1 0-unit decrease in pH from 7 0 to 6.0 might not be. Likewise, a historical decrease in acid neutralizing capacity from 125 μeq/L to 25 μeq/L (net loss of 100 μeq/L) might have significant biological implications, but an equivalent loss from 400 to 300 μeq/L might be less important in determining the extent to which the biotic resource is at risk. Understanding biological implications of chemical changes is thus vitally important in developing regional relationships between acidic deposition loadings and chemical response, because assessments of the subpopulations or subregions at risk ultimately must include the response of surface water biota.

The final component of the classification scheme is to examine whether the conclusions are sound through the acquisition of empirical data This process requires examination of how surface waters respond over the long term as a result of changes in acidic deposition Projections of future acidification or recovery in response to increased or decreased acid loadings can be confirmed only by data collection such as planned by the Temporally Integrated Monitoring of Ecosystem project. If conclusions are not corroborated by actual observations, the Program will re-examine the factors controlling sensitivity and the criteria used to define the subpopulation at risk.

1.4.2 Focus

The research strategy for the Aquatic Effects Research Program established the frame from which regional-scale conclusions can be inferred quantitatively. This strategy permits and lays the groundwork for the following steps:

1. Estimating the current status, extent, and location of surface waters in the United States that are potentially sensitive to acidic deposition.
2. Forecasting the future status of surface waters potentially affected by current and alternative levels of acidic deposition.
3. Critically assessing existing effects models to identify the most influential factors controlling changes in surface water chemistry.
4. Identifying research to improve the understanding of the most critical factors (identified in model evaluation) controlling sensitivity of surface water.
5. Developing an approach to verify model forecasts for the expected time frames of acidification at various deposition levels through manipulation and process level studies on watersheds.
6. Estimating potential rates of recovery based on projections from verified models.

Although research efforts beyond 1988 presently do not include plans for additional broad-scale surveys, the site-specific studies implemented in latter phases of the program are being conducted to improve the understanding of the extent of acidic deposition effects and the factors that control them from a regional perspective. Studies have been integrated at selected sites to maximize scientific gain and the effectiveness of funding. The regional significance and applicability of the issues being investigated remain the primary criteria for determining whether a project is undertaken.

For the past two years, the Program has focused, and will continue to focus, on the following:

1. Contributions to the 1990 NAPAP goal of assessing the effects of acidic deposition on surface waters in the United States, through synthesis and integration of program results.
2. Implementation of research designed to verify model forecasts and assessment conclusions related to future effects of acidic deposition on aquatic ecosystems
3. Establishment of a regionally meaningful long-term monitoring network to detect biologically significant changes in surface water chemistry (both acidification and recovery) that can be related to a known population of aquatic systems.

The following are specific questions that continue to guide analysis of existing data and additional research:

1. What is the current chemical status of aquatic resources in regions potentially sensitive to acidic deposition?
2. What is the biological resource at risk in these regions and what are critical values indicating this resource is at risk?

3. What are the important biogeochemical factors influencing the resource at risk and controlling its sensitivity to acidic deposition?
4. What has happened to the chemical status of the resource at risk relative to its current status as a result of acidic deposition?
5. What will happen to the resource at risk in the future at current and alternative levels of deposition?
6. What are the biological implications of past changes in the chemical status of this aquatic resource?
7. What are the levels of acidic deposition below which adverse biological effects are minimized?
8. What is the rate of recovery of currently acidic systems at various levels of deposition?
9. How will we know whether additional systems are acidifying or whether recovery is occurring?

1.4.3 Program Elements – Future Activities and Emphasis

The Aquatic Effects Research Program is being redirected from survey activities to forecasts, verification, and validation. After completion of the Mid-Appalachian survey, the Direct/Delayed Response Project will shift in emphasis toward data synthesis, integration, and analysis using output from the manipulation studies and classification activities. Analyses of National Surface Water Survey data will continue refinement of the established foundation to allow further, well-focused regional extrapolation of site-specific results. Should continued analysis indicate the need to conduct additional surveys in certain regions or subregions, the frame established for National Surface Water Survey will form their basis.

National Surface Water Survey

The emphasis of the National Surface Water Survey, now in the final stages of the synoptic survey approach, has shifted from collecting high-quality baseline data to refining estimates of the current status and extent of acidic and potentially sensitive aquatic systems. Of primary importance is maximizing the usefulness of information available from the survey for system classification and characterization. The approach focuses on refining the estimates by considering small lakes and streams, aquatic systems outside the National Surface Water Survey study regions, and seepage and alpine lakes. Smaller scale studies addressing specific questions will continue to focus on policy-relevant issues.

Direct/Delayed Response Project

The Direct/Delayed Response Project will continue to analyze watershed response to acidic deposition in the Northeast, Southern Blue Ridge Province, and Mid-Appalachians. Future activities will emphasize the integration of watershed and surface water data and the development of

procedures to classify watershed responses as a function of acidic deposition. The classification approach will continue to employ multivariate statistical procedures, empirical models, and dynamic watershed models to correlate future watershed response estimates with the current resource status. These classification procedures and protocols will contribute to the development of exposure/effects relationships through forecasts of acidification or recovery of surface waters.

Watershed Processes and Manipulations Studies

Watershed Processes and Manipulations studies will continue beyond 1990 at the Maine watershed site. These studies will provide long-term verification of Direct/Delayed Response Project forecasts and enhanced understanding of processes and watershed interactions controlling surface water acidification. Soil process studies include sulfate mobility, aluminum mobilization, base cation supply, and mineral weathering, some of which will be integrated with the Regional Episodic and Acidic Manipulations study under the Episodic Response Project. Other studies will be implemented to determine if the Direct/Delayed Response Project dynamic models and other more simplistic empirical models can be used to forecast recovery in response to lower levels of acidic deposition relative to current levels.

The Little Rock Lake acidification study will continue to examine chemical and biological response to direct additions of acids, providing data for examination of a number of acidification-related hypotheses. Studies have been initiated to evaluate the applicability of the findings to other regions and to examine how similar the response of Little Rock Lake is to other sites in the region that have longer-term data records. Both of these projects will offer the opportunity to study the rate and nature of recovery after acid addition is terminated.

Episodic Response Project

The Episodic Response Project will help to refine estimates of the size of the aquatic resource that has changed or is at risk of changing due to acidic deposition. The Episodic Response Project focuses on acquiring biologically relevant chemical data to gain a better understanding of biological effects (principally fish-related) that are due to acute acidification The specific objectives are to understand the frequency, duration, and magnitude of episodes, the key factors that influence their occurrence, the impacts episodes have on fish populations, and their regional extent. A fifth objective, although not expected to be completed by 1990, is to contribute to the identification of region-specific, exposure/effects estimates.

Data from intensive experimental studies on hydrochemical and biological processes, along with limited surveys of chemistry and fish will form the basis for developing regionally applicable models of chemical and biological response. After calibration and verification, the models will be

applied to the statistical frame of the National Surface Water Survey to provide estimates of biologically relevant chemical data as well as effects on fish on a regional basis.

The Fernow Watershed in West Virginia was selected for implementation of the intensive experimental studies. This site has been the focus of an ongoing study funded by the USDA Forest Service, and thus provides empirical data needed to begin model development and verification. Field studies at Fernow are expected to begin late this year.

Long-Term Monitoring

As now planned, sites for the Temporally Integrated Monitoring of Ecosystems study will be established throughout the United States by 1991. The objective of studying these sites is to make timely identifications of changes in aquatic ecosystems related to increased or decreased levels of acidic deposition. The monitored systems will be selected so that evidence of recovery or acidification can be used to infer regional changes through the regionalized frame developed for the Aquatic Effects Research Program. If significant changes or trends are detected, an additional survey of the potentially affected surface waters can be conducted that can be compared to the results of the National Surface Water Survey data and can be used to identify regional patterns in the acidification/recovery index. Complementing this project are two supporting projects designed to improve presently used analytical methods and to quantify data quality through rigorous quality assurance evaluations. These projects will enhance the capability of detecting trends and will improve the certainty with which long-term, regional-scale conclusions can be made.

Synthesis and Integration

A major emphasis for the program through 1990 will involve developing the classification scheme described in Section 1.4.1. These analyses are the foundation for reporting on program results that will contribute to the 1990 NAPAP assessment.

1.4.4 Program Guidance

The program has been guided by NAPAP, the Multimedia Energy Research Committee, the Policy/Assessment Committee (established specifically for this program), and the Aquatic Effects Research Program management team. As the program shifts direction, its guidance will have to be precise and focused; future goals and objectives, as well as assessment, policy, and scientific needs, will have to be integrated carefully. Although the research committee by which program activities beyond 1990 will be guided is not yet formalized, the current guidance structure will continue to operate in designing activities to contribute to NAPAP's 1990 assessment and to plan research on important issues to address in the future.

1.4.5 Major Outputs

The major output from the Aquatic Effects Research Program will be to provide information for answering the policy questions listed in Section 1.1.1 on a region-specific basis. When answering these questions, acidification must be considered from both a regional and a site-specific perspective, and some acidification processes may be more important in some regions or at some sites than others. Because of these considerations, prioritizing projects in specific regions is the most effective way to provide quality information. The National Surface Water Survey has been and will continue to be the basis for this prioritization (Table 2). The target dates for responding to the policy questions are shown in Table 3.

Table 2. Regional Location of Projects within the Aquatic Effects Research Program

Region	AERP Projects[a]
Northeast	NLS, DDRP, WMP, ERP, BRC, TIME
Middle Atlantic	NSS, DDRP, ERP, REAM, TIME
Southern Blue Ridge Province	NLS, NSS, DDRP, TIME
Southeast	NSS, TIME
Florida	NLS, NSS, BRC, TIME
Upper Midwest	NLS, TIME
Upper Peninsula of Michigan	NLS, BRC, TIME
West	NLS, TIME

[a] NLS - National Lake Survey
DDRP - Direct/Delayed Response Project
WMP - Watershed Manipulation Project
ERP - Episodic Response Project
BRC - Biologically Relevant Chemistry
TIME - Temporally Integrated Monitoring of Ecosystems (proposed locations)
NSS - National Stream Survey
REAM - Regional Episodes and Acidic Manipulations

Table 3. Target Dates for Addressing Policy Questions in Terms of Chronic Exposure (Long-Term Acidification) or Acute Exposure (Short-Term Acidification) to Acidic Deposition

Issue	Resource	Location	Date
Long-Term Acidification			
Current Status	Lakes	Northeast, Florida, Southern Blue Ridge Province, Upper Midwest, West	1987/88
Current Status	Streams	Southern Blue Ridge Province, Southeast, Middle Atlantic	1988/89
Future	Lakes, Streams	Northeast, Southern Blue Ridge Province	1988/89
Future	Lakes, Streams	Middle Atlantic	1989/90
Validation/Monitoring	Lakes, Streams	All Regions	1995 +
Short-Term Acidification			
Current Status	Streams	Northeast, Middle Atlantic	1990/91
Dose/Response	Streams	Northeast, Middle Atlantic	1991
Synthesis/Integration	Lakes, Streams	All Regions	1989/90

1.5 AQUATIC EFFECTS RESEARCH AFTER 1990

Research on aquatic effects under NAPAP's Aquatic Effects Task Group has focused on amassing scientifically sound information with quantifiable certainty to support policymaking. The 10-year NAPAP span was intended to expedite investigations into the most basic and urgent questions concerning the extent and effects of acidic deposition in the United States. When NAPAP delivers the Integrated Assessment, much of the active research in aquatic effects will have been completed. Several efforts begun under NAPAP, however, are proposed for continuation to investigate critical gaps in our current understanding of acidic deposition, although the research committee by which these efforts will be guided is not yet finalized.

1.5.1 Watershed Processes and Manipulations Studies

Watershed Manipulation Project

The Watershed Manipulation Project, initiated in the field during 1987, will continue beyond 1990 to fulfill its original objectives. The studies at Bear Brook, Maine, will assess the response of watershed soils and surface waters to altered sulfur deposition, determine the interactions among biogeochemical mechanisms controlling surface water response to acidic deposition, and test the behavior and performance of the models used in Direct/Delayed Response Project forecasts of acidification trends.

The catchments at the Bear Brook study site have been monitored since Fall of 1987 to establish a calibration between the two catchments. The catchment level manipulation will begin in 1989 and will continue until 1992. Thereafter, the catchments will be studied to examine the rate and process of recovery. This component of the research will help verify the forecast models, while plot and laboratory studies associated with the project will facilitate the development and refinement of model formulations. In addition, the Bear Brook site offers an excellent setting to examine other issues of concern such as nitrogen deposition.

Regional Episodic and Acidic Manipulations

The Regional Episodic and Acidic Manipulations work at the Fernow Experimental Forest in West Virginia (USDA Forest Service) supports objectives of both the Watershed Manipulation Project and the Episodic Response Project. The essence of the study is a watershed manipulation experiment similar to the watershed manipulation study at Bear Brook, but without the intensive process research. Catchment manipulation at the Fernow sites will begin in 1989 and end in 1992. Surface water chemistry responses at both chronic and episodic time scales will be examined. These data will be used to test episodic and chronic acidification models and to draw conclusions about basic controls of watershed acidification.

Little Rock Lake

The Little Rock Lake, Wisconsin, experiment has employed a split basin design to study the expression and mechanisms of effects of decreasing pH on warmwater lake ecosystems. An agreement with the State of Wisconsin dating from 1983 requires that the lake be restored to its original condition at the end of the experiment, which was originally scheduled for 1990. Although the restoration could easily be accomplished by removing the barrier between the two halves of the lake, a unique opportunity exists to observe the system's natural recovery by maintaining the barrier and terminating acidic inputs. It is most appropriate to continue to study the lake during a post-treatment phase using directly comparable techniques to compare the two phases. Three years is expected to be adequate time for the lake recovery study. This continuation of the Little Rock Lake project will provide answers to questions concerning the time for recovery for various components of the lake system and the extent. The three-year post-treatment research project should allow the lake to stabilize or provide sufficient data to project its eventual stable condition based on the observations to date.

1.5.2 Long-Term Monitoring – The Temporally Integrated Monitoring of Ecosystems Project

The Temporally Integrated Monitoring of Ecosystems project will continue within the current aquatic team structure. The national base program beyond 1990 will include field sample collection, laboratory analyses, data base management, interpretation, and reporting. The Temporally Integrated Monitoring of Ecosystems project will establish a design-based system of monitoring sites with the capability to document chemical and biological changes in the status of lakes and streams in regions receiving acidic deposition. Through integration with other monitoring studies on deposition, soils, or forests, Temporally Integrated Monitoring of Ecosystems can address probable causes for observed changes in individual systems. The Temporally Integrated Monitoring of Ecosystems project is expected to provide a first step toward a broader national perspective on the ecological monitoring of surface waters; its successful design and implementation will, in fact, address many of the technical obstacles facing a broader, expanded ecological monitoring program within EPA's Office of Research and Development that is currently in the planning phase.

SECTION 2

PROJECT SUMMARIES

2.1 PROGRAM STRUCTURE – OVERVIEW

This section contains summaries of research activities within the Aquatic Effects Research Program (AERP) that have been approved for funding in fiscal year 1989. Each subsection corresponds to one of the Planned Program Accomplishments (PPA), the mechanism by which EPA's Office of Research and Development tracks its research projects and deliverables. Each PPA is based on a program within the AERP designed to focus on a particular research goal:

PPA Code	Program Title
E-01	National Surface Water Survey
E-07	Direct/Delayed Response Project
E-05	Watershed Processes and Manipulations
E-08	Episodic Response Project
E-03	Biologically Relevant Chemistry
E-09	Synthesis and Integration
E-06	Long-Term Monitoring
E-04	Indirect Human Health Effects

Within each PPA, there are three levels of summaries that can be conceptualized by a hierarchical tier, as shown in Figure 7. The research summary at the program level summarizes the research activities at the program element and project levels, but individual summaries for all levels are included to provide more specific information.

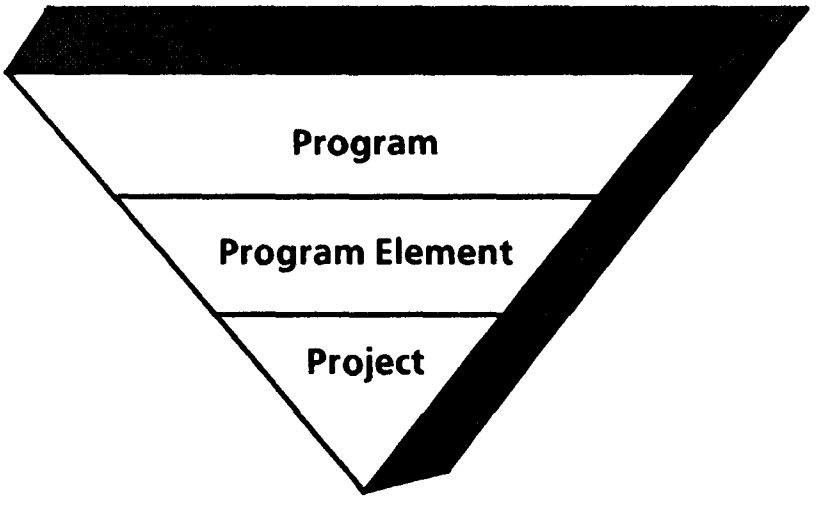


Figure 7. Conceptualization of the levels within each Planned Program Accomplishment.

Each summary is identified and tracked by an EPA code number. Each summary also is identified by a second code number that corresponds to a research framework established by NAPAP (see Section 1, page 1-1). These codes allow the project to be tracked both within the EPA's Aquatic Effects Research Program and within the context of the broader program that involves several other federal agencies. For more information on the NAPAP organizational structure, consult the Council on Environmental Quality, 722 Jackson Place NW, Washington, DC (202-395-5771). An example of the hierarchy with its paired codes is shown in Table 4.

Table 4. Example of Aquatic Effects Research Program Structure and Codes

Level	EPA Code (NAPAP Code)	Short Title
Program	E-01 (6A-1)	National Surface Water Survey
Program Element	E-01.1 (6A-1.01)	National Lake Survey
Project	E-01.1A (6A-1.01A)	Western Lake Survey

Each summary provides the following information:

- the complete title and short title of the program (or program element, project);
- region(s) and state(s) (where the research is being conducted);
- goal(s) and objective(s) (what the research hopes to accomplish);
- rationale (reason for conducting the research); and
- approach (direction taken to reach the research goals).

In addition, a list of key words is provided for each summary. An index of the key words is provided to facilitate the use of this document by scientists and administrators interested in a particular aspect of research. The key words are divided into four categories: (1) "medium" - the primary discipline (chemistry, biology) or specific component or process of the ecosystem (e.g., cisterns, deposition, snowpack) upon which the activity focuses; (2) chemicals - principal chemical constituents measured in the study; (3) approach - types of data acquisition methods and data analysis used; and (4) processes - type of acidification-related mechanism being studies (e.g., sulfate adsorption, base cation supply).

At the end of each summary, the EPA and NAPAP code numbers, status, period of performance, and the key contact individual(s) are also included. Although these summaries provide useful information regarding various levels of the PPAs, they are not intended to be thorough descriptions of all Aquatic Effects Research Program activities. For more detailed information on a research activity, the designated technical contact should be consulted.

2.2 NATIONAL SURFACE WATER SURVEY – PROGRAM E-01

[Program/Program Element/Project]

TITLE: Present Chemical Status of Surface Waters in Low Alkalinity Regions of the United States

SHORT TITLE: National Surface Water Survey

REGION(S)/STATE(S): Middle Atlantic (DC, DE, MD, NJ, NY, PA, RI, VA, WV), Northeast (CT, MA, ME, NH, NJ, NY, PA, RI, VT), Southeast (AL, AR, FL, GA, KY, MS, NC, OK, SC, TN, VA), Southern Blue Ridge Province (GA, NC, SC, TN), West (CA, CO, ID, MT, NM, NV, OR, UT, WA, WY)

GOAL(S)/OBJECTIVE(S): To quantify with known statistical confidence the current status, extent, and chemical and biological characteristics of surface waters in regions of the United States potentially sensitive to the effects of acidic deposition. To examine, by applying scientific principles, concepts, and resolution of uncertainty in methods and approach, the extent to which current chemical status of aquatic ecosystems can be attributed to acidic deposition.

RATIONALE: To understand the environmental effects of acidic deposition, it is necessary to have a quantitative regional estimate with known confidence of the status and extent of acidic and low acid neutralizing capacity lakes and streams. Water quality data bases for surface waters cannot be used for making such estimates because the studies they document employed inadequate statistical sampling designs, inconsistent field and laboratory methods, or insufficient chemical measurements to adequately characterize lake and stream water quality on a regional basis.

APPROACH: Regional-scale studies focus on those areas of the United States where existing chemical and geological data indicate waters with low alkalinity. The population of interest is identified and a statistical sample of these systems is obtained using appropriate methods followed by field sampling and complete chemical analyses. Estimates of the chemical status (e.g., proportion of lakes with low acid neutralizing capacity) of entire resource populations or subpopulations are possible using this approach. Uncertainties in estimates are further refined through specific research projects.

KEY WORDS:

Medium:	Chemistry, Deposition, Lakes, Seepage Lakes, Snowpack, Streams
Chemicals:	Acid Neutralizing Capacity, Acidic Cations, Aluminum, Ammonium, Base Cations, Conductance, Major Ions, Metals, Nitrate, Organics, pH, Sulfate
Approach:	Existing Data Analyses, Field Sampling, Literature
Processes:	Aluminum Speciation, Chronic Acidification, Episodic Acidification, Hydrology, Mineral Weathering, Within-Lake Acid Neutralizing Capacity Generation

PPA: E-01 **EPA Code:** E-01 **NAPAP Code:** 6A-1

Element: Program

Contributing to: E-03, E-04, E-05, E-06, E-07, E-08, E-09

Cross Reference: None

Status: Ongoing **Period of Performance:** 1984 to 1991

Contact: Dixon Landers

TITLE: Present Chemical Status of Lakes in Low Alkalinity Regions of the United States

SHORT TITLE: National Lake Survey

REGION(S)/STATE(S): Northeast (CT, MA, ME, NH, NJ, NY, PA, RI, VT), West (CA, CO, ID, MT, NM, NV, OR, UT, WA, WY)

GOAL(S)/OBJECTIVE(S): To quantify, with known statistical confidence, the current status, extent, and chemical and biological characteristics of lakes in regions of the United States that are potentially sensitive to acidic deposition.

RATIONALE: To understand the environmental effects of acidic deposition, it is necessary to have a quantitative regional estimate with known confidence of the status and extent of acidic and low acid neutralizing capacity lakes. Water quality data bases for lakes cannot be used for making such estimates because the studies they document employed inadequate statistical sampling designs, inconsistent field and laboratory methods, or insufficient chemical measurements to adequately characterize lake water quality on a regional basis.

APPROACH: Lake resources are estimated on a regional scale, and a randomly selected subset of lakes is sampled using appropriate methods. The sample results are then weighted in order to estimate the chemical compositions of lake populations with known confidence. Uncertainties with time of sampling (i.e., season), spatial variability, and population definition (i.e., lake size) are included in specific research projects to improve confidence in estimates.

KEY WORDS:

Medium:	Chemistry, Deposition, Lakes, Snowpack
Chemicals:	Acid Neutralizing Capacity, Aluminum, Ammonium, Base Cations, Conductance, Major Ions, Metals, Nitrate, Organics, pH, Sulfate
Approach:	Field Sampling, Literature
Processes:	Aluminum Speciation, Chronic Acidification, Episodic Acidification, Mineral Weathering

PPA: E-01 **EPA Code:** E-01.1 **NAPAP Code:** 6A-1.01A

Element: Program Element

Contributing to: E-03, E-05, E-06, E-07, E-08, E-09

Cross Reference: Program: National Surface Water Survey (E-01)

Status: Ongoing **Period of Performance:** 1985 to 1988

Contact: Dixon Landers

TITLE: Present Chemical Status of Lakes in the Mountainous Western United States

SHORT TITLE: Western Lake Survey

REGION(S)/STATE(S): West (CA, CO, ID, MT, NM, NV, OR, UT, WA, WY)

GOAL(S)/OBJECTIVE(S): To estimate the number, distribution, and characteristics of lakes in those areas of the western United States believed to contain the most low alkalinity lakes.

RATIONALE: Existing data on western lakes are inadequate to make regional-scale, quantitative assessments about the current chemical status of lakes, particularly in high altitude wilderness areas of the West.

APPROACH: A probability-based survey of lakes in areas believed to contain the most low alkalinity lakes in the mountainous areas of the western United States was conducted in fall 1985. This "index" sample provided a basis for assessing lakes in the West and a framework for comparing them with lakes in the East. The Western Lake Survey differed from the Eastern Lake Survey in several respects: the Western Lake Survey was conducted in fall 1985; the minimum lake size in the sampling frame was 1 hectare; and lakes in wilderness areas were accessed by ground rather than by helicopter.

KEY WORDS:
Medium: Chemistry, Lakes
Chemicals: Acid Neutralizing Capacity, Aluminum, Base Cations, Conductance, Metals, Nitrate, Organics, pH, Sulfate
Approach: Field Sampling
Processes: Chronic Acidification

PPA: E-01 **EPA Code:** E-01.1A **NAPAP Code:** 6A-1 01A1

Element: Project

Contributing to: E-05, E-06, E-09

Cross Reference: Program: National Surface Water Survey (E-01)
Program Element: National Lake Survey (E-01.1)

Status: Completed **Period of Performance:** 1985 to 1988

Contact: Dixon Landers

TITLE: Quantifying Seasonal Variability in Lakes in the Northeastern United States

SHORT TITLE: Northeastern Seasonal Variability

REGION(S)/STATE(S): Northeast (CT, MA, ME, NH, NJ, NY, PA, RI, VT)

GOAL(S)/OBJECTIVE(S): To evaluate how the chemical status of lakes in the northeastern United States, developed during Phase I of the National Lake Survey, might vary seasonally.

RATIONALE: The National Surface Water Survey was designed as a phased project to document the present chemical and biological status of lakes and streams in regions of the United States that are potentially sensitive to acidic deposition. By seasonally sampling select surface waters, temporal variability in Phase I aquatic resources can be quantified. Phase I of the National Lake Survey quantified surface water chemistry in areas of the United States expected to contain the majority of low alkalinity lakes during a fall "index" period. Phase II was designed to quantify chemical variability within and among lakes on a regional basis using the subset of lakes sampled in Phase I.

APPROACH: One hundred and fifty lakes sampled in the northeastern United States during Phase I of the Eastern Lake Survey were resampled in the spring, summer, and fall of 1986 to assess seasonal lake chemical variability. The specific water chemistry variables measured in Phase I also were measured in Phase II.

KEY WORDS:
Medium: Chemistry, Lakes
Chemicals: Acid Neutralizing Capacity, Aluminum, Base Cations, Metals, Nitrate, Organics, pH, Sulfate
Approach: Field Sampling
Processes: Aluminum Speciation, Chronic Acidification

PPA: E-01 **EPA Code:** E-01.1B **NAPAP Code:** 6A-1.01A2

Element: Project

Contributing to: E-03, E-06, E-07, E-08, E-09

Cross Reference: Program: National Surface Water Survey (E-01)
Program Element: National Lake Survey (E-01.1)

Status: Ongoing **Period of Performance:** 1986 to 1989

Contact: Dixon Landers

TITLE: Lake Acidification in the Front Range of Colorado

SHORT TITLE: Front Range Lake Acidification

REGION(S)/STATE(S): West (CO)

GOAL(S)/OBJECTIVE(S): To determine if literature references to lake acidification in the Front Range of Colorado are consistent with results from analyses of complete chemical data.

RATIONALE: Of the regions in the West receiving acidic deposition, the Front Range of Colorado is an area of concern because it is close to the Denver metropolitan area and because previous studies conducted in this area have concluded that lake acidification has occurred.

APPROACH: Approximately 43 lakes will be sampled annually, as per a previous study (1979), and 5-10 lakes will be sampled biweekly to determine if lake sulfate concentrations reflect acidification by acidic deposition. Complete chemical characterization will be performed. Maximum acidification will be estimated using a new method that differentiates estimated normal regional atmospheric deposition of sulfate from weathering of sulfur minerals in watersheds. The activities for this project with regard to the National Surface Water Survey have been completed; some of these activities will now be conducted as part of the Long-Term Monitoring Program (E-06) (see page 2-137).

KEY WORDS:
Medium: Chemistry, Deposition, Lakes
Chemicals: Acid Neutralizing Capacity, Base Cations, Nitrate, pH, Sulfate
Approach: Field Sampling, Literature
Processes: Chronic Acidification, Mineral Weathering

PPA: E-01 **EPA Code:** E-01.1C **NAPAP Code:** N/A

Element: Project

Contributing to: E-03, E-05, E-06, E-08, E-09

Cross Reference: Program: National Surface Water Survey (E-01)
Program Element: National Lake Survey (E-01.1)

Status: Completed **Period of Performance:** 1987 to 1988

Contact: Dixon Landers

TITLE: Chemistry of Lakes in High Elevation, Western Wilderness Areas

SHORT TITLE: Mt. Zirkel Lake Study

REGION(S)/STATE(S): West (CO)

GOAL(S)/OBJECTIVE(S): To characterize the chemistry of 10 high-elevation lakes in the Mount Zirkel and Weminuche Wilderness Areas during a summer index period; to determine temporal variability of key chemical parameters in four of the lakes; and to examine the relationship between major ions in precipitation and lake water.

RATIONALE: Concern about acidic deposition is growing in the western United States. Development of energy and metal resources is expected to increase atmospheric emissions of acid precursors and trace metals. Of particular note are developments near wilderness areas or national parks. Because federal permits are required for these areas, air quality is protected from degradation. This project will evaluate the present water quality of lakes in these areas to help develop emissions permits and control strategies, to establish a data base for monitoring long-term effects, and to evaluate selected monitoring methods.

APPROACH: Ten lakes (four in Mt. Zirkel Wilderness Area and six in Weminuche Wilderness Area) were selected for study because of their low alkalinity and sulfate concentrations. These lakes likely would exhibit strong trends in response to acidic inputs if sulfate deposition is the major source of acidity. Sampling is conducted in the summer at two depths for the Mt. Zirkel lakes and at the outflow for the Weminuche lakes. Samples from the Mt. Zirkel lakes are preserved and analyzed for a number of chemical properties, while samples from the Weminuche lakes are analyzed for major ions only. Yearly sampling will show long-term trends, if any occur. The activities for this project with regard to the National Surface Water Survey have been completed; a portion of these activities will continue as part of the Long-Term Monitoring Program (E-06) (see page 2-138).

KEY WORDS:
Medium: Chemistry, Deposition, Lakes
Chemicals: Conductance, Major Ions, pH, Sulfate
Approach: Field Sampling
Processes: Chronic Acidification

PPA: E-01 **EPA Code:** E-01.1D **NAPAP Code:** N/A

Element: Project

Contributing to: E-03, E-05, E-06, E-08, E-09

Cross Reference: Program: National Surface Water Survey (E-01)
Program Element: National Lake Survey (E-01.1)

Status: Completed **Period of Performance:** 1987 to 1988

Contact: Dixon Landers

TITLE: Seasonal and Episodic Water Quality Changes in Precipitation and Lake Water in Northern New Mexico

SHORT TITLE: New Mexico Lake Study

REGION(S)/STATE(S): West (NM)

GOAL(S)/OBJECTIVE(S): To monitor atmospheric deposition at a high altitude site characteristic of northern New Mexico. To determine the frequency, duration, and magnitude of acidic episodes in precipitation, snowmelt, and adjacent lakes.

RATIONALE: The Western Lake Survey provided only fall data for lakes in high mountainous regions. Very little is known of the possible effects of spring snowmelt or precipitation events on these dilute systems. Further, there are very few high altitude sites at which deposition chemistry is measured. The New Mexico Lake Study will provide needed information in both of these areas.

APPROACH: Precipitation chemistry will be monitored by an NADP-type deposition sampling station at the 3,110-foot level in the Sangre de Cristo Mountains in northern New Mexico. Snowpack chemistry at that location will be determined monthly during the winter, and snowmelt will be sampled using a 1.5-m diameter fiberglass snowmelt collector. The nine adjacent Latir lakes will be monitored for changes in water chemistry associated with snowmelt and precipitation. The activities for this project, with regard to the National Surface Water Survey, have been completed; if these activities continue, depending on the results of the first year of study, they will be addressed as part of the Long-Term Monitoring Program (E-06) (see page 2-139).

KEY WORDS:
Medium: Chemistry, Deposition, Lakes, Snowpack
Chemicals: Acid Neutralizing Capacity, Aluminum, Ammonium, Major Ions, Organics, pH
Approach: Field Sampling
Processes: Episodic Acidification

PPA: E-01 EPA Code: E-01.1E NAPAP Code: N/A

Element: Project

Contributing to: E-03, E-05, E-06, E-08, E-09

Cross Reference: Program: National Surface Water Survey (E-01)
Program Element: National Lake Survey (E-01.1)

Status: Completed Period of Performance: 1987 to 1988

Contact: Dixon Landers

TITLE: Present Chemical Status of Streams in Low Alkalinity Regions of the United States

SHORT TITLE: National Stream Survey

REGION(S)/STATE(S): Middle Atlantic (DC, DE, MD, NJ, NY, PA, RI, VA, WV), Southeast (AL, AR, FL, GA, KY, MS, NC, OK, SC, TN, VA), Southern Blue Ridge Province (GA, NC, SC, TN)

GOAL(S)/OBJECTIVE(S): To determine the percentage, extent, and location of streams in the United States that are presently acidic or have low acid neutralizing capacity, and may therefore be susceptible to future acidification. To identify streams that represent important classes in each region for possible use in more intensive studies or long-term monitoring.

RATIONALE: To understand the environmental effects of acidic deposition, it is necessary to have a quantitative regional estimate with known confidence of the status and extent of acidic and low acid neutralizing capacity streams. Water quality data bases for streams cannot be used for making such estimates because the studies they document employed inadequate statistical sampling designs, inconsistent field and laboratory methods, or insufficient chemical measurements to adequately characterize stream water quality on a regional basis.

APPROACH: The National Stream Survey provides an overview of stream water chemistry in regions of the United States that were expected, on the basis of previous alkalinity data, to contain predominantly low acid neutralizing capacity waters. The National Stream Survey employed a randomized, systematic sample of regional stream populations, and used rigorous quality assurance protocols for field sampling and laboratory chemical analysis. Many chemical variables important to aquatic biota were measured, in addition to major cations, anions, pH, and acid neutralizing capacity.

KEY WORDS:

Medium:	Chemistry, Streams
Chemicals:	Acid Neutralizing Capacity, Aluminum, Major Ions, Metals, Nitrate, Organics, pH, Sulfate
Approach:	Field Sampling
Processes:	Chronic Acidification

PPA: E-01 **EPA Code:** E-01.2 **NAPAP Code:** 6A-1.01B

Element: Program Element

Contributing to: E-03, E-04, E-05, E-06, E-07, E-08, E-09

Cross Reference: Program: National Surface Water Survey (E-01)

Status: Completed **Period of Performance:** 1984 to 1988

Contact: Phil Kaufmann

TITLE: Present Chemical Status of Streams in the Southern Blue Ridge Province

SHORT TITLE: Southern Blue Ridge Stream Survey

REGION(S)/STATE(S): Southern Blue Ridge Province (GA, NC, SC, TN)

GOAL(S)/OBJECTIVE(S): To test the feasibility of the National Stream Survey sampling design. To test, evaluate, and refine the National Stream Survey logistics plan, data analysis plan, and alternative sample collection, preparation, and analytical techniques before undertaking the full-scale survey.

RATIONALE: Prior to this pilot survey, a large-scale synoptic survey of stream water quality had not been successfully conducted over a short period of time using a probability sampling frame and rigorous quality assurance protocols. This survey provided unbiased regional estimates with known confidence of the present chemical status of streams.

APPROACH: The Southern Blue Ridge Stream Survey used a randomized, systematic sample of streams and rigorous quality assurance protocols for field sampling, sample transport, and laboratory chemical analysis. A relatively complete set of biologically and geochemically relevant variables was measured. The survey maximized regional sampling density and the number of samples taken in the spring and summer to optimize the sampling design in the full National Stream Survey.

KEY WORDS:
Medium: Chemistry, Streams
Chemicals: Acid Neutralizing Capacity, Aluminum, Major Ions, Metals, Nitrate, Organics, pH, Sulfate
Approach: Field Sampling
Processes: Chronic Acidification

PPA: E-01 **EPA Code:** E-01.2A **NAPAP Code:** 6A-1.01B1

Element: Project

Contributing to: E-03, E-04, E-05, E-06, E-07, E-08, E-09

Cross Reference: Program: National Surface Water Survey (E-01)
Program Element: National Stream Survey (E-01.2)

Status: Completed **Period of Performance:** 1984 to 1987

Contact: Phil Kaufmann

TITLE: Present Chemical Status of Streams in the Middle Atlantic Region

SHORT TITLE: Middle Atlantic Stream Survey

REGION(S)/STATE(S): Middle Atlantic (DC, DE, MD, NJ, NY, PA, RI, VA, WV)

GOAL(S)/OBJECTIVE(S): To determine the percentage, extent, and location of streams in the Middle Atlantic that are presently acidic or have low acid neutralizing capacity, and are therefore susceptible to becoming acidic in the future. To identify streams that represent important classes in this region for possible use in more intensive studies or long-term monitoring.

RATIONALE: Previously existing stream water quality data bases are inadequate for making quantitative regional chemical distribution estimates in this region. The Middle Atlantic region currently receives acidic deposition. To understand the environmental effects of acidic deposition, it is necessary to quantify the status and extent of acidic and low acid neutralizing capacity streams.

APPROACH: The Middle Atlantic Stream Survey was a synoptic survey of water chemistry in this region. It employed a randomized systematic sample of streams and used rigorous quality assurance protocols for field sampling, sample transport, and laboratory chemical analysis. A relatively complete set of biologically and geochemically relevant variables was measured. Some measure of temporal and upstream/downstream variability was included in the sampling design.

KEY WORDS:
Medium: Chemistry, Streams
Chemicals: Acid Neutralizing Capacity, Aluminum, Major Ions, Metals, Nitrate, Organics, pH, Sulfate
Approach: Field Sampling
Processes: Chronic Acidification

PPA: E-01 **EPA Code:** E-01.2B **NAPAP Code:** 6A-1.01B2

Element: Project

Contributing to: E-03, E-04, E-05, E-06, E-07, E-08, E-09

Cross Reference: Program: National Surface Water Survey (E-01)
Program Element: National Stream Survey (E-01.2)

Status: Completed **Period of Performance:** 1986 to 1988

Contact: Phil Kaufmann

TITLE: Present Chemical Status of Streams in the Southeastern United States – Synoptic Chemical Survey

SHORT TITLE: Southeast Screening

REGION(S)/STATE(S): Southeast (AL, AR, FL, GA, KY, MS, NC, OK, SC, TN, VA)

GOAL(S)/OBJECTIVE(S): To determine the percentage, extent, and location of streams in the Southeast and Florida that are presently acidic or have low acid neutralizing capacity, and may therefore be susceptible to becoming acidic in the future. To identify streams that represent important classes in this region for possible use in more intensive studies or long-term monitoring.

RATIONALE: Previously existing stream water quality data bases are inadequate for making quantitative regional chemical distribution estimates in this region. To understand the effect of acidic deposition on streams in this region, it is necessary to quantitatively estimate, with known confidence, the status and extent of acidic and low acid neutralizing capacity streams.

APPROACH: The Southeast Screening was a synoptic survey of water chemistry in this region. It employed a randomized, systematic sample of streams and used rigorous quality assurance protocols for field sampling and laboratory chemical analysis. A relatively complete set of biologically and geochemically relevant variables was measured. The index chemical values were evaluated from single springtime samples at the upstream and downstream ends of sample stream reaches in the drainage network.

KEY WORDS:

Medium:	Chemistry, Streams
Chemicals:	Acid Neutralizing Capacity, Aluminum, Major Ions, Metals, Nitrate, Organics, pH, Sulfate
Approach:	Field Sampling
Processes:	Chronic Acidification

PPA: E-01 **EPA Code:** E-01.2C **NAPAP Code:** 6A-1.01B3

Element: Project

Contributing to: E-03, E-04, E-05, E-06, E-07, E-08, E-09

Cross Reference: Program: National Surface Water Survey (E-01)
Program Element: National Stream Survey (E-01.2)

Status: Completed **Period of Performance:** 1986 to 1988

Contact: Phil Kaufmann

TITLE: Refining Estimates of Current Chemical Status of Special Subpopulations

SHORT TITLE: Subpopulational Studies

REGION(S)/STATE(S): Upper Midwest (MI, MN, WI), Southeast (FL), West (AK)

GOAL(S)/OBJECTIVE(S): To resolve questions regarding particular subsets of lakes identified in Phase I of the National Surface Water Survey, which constitute a major portion of the acidic or low acid neutralizing capacity population of lakes. To describe the relationship between the chemistry of acidic seepage lakes and atmospheric deposition, to quantify factors controlling current seepage lake chemistry, and to forecast the future response of acidic seepage lakes to acidic deposition. Specifically, to examine in more detail the chemistry of seepage lakes.

RATIONALE: Seepage lakes, those without surface water inlets and outlets, constitute two-thirds of the acidic lake population in the eastern United States. Very little is known, however, about the relationship between regional seepage lake chemistry and acidic deposition. Determining the current status of seepage lakes will help in understanding all sensitive aquatic resources.

APPROACH: Seepage lakes are being examined by two methods. First, existing data on lake and deposition chemistry are being compared to calculate enrichment/depletion ratios of major ions. These results will provide regional estimates of the amount of groundwater inputs, the amount of acid neutralizing capacity that is internally generated, and the relative contribution of acidic deposition to the acid status of these waters. Second, measurements of deposition and groundwater inputs are proposed for a small number of acidic seepage lakes to evaluate the relative importance of deposition and natural processes in determining acidic status.

Field sampling also will be conducted to quantify the relationship between groundwater and seepage lake chemistry in Florida and the Upper Midwest. Chemical enrichment factors will be evaluated for seepage lakes in the Midwest. Background chemistry in seepage lakes not impacted by deposition will be evaluated in the far West.

KEY WORDS:
Medium: Chemistry, Deposition, Groundwater, Lakes, Seepage Lakes
Chemicals: Acid Neutralizing Capacity, Acidic Cations, Base Cations, Major Ions, Nitrate, Organics, Sulfate
Approach: Existing Data Analyses, Field Sampling
Processes: Chronic Acidification, Hydrology, Within-Lake Acid Neutralizing Capacity Generation

PPA: E-01 EPA Code: E-01.3 NAPAP Code: 6A-1.02

Element: Program Element

Contributing to: E-05, E-09

Cross Reference: Program: National Surface Water Survey (E-01)

Status: Ongoing Period of Performance: 1988 to 1991

Contact: Dixon Landers

TITLE: Evaluating the Relationship Between Atmospheric Deposition and Seepage Lake Water Chemistry in Florida

SHORT TITLE: Florida Lake Acidification Project

REGION(S)/STATE(S): Southeast (FL)

GOAL(S)/OBJECTIVE(S): To evaluate the relationship between deposition chemistry and the chemistry of seepage lakes in Florida.

RATIONALE: By measuring deposition chemistry (wet and dry) and groundwater inputs, the internal generation of acid neutralizing capacity and other important processes that control the chemistry of seepage lakes can be estimated.

APPROACH: Wet deposition and aerosol chemistry from the Florida Acid Deposition Network will be used to estimate total deposition in Florida. A study lake in the Florida Panhandle has been selected and will be instrumental in providing quantitative estimates of major inputs and sinks in a clearwater, acidic seepage lake. Direct measurements of deposition, groundwater, and lake chemistry combined with information on important processes will assist in evaluating the relative importance of natural and anthropogenic sources of acidity.

KEY WORDS:
Medium: Chemistry, Deposition, Groundwater, Lakes, Seepage Lakes
Chemicals: Major Ions, Nitrate, Sulfate
Approach: Field Sampling
Processes: Chronic Acidification, Hydrology, Within-Lake Acid Neutralizing Capacity Generation

PPA: E-01 **EPA Code:** E-01.3A **NAPAP Code:** 6A-1.02A

Element: Project

Contributing to: E-05, E-09

Cross Reference: Program: National Surface Water Survey (E-01)
Program Element: Subpopulational Studies (E-01.3)

Status: Ongoing **Period of Performance:** 1988 to 1991

Contact: Dixon Landers

TITLE: Chemical Characterization of a Subset of Seepage Lakes in Alaska

SHORT TITLE: Alaska Seepage Lake Studies

REGION(S)/STATE(S): Upper Midwest (MI, MN, WI), West (AK)

GOAL(S)/OBJECTIVE(S): To characterize lakes in Alaska, a low deposition region, that have similar hydrologic, watershed, and chemical characteristics to lakes in the Upper Midwest. To evaluate the influence of deposition on seepage lakes by comparing similar lakes under low and moderate levels of acidic deposition.

RATIONALE: The lakes of the Kenai Peninsula in south-central Alaska are very similar in origin, age, and watershed vegetation to typical lakes in the Upper Midwest. There is relatively little chemical information regarding these lakes, which are located in an area of current oil exploration. It has been determined, however, that these lakes receive only background levels of deposition. Because these Alaskan lakes are so similar to lakes in the Upper Midwest, which were included in the Eastern Lake Survey, comparisons of their chemical characteristics may be useful in understanding possible effects of acidic deposition. The Alaskan lakes could be presumed to represent seepage lakes under near pristine conditions.

APPROACH: A population-based sample of about 60 lakes were taken in August 1988 when the lakes in the Kenai Peninsula were undergoing fall turnover. Complete chemical characterization will be determined for cations, anions, acid neutralizing capacity, conductivity, pH, and other parameters. The cumulative frequency curves will be generated and compared to lake populations in the Upper Midwest.

KEY WORDS:
Medium: Chemistry, Deposition, Lakes, Seepage Lakes
Chemicals: Acid Neutralizing Capacity, Major Ions, Organics
Approach: Field Sampling
Processes: Chronic Acidification, Hydrology

PPA: E-01 **EPA Code:** E-01.3B **NAPAP Code:** 6A-1.02B

Element: Project

Contributing to: E-05, E-09

Cross Reference: Program: National Surface Water Survey (E-01)
Program Element: Subpopulational Studies (E-01.3)

Status: Ongoing **Period of Performance:** 1988-1991

Contact: Dixon Landers

TITLE: Chemical Characterization of a Subset of Seepage Lakes in the Upper Midwest

SHORT TITLE: Upper Midwest Seepage Lake Studies

REGION(S)/STATE(S): Upper Midwest (MI, MN, WI)

GOAL(S)/OBJECTIVE(S): To better understand the process of seepage lake acidification and to determine the role of acidic deposition in altering seepage lake chemistry.

RATIONALE: Seepage lakes in the Upper Midwest are susceptible to effects from acidic deposition; understanding their important processes, especially internal acid neutralizing capacity generation, assists in determining potential sensitivity of this resource.

APPROACH: Enrichment factor analysis and a review of site-specific information from intensively studied systems (Little Rock Lake, Vandercook Lake, etc.) will be used to determine the relative importance of various biogeochemical processes involved in alkalinity regulation. The relationship between acidic deposition rates (H^+ loading) and lakewater chemistry will be evaluated by empirical analysis (e.g., H^+ loading vs. acid neutralizing capacity) using several distinct groups of lakes in the Upper Midwest and other regions with higher and lower H^+ loadings. Finally, deterministic modeling will be used to make regional forecasts of the effects of increasing or decreasing acidic deposition rates.

KEY WORDS:
Medium: Deposition, Lakes, Seepage Lakes
Chemicals: Acid Neutralizing Capacity, Acidic Cations, Base Cations, Organics
Approach: Existing Data Analyses
Processes: Chronic Acidification

PPA: E-01 EPA Code: E-01.3C NAPAP Code: 6A-1.02C

Element: Project

Contributing to: E-05, E-09

Cross Reference: Program: National Surface Water Survey (E-01)
Program Element: Subpopulational Studies (E-01.3)

Status: Ongoing Period of Performance: 1988-1991

Contact: Dixon Landers

2.3 DIRECT/DELAYED RESPONSE PROJECT – PROGRAM E-07

[Program/Program Element/Project]

TITLE: Forecasting Regional-Scale Surface Water Acidification in Potentially Sensitive Regions of the United States

SHORT TITLE: Direct/Delayed Response Project

REGION(S)/STATE(S): Mid-Appalachians (DE, MD, NJ, NY, PA, VA, WV), Middle Atlantic (DE, MD, NJ, NY, PA, RI, VA, WV), Northeast (CT, MA, ME, NH, NY, PA, RI, VT), Southeast (AL, AR, GA, KY, MS, NC, SC, TN, VA), Southern Blue Ridge Province (GA, NC, SC, TN, VA)

GOAL(S)/OBJECTIVE(S): To forecast future effects of acidic deposition on surface water chemistry in the Northeast, Southern Blue Ridge Province, and Mid-Appalachians and (1) to characterize the regional variability of soil and watershed characteristics, (2) to determine which soil and watershed characteristics are most strongly related to surface water chemistry, (3) to estimate the relative importance of key watershed processes across the study regions, and (4) to classify a sample of watersheds according to their response characteristics to acidic deposition.

RATIONALE: This work will forecast future effects of acidic deposition on surface water chemistry to help assess potential adverse effects.

APPROACH: This project applies to the Northeast (New York and New England) and the Southern Blue Ridge Province (eastern Tennessee, western North Carolina, northern Georgia), and has recently been extended to the Mid-Appalachian Region (Pennsylvania, West Virginia, Maryland, Virginia). This project includes sampling soil, analyzing characteristics for a select number of watersheds, and applying analytical and forecasting methods to explain the interaction of acidic deposition with such systems. This study will help forecast future effects of acidic deposition on these watersheds and associated lakes and streams.

KEY WORDS:

Medium:	Chemistry, Deposition, Lakes, Soils, Streams, Vegetation, Watersheds, Wetlands
Chemicals:	Acid Neutralizing Capacity, Aluminum, Base Cations, Cation Exchange Complex, Clay Minerals, Nitrate, Organics, pH, Soil Chemistry, Sulfate
Approach:	Aggregation, Correlative Analyses, Existing Data Analyses, Field Mapping, Field Sampling, Input-Output Budgets, Laboratory, Literature, Modeling, Single-Factor Analyses
Processes:	Base Cation Exchange, Base Cation Supply, Chronic Acidification, Community Response, Hydrology, Mineral Weathering, Sulfate Adsorption, Sulfate Reduction, Sulfur Cycling, Sulfur Retention

PPA: E-07 **EPA Code:** E-07 **NAPAP Code:** 6B-1

Element: Program

Contributing to: E-03, E-05, E-06, E-09

Cross Reference: None

Status: Ongoing **Period of Performance:** 1984 to 1991

Contact: M. Robbins Church

TITLE: Regional Surveys of Physicochemical Characteristics of Soils for Use in Forecasting Surface Water Acidification

SHORT TITLE: Soil Surveys

REGION(S)/STATE(S): Mid-Appalachians (MD, PA, VA, WV), Northeast (CT, MA, ME, NH, NY, PA, RI, VT), Southern Blue Ridge Province (GA, NC, SC, TN, VA)

GOAL(S)/OBJECTIVE(S): To provide the Direct/Delayed Response Project with high-quality, internally consistent data on soils and other watershed characteristics needed for Level I, II, and III analyses To provide related projects with data to help select sites and develop future research projects.

RATIONALE: The Direct/Delayed Response Project aims to characterize the responses of watersheds to varying levels of acidic deposition on a regional basis. Related projects (Watershed Manipulation Project, Temporally Integrated Monitoring of Ecosystems) will focus on the responses of representative watersheds. These projects require two types of high-quality, internally consistent data bases on watershed characteristics of importance for relating the response of surface waters to acidic deposition: (1) regional data bases and (2) watershed-specific data bases.

A pilot soil survey conducted in 1984 concluded that existing data bases were not adequate because of the following: (1) most sites of interest are in remote areas not covered by existing soil maps of adequate resolution; (2) most soils of interest are nonagricultural soils for which few, if any, data on physical and chemical properties exist; (3) the laboratory analyses rarely include certain critical parameters, such as sulfate adsorption or unbuffered cation exchange capacity; and (4) major questions regarding data comparability and reliability arise because many different analytical techniques were used and because quality assurance/quality control information generally is not available. Soil surveys specifically designed to meet the needs of this program were conducted.

APPROACH: Activities in each region include watershed selection, watershed mapping, soil sampling, and laboratory analysis. Soil survey field activities have been completed in the Northeast and the Southern Blue Ridge Province; they are underway in the Mid-Appalachian region.

1. *Watershed Selection.* Watersheds are selected probabilistically from National Surface Water Survey sites or according to criteria developed for special purposes.
2. *Watershed Mapping.* Experienced Soil Conservation Service field crews map soils, vegetation, and depth-to-bedrock at a scale of 1:24,000. Bedrock geology maps for each watershed are produced from existing maps.
3. *Soil Sampling.* The soil maps are used to define soils representing each region or watershed as appropriate. Soil Conservation Service personnel sample these soils at locations specified by the Direct/Delayed Response Project.
4. *Laboratory Analysis.* Field crews deliver soil samples to laboratories that dry and otherwise prepare the samples for chemical and physical analysis, analyze some samples, then ship the samples and audit samples to the analytical laboratories where most of the analyses are performed.

KEY WORDS:

Medium:	Chemistry, Lakes, Soils, Watersheds, Wetlands
Chemicals:	Aluminum, Nitrate, Sulfate
Approach:	Aggregation, Existing Data Analyses, Field Mapping, Field Sampling, Input-Output Budgets, Laboratory
Processes:	Base Cation Exchange, Chronic Acidification, Mineral Weathering, Sulfate Adsorption, Sulfate Reduction, Sulfur Cycling

PPA: E-07 **EPA Code:** E-07.1 **NAPAP Code:** 6C-2.11

Element: Program Element

Contributing to: E-05, E-06, E-09

Cross Reference: Program: Direct/Delayed Response Project (E-07)

Status: Ongoing **Period of Performance:** 1984 to 1991

Contact: M. Robbins Church

TITLE: Regional Soil Surveys in the Northeast, Southern Blue Ridge Province, and Mid-Appalachians

SHORT TITLE: Regional Soil Surveys

REGION(S)/STATE(S): Mid-Appalachians (MD, PA, VA, WV), Northeast (CT, MA, ME, NH, NY, PA, RI, VT), Southern Blue Ridge Province (GA, NC, SC, TN, VA)

GOAL(S)/OBJECTIVE(S): To provide the Direct/Delayed Response Project with high-quality, internally consistent regional data on soils and other watershed characteristics that can be extrapolated for regions of concern to generate and test statistical hypotheses within and among regions. To provide related projects (Watershed Manipulation Project, Temporally Integrated Monitoring of Ecosystems) with a basis for ensuring and documenting that sites selected for study are representative.

RATIONALE: The Direct/Delayed Response Project aim is to characterize the responses of watersheds to varying levels of acidic deposition on a regional basis. Related projects (Watershed Manipulation Project, Temporally Integrated Monitoring of Ecosystems) will focus on the responses of representative watersheds. The success of these projects depends upon access to high-quality, regionally consistent data bases on watershed characteristics of importance for relating the response of surface waters to acidic deposition. A pilot soil survey conducted in 1984 demonstrated that existing data bases were not adequate for use in the Direct/Delayed Response Project. Therefore, it was impossible for these projects to access the required regional data bases without performing soil surveys specifically designed to meet their needs.

APPROACH: Activities in each region include watershed selection, watershed mapping, soil sampling, and laboratory analysis. Soil survey field activities have been completed in the Northeast and Southern Blue Ridge Province; they are underway in the Mid-Appalachian region.

1. *Watershed Selection.* Watersheds are selected from those included in the National Surface Water Survey and constitute a probabilistic sample of surface waters in the populations of interest.
2. *Watershed Mapping.* Experienced Soil Conservation Service soil scientists map soils, vegetation, and depth-to-bedrock at a scale of 1:24,000. Bedrock geology maps for each watershed are produced from existing maps.
3. *Soil Sampling.* The soil maps are used to define soil sampling classes that represent soils within each region. Soil Conservation Service personnel sample these classes at randomly selected locations. The pedons of a given soil sampling class collectively represent that class throughout the region.
4. *Laboratory Analysis.* Field crews deliver soil samples to laboratories that dry and otherwise prepare the samples for chemical and physical analysis, conduct some soil analyses, then ship the samples along with audit samples to the analytical laboratories where most of the analyses are performed.

KEY WORDS:

Medium:	Chemistry, Soils, Watersheds
Chemicals:	Aluminum, Nitrate, Sulfate
Approach:	Field Mapping, Field Sampling, Laboratory
Processes:	Base Cation Exchange, Chronic Acidification, Mineral Weathering, Sulfate Adsorption

PPA: E-07 **EPA Code: E-07.1A** **NAPAP Code: 6C-2.11A**

Element: Project

Contributing to: E-05, E-06, E-09

Cross Reference: Program: Direct/Delayed Response Project (E-07)
Program Element: Soil Surveys (E-07.1)

Status: Ongoing **Period of Performance:** 1984 to 1991

Contact: M. Robbins Church

TITLE: Verifying the Extent of Sulfate Retention in Northeastern Watersheds

SHORT TITLE: Special Soil Studies (Sulfate Retention)

REGION(S)/STATE(S): Northeast (CT, MA, ME, NH, NY, PA, RI, VT)

GOAL(S)/OBJECTIVE(S): To identify watersheds in the northeastern United States that have high rates of net sulfate retention. To (1) identify the process(es) that retain sulfate, and (2) if the process is adsorption, estimate time needed to reach sulfur steady state.

RATIONALE: Available data suggest that sulfur budgets for most watersheds in the northeastern United States are at or very close to steady state, yet some systems in the region are calculated to retain a significant fraction of sulfur inputs. To make reliable forecasts of the future effects of acidic deposition on surface water quality in the region, it is essential to determine if net sulfate retention is actually occurring (or alternatively, if it is an artifact resulting from uncertainty in input-output budgets). If retention is occurring, then it must be determined whether and at what rate sulfate concentrations will increase to steady state. The processes that retain sulfate and the capacity of the watershed to continue retention must be evaluated. If these systems are retaining sulfate through processes other than adsorption, watershed chemistry models currently used may have to be modified to forecast future watershed response accurately.

APPROACH: Based on existing, preliminary input-output budgets for approximately 700 drainage lakes and impoundments in the northeastern United States sampled during the Eastern Lake Survey, 45 lakes with high computed sulfur retention rates have been selected for further study. Aerial photos of each site have been taken and interpreted to determine potential land-use factors affecting sulfate mobility (e.g., wetlands, agricultural disturbance), and soils in the watersheds are being mapped in detail to identify soil taxonomic units and to characterize bedrock, vegetation, and soil physical features. Data will be compared to those collected from the original 145 Direct/Delayed Response Project watersheds to identify factors contributing to sulfur retention. If the causes of retention are not resolved on the basis of watershed mapping data, additional soil sampling at some or all of the watersheds will be considered. For sites where retention occurs by adsorption, time to reach steady state will be forecasted using soil chemistry data with the sulfate subroutine of a watershed chemistry model.

KEY WORDS:
Medium: Chemistry, Lakes, Soils, Wetlands
Chemicals: Sulfate
Approach: Aggregation, Existing Data Analyses, Field Mapping, Input-Output Budgets
Processes: Sulfate Adsorption, Sulfate Reduction, Sulfur Cycling

PPA: E-07 **EPA Code:** E-07.1B **NAPAP Code:** 6C-2.11B

Element: Project

Contributing to: E-05, E-06, E-09

Cross Reference: Program: Direct/Delayed Response Project (E-07)
Program Element: Soil Surveys (E-07.1)

Status: Ongoing **Period of Performance:** 1987 to 1990

Contact: M. Robbins Church

TITLE: Developing Relationships Among Regional Soil Survey Data Bases to Extend the Utility of Analyses in the Direct/Delayed Response Project

SHORT TITLE: Regionalization of Soil Chemistry

REGION(S)/STATE(S): Mid-Appalachians (DE, MD, PA, VA, WV), Northeast (CT, MA, NH, NY, PA, RI, VT), Southern Blue Ridge Province (GA, NC, SC, TN, VA)

GOAL(S)/OBJECTIVE(S): To combine information from the Direct/Delayed Response Project soil survey data bases with information contained in the SOILS 5 and other preexisting data bases for soils in other regions.

RATIONALE: This work will combine information from the Direct/Delayed Response Project soil surveys with information from existing soils data bases to make extrapolations to other regions not surveyed in the Direct/Delayed Response Project. This will help to *a priori* characterize soils in other regions and evaluate their potential responses to continued acidic deposition.

APPROACH: This work will combine the Direct/Delayed Response Project soil survey data from the Northeast, Southern Blue Ridge Province, and Mid-Appalachians with information on soils in other regions in the East, such as other areas of the Blue Ridge and Appalachians. Statistical analyses of the relationship between specific chemical analyses undertaken in the Direct/Delayed Response Project and standard analyses used in previous soil surveys will be used to compare and combine the data bases.

KEY WORDS:
Medium: Chemistry, Soils
Chemicals: Base Cations, Sulfate
Approach: Field Sampling, Laboratory, Literature
Processes: Base Cation Supply, Sulfate Adsorption

PPA: E-07 EPA Code: E-07.2 NAPAP Code: 6C-2.12

Element: Program Element

Contributing to: E-05, E-06, E-09

Cross Reference: Program: Direct/Delayed Response Project (E-07)

Status: Initiating Period of Performance: 1988 to 1990

Contact: M. Robbins Church

TITLE: Relationships Between Watershed Characteristics and Surface Water Chemistry

SHORT TITLE: Correlative Analyses

REGION(S)/STATE(S): Mid-Appalachians (MD, PA, VA, WV), Northeast (CT, MA, ME, NH, NJ, NY, PA, RI, VT), Southeast (AL, AR, GA, KY, MS, NC, SC, TN, VA), Southern Blue Ridge Province (GA, NC, SC, TN, VA)

GOAL(S)/OBJECTIVE(S): To determine which soil and watershed characteristics are most strongly related to surface water chemistry. To estimate the relative importance of key watershed processes in the regions of study.

RATIONALE: These analyses will show clearly how watershed and soil characteristics relate to surface water chemistry. This relationship is important for determining the types of models that are best suited for forecasting future surface water chemistry and the best methods for evaluating surface water chemistry both through single-factor response time estimates and complex dynamic watershed models.

APPROACH: This work is being undertaken for sample watersheds in the Northeast, the Southern Blue Ridge Province, and the Mid-Appalachians. This work will apply statistical analyses to data gathered from watershed mapping and sampling in the Direct/Delayed Response Project. It will assess the relationships among these factors and surface water chemistry measured in the watersheds. The standard mapping and sampling data sets from the Direct/Delayed Response Project will allow the clearest determination of relationships possible. Previous investigations on regional relationships have been limited by the lack of internal consistence of the data sets examined.

KEY WORDS:

Medium:	Chemistry, Deposition, Lakes, Soils, Streams, Vegetation, Watersheds, Wetlands
Chemicals:	Acid Neutralizing Capacity, Base Cations, Nitrate, Organics, pH, Soil Chemistry, Sulfate
Approach:	Aggregation, Correlative Analyses, Existing Data Analyses, Field Sampling, Input-Output Budgets, Literature, Modeling
Processes:	Base Cation Supply, Community Response, Hydrology, Mineral Weathering, Sulfate Adsorption, Sulfate Reduction, Sulfur Retention

PPA: E-07 **EPA Code:** E-07.3 **NAPAP Code:** 6C-2.09

Element: Program Element

Contributing to: E-05, E-06, E-09

Cross Reference: Program: Direct/Delayed Response Project (E-07)

Status: Ongoing **Period of Performance:** 1984 to 1990

Contact: M. Robbins Church

TITLE: Extent of Sulfur Retention in Watersheds in the Eastern United States

SHORT TITLE: Evidence of Sulfur Retention

REGION(S)/STATES(S): Mid-Appalachians (DE, MD, VA, WV), Northeast (CT, MA, ME, NH, NJ, NY, PA, RI, VT), Southeast (AL, AR, GA, KY, MS, NC, SC, TN, VA)

GOAL(S)/OBJECTIVE(S): To determine the amount of sulfur retained in watersheds studied in the Direct/Delayed Response Project.

RATIONALE: Retention of sulfur from atmospheric deposition in watersheds is an important factor affecting surface water acidification. Sulfate can act as a mobile anion, carrying with it combinations of base cations and acid cations. In general, northern soils have relatively little ability to adsorb additional atmospherically deposited sulfur, whereas southern soils have a greater ability to do so. The sulfur retention status of soils can change with time due to the effects of continued loading from atmospheric deposition. Such soils can lose part of their ability to retain sulfur, possibly resulting in increased leaching of acids to surface waters. Determining the current status of sulfur retention in soils and watersheds is useful in projecting future effects of constant or altered levels of sulfur deposition.

APPROACH: This project will employ an input/output analysis approach. Annual inputs are being provided from the National Acid Precipitation Assessment Program's Task Group IV (Deposition Monitoring and Air Quality). Outputs are computed using lake and stream chemistry from the National Surface Water Survey in the East and estimates of annual runoff from maps produced by the U.S. Geological Survey. Input-output status of watersheds in the Northeast, mountainous Mid-Appalachians, and portions of the South are being compared and contrasted. The hypothesis that northeastern watersheds are at steady state under current loadings will be examined. Input-output status will be examined in light of the potential for internal watershed sources of sulfur and with regard to relationships of status with soils characteristics. Results of the analyses will be displayed both as distribution of percent sulfur retention and as maps of percent sulfur retention.

KEY WORDS:
Medium: Chemistry, Lakes, Soils, Streams, Watersheds
Chemicals: Sulfate
Approach: Correlative Analyses, Field Sampling, Input-Output Budgets, Literature
Processes: Sulfur Retention

PPA: E-07 **EPA Code:** E-07.3A **NAPAP Code:** 6C-2.09A

Element: Project

Contributing to: E-05, E-06, E-09

Cross Reference: Program: Direct/Delayed Response Project (E-07)
Program Element: Correlative Analyses (E-07.3)

Status: Ongoing **Period of Performance:** 1984 to 1990

Contact: M. Robbins Church

TITLE: Relationship Between Hydrologic Factors and Surface Water Chemical Characteristics

SHORT TITLE: Hydrology/Water Chemistry

REGION(S)/STATE(S): Northeast (CT, MA, ME, NH, NY, PA, RI, VT), Southern Blue Ridge Province (GA, NC, SC, TN)

GOAL(S)/OBJECTIVE(S): Within watersheds, hydrologic flowpath has been identified as an important factor determining the relationship between acidic deposition and surface water chemistry. Detailed information on hydrologic flowpath is difficult to obtain, often requiring extensive field studies on individual watersheds. The goals of this project are to (1) use indirect methods, such as mapped geomorphic parameters, to estimate the hydrologic flowpath, (2) relate flowpath to hydrologic soil contact, and (3) relate hydrologic soil contact to surface water chemistry.

RATIONALE: The route that precipitation follows through a watershed to receiving surface waters is an important factor in determining surface water chemistry. If the flowpath is predominantly shallow, subsurface flow resulting in rapid runoff, the chemistry of the water reaching the surface water system will more closely reflect the precipitation chemistry. If the major flowpath is deep, resulting in longer residence times in the soil, the increased contact with exchange and adsorption sites yields a greater potential for neutralization of acidic deposition inputs. Determining the correlation between hydrologic soil contact and surface water chemistry will provide important information about the long-term effects of acidic deposition on surface water chemistry.

APPROACH: Hydrologic contact time is being estimated by (1) using topographic maps of individual watersheds to measure geomorphic and hydrologic parameters, (2) applying a modified Darcy's Law to soil permeability and hydraulic conductivity data collected as part of the Direct/Delayed Response Project Soil Survey, and (3) using the hydrologic model TOPMODEL to study watersheds and estimate hydrologic parameters for determining possible flowpath. Correlations between these estimates and surface water chemistry data, collected in the Eastern Lake Survey – Phase I, will be performed.

KEY WORDS:
Medium: Chemistry, Soils, Watersheds
Chemicals: Base Cations, Sulfate
Approach: Correlative Analyses, Modeling
Processes: Hydrology

PPA: E-07 **EPA Code:** E-07.3B **NAPAP Code:** 6C-2.09B

Element: Project

Contributing to: E-05, E-09

Cross Reference: Program: Direct/Delayed Response Project (E-07)
Program Element: Correlative Analyses (E-07.3)

Status: Ongoing **Period of Performance:** 1984 to 1990

Contact: M. Robbins Church

TITLE: Aggregation of Soils Data to Develop Regional Soil Chemical Characteristics at Watershed Scales

SHORT TITLE: Soil Aggregation

REGION(S)/STATE(S): Mid-Appalachians (MD, PA, VA, WV), Northeast (CT, MA, ME, NH, NY, PA, RI, VT), Southern Blue Ridge Province (GA, NC, SC, TN)

GOAL(S)/OBJECTIVE(S): To evaluate appropriate aggregation schemes to estimate typical soil characteristics in watersheds located in regions susceptible to acidic deposition for use in the three levels of analysis in the Direct/Delayed Response Project.

RATIONALE: Soil sampling for physical and chemical characteristics is expensive and time consuming. In describing the regional characteristics of soils, it is impractical to perform detailed and complete studies of all soils that exist within the study area. By designing a probabilistic sampling scheme within the region, this problem becomes manageable. Although the detail within individual watersheds is reduced by aggregation techniques, sufficient information on soil characteristics is retained to correlate soil properties with observed surface water chemistry on a regional basis.

APPROACH: A probability sample of watersheds, stratified by alkalinity, was selected from the Eastern Lake Survey target population. Soils, along with other watershed characteristics, were mapped to a six-acre resolution. Based on the mapped information, soils (representing about 365 identified soil series) in the Northeast were grouped into 38 sampling classes. In the Southern Blue Ridge Province, soils were grouped into 12 sampling classes. Similarly, soils in the Mid-Appalachians also are being addressed. Subsequent analyses are based on data aggregated within these sampling classes. According to the needs of the user, data might be aggregated by horizon, by pedon, or across sampling classes. Also, data might be areally weighted for whole watersheds or specific "buffer" zones (e.g., 30-m buffer strips around the perimeter of the lakes, the riparian zones), again, according to the requirements of the data user.

KEY WORDS:
Medium: Chemistry, Soils
Chemicals: Soil Chemistry
Approach: Aggregation, Correlative Analyses, Existing Data Analyses
Processes: N/A

PPA: E-07 **EPA Code:** E-07.3C **NAPAP Code:** 6C-2.09C

Element: Project

Contributing to: E-05, E-09

Cross Reference: Program: Direct/Delayed Response Project (E-07)
Program Element: Correlative Analyses (E-07.3)

Status: Ongoing **Period of Performance:** 1984 to 1990

Contact: M. Robbins Church

TITLE: Relationship Between Surface Water Chemistry and Soil Chemical Properties

SHORT TITLE: Soil/Water Interactions

REGION(S)/STATE(S): Mid-Appalachians (MD, PA, VA, WV), Northeast (CT, MA, ME, NH, NY, PA, RI, VT), Southern Blue Ridge Province (GA, NC, SC, TN, VA)

GOAL(S)/OBJECTIVE(S): To establish, on a regional basis, a statistically valid description of those physical and chemical soil characteristics that correlate with observed surface water chemical composition, including pH and acid neutralizing capacity.

RATIONALE: Meteoric waters, for the most part, must pass through soils before emerging as surface waters. Interactions between soils and water, therefore, play a major role in determining the final compositions of waters that emerge. Although numerous, process-level studies provide information regarding the type of interactions that should be expected from individual processes, it is difficult to develop a unified understanding of the most critical processes, especially from a regional perspective, from the information now available. This statistical study will establish, within the constraints of the sampling program, those processes that are most closely correlated with, and therefore, presumably related to, observed surface water chemical composition. The study also will provide a way to test hypotheses relating to those processes, and help define those areas in which additional process-level research might be needed.

APPROACH: Physical and chemical soils data have been collected from a probability sample of watersheds in the Northeast and Southern Blue Ridge Province and are currently being collected in the Mid-Appalachians. Water chemistry data are available from the Eastern Lake Survey – Phase I. The soils data are being grouped by predefined sampling classes. According to the needs of the specific analysis, data may be aggregated by horizon, by pedon, or across sampling classes. Data will be areally weighted for whole watersheds or specific "buffer" zones (e.g., the riparian zones), according to the specific analysis being conducted. Bivariate and multivariate analyses, using water chemistry as the dependent variable, are being conducted using the data aggregated according to these various schemes.

KEY WORDS:

Medium:	Chemistry, Deposition, Lakes, Soils, Streams, Watersheds
Chemicals:	Acid Neutralizing Capacity, Base Cations, Organics, pH, Soil Chemistry
Approach:	Aggregation, Correlative Analyses, Existing Data Analyses
Processes:	Base Cation Supply, Hydrology, Mineral Weathering, Sulfate Adsorption

PPA: E-07 **EPA Code:** E-07.3D **NAPAP Code:** 6C-2.09D

Element: Project

Contributing to: E-05, E-09

Cross Reference: Program: Direct/Delayed Response Project (E-07)
Program Element: Correlative Analyses (E-07.3)

Status: Ongoing **Period of Performance:** 1984 to 1990

Contact: M. Robbins Church

TITLE: Relationship Between Surface Water Chemistry and Vegetation

SHORT TITLE: Water Chemistry/Vegetation

REGION(S)/STATE(S): Mid-Appalachians (MD, PA, VA, WV), Northeast (CT, MA, ME, NH, NJ, NY, PA, RI, VT), Southern Blue Ridge Province (GA, NC, SC, TN, VA)

GOAL(S)/OBJECTIVE(S): To generate and statistically test hypotheses relating vegetation of watersheds to surface water chemistry.

RATIONALE: Relationships between vegetation type and surface water chemistry might exist because foliage or litter directly intercept and alter the chemistry of water flowing through watersheds, because (1) indirect effects are mediated by the effects of vegetation on chemical cycling (e.g., cations), (2) vegetation affects soil-forming processes, or (3) the distribution of vegetation depends on watershed status or processes that also affect surface water chemistry. For instance, wetland vegetation might indicate that sulfate reduction is important. The regional data bases of the Direct/Delayed Response Project provide a statistical basis for testing many of the hypotheses that may link vegetation and surface water chemistry.

APPROACH: Vegetation cover maps (six-acre minimum delineations) are available for each watershed from the mapping phase of the Direct/Delayed Response Project. Data on where specific classes of wetlands occur (one-acre minimum delineations) are available from ground-truthed interpretation of aerial photos (stereo color infrared) of Direct/Delayed Response Project watersheds. The latter are available for the Northeast and for the Mid-Appalachians. Statistical analysis relating vegetation classes in watersheds or portions of watersheds provides a way to test the importance of proposed vegetation-water chemistry relationships on a regional scale.

KEY WORDS:
Medium: Chemistry, Vegetation, Watersheds
Chemicals: Base Cations, Nitrate, Organics, Sulfate
Approach: Correlative Analyses, Existing Data Analyses
Processes: Community Response, Sulfate Reduction

PPA: E-07 **EPA Code:** E-07.3E **NAPAP Code:** 6C-2.09E

Element: Project

Contributing to: E-05, E-09

Cross Reference: Program: Direct/Delayed Response Project (E-07)
Program Element: Correlative Analyses (E-07.3)

Status: Ongoing **Period of Performance:** 1986 to 1990

Contact: M. Robbins Church

TITLE: Relationship Between Surface Water Chemistry and Wetlands

SHORT TITLE: Surface Water/Wetland Relationships

REGION(S)/STATE(S): Northeast (CT, MA, ME, NH, NY, PA, RI, VT)

GOAL(S)/OBJECTIVE(S): To determine the relationship(s) between presence/area of wetlands and surface water chemistry in Direct/Delayed Response Project watersheds; in particular, to determine the relationship between wetlands and sulfate retention. If a significant correlation exists between wetlands and sulfate retention, identify and quantify the processes involved.

RATIONALE: A principal objective of the Direct/Delayed Response Project is to characterize sulfate mobility in watersheds of the northeastern United States, and to forecast future changes in sulfate mobility under current or altered levels of deposition. Data analyses and forecasting models used in the Direct/Delayed Response Project have heretofore assumed that adsorption is the principal control on surface water chemistry, and that sulfate reduction in wetlands and lake sediments is a minor sulfur sink. Preliminary analysis of data from the Eastern Lake Survey – Phase I suggests a positive correlation between the fraction of a watershed covered by wetlands and sulfate retention by that watershed. Adsorption is an improbable sulfur sink in wetlands, so confirmation of a wetland–sulfate retention relationship in further data analyses would suggest a need to reassess the assumptions and models used in the Direct/Delayed Response Project, at least for watersheds with significant wetland areas. The purpose of this project is to conduct a thorough analysis of existing data to determine whether a significant relationship, in fact, exists between wetlands and sulfate retention, or between wetlands and other water chemistry parameters of concern If such relationships are identified, additional studies will be required to determine the nature and capacity of the processes involved.

APPROACH: The initial approach to this project will be to compile existing data from the Eastern Lake Survey and the Direct/Delayed Response Project, and to evaluate relationships between sulfate budgets and wetlands using statistical approaches. A concurrent activity within the Direct/Delayed Response Project, the Northeast Sulfate Retention Project (listed as a project under the "Soil Surveys" program element of the Direct/Delayed Response Project) will generate detailed mapping data for 45 watersheds in the Northeast with high sulfate retention, many of which also have substantial wetlands cover. Data from those 45 sites will be examined in detail to evaluate the relationship between sulfate retention and wetlands. If such relationships do exist, and if retention cannot be effectively characterized on the basis of map data, consideration will be given to further soil sampling and/or quantification of sulfate reduction processes within wetlands.

KEY WORDS:

Medium:	Chemistry, Soils, Vegetation, Wetlands
Chemicals:	Organics, Sulfate
Approach:	Correlative Analyses, Input-Output Budgets, Literature
Processes:	Sulfate Reduction, Sulfur Retention

PPA: E-07 **EPA Code:** E-07.3F **NAPAP Code:** 6C-2.09F

Element: Project

Contributing to: E-05, E-09

Cross Reference: Program: Direct/Delayed Response Project (E-07)
Program Element: Correlative Analyses (E-07.3)

Status: Ongoing **Period of Performance:** 1987 to 1990

Contact: M. Robbins Church

TITLE: Single-Factor Analyses of Direct/Delayed Response Project Data

SHORT TITLE: Single-Factor Analyses

REGION(S)/STATE(S): Mid-Appalachians (DE, MD, PA, VA, WV), Northeast (CT, MA, ME, NH, NY, PA, RI, VT), Southern Blue Ridge Province (GA, NC, SC, TN, VA)

GOAL(S)/OBJECTIVE(S): To use mathematical/model representations of two key processes – sulfate adsorption and base cation supply in order to determine current and forecasted future responses of watersheds in the Northeast, Mid-Appalachians, and the Southern Blue Ridge Regions to various levels of acidic deposition. More specifically, to determine if these processes are at steady state or whether they are undergoing dynamic change such that the effects of acidic deposition in the future may be more pronounced than those currently observed.

RATIONALE: These types of analyses allow forecasts based upon an examination of individual soil processes in isolation from all other confounding factors. Changes can be examined that might occur even at current loadings of deposition. Forecasts of future responses of these factors are required to verify and place in context the importance of the roles of each of these processes in future surface water acidification.

APPROACH: These analyses are being undertaken with information gathered as part of the soils surveys in the Northeast, Mid-Appalachians, and the Southern Blue Ridge Province. Chemical data from the soils analyses and mapping data in watersheds are being evaluated to forecast future responses of these processes on a watershed basis and the resulting effects on surface water chemistry.

KEY WORDS:

Medium:	Chemistry, Lakes, Soils, Streams, Watersheds
Chemicals:	Base Cations, Cation Exchange Complex, Clay Minerals, Sulfate
Approach:	Aggregation, Existing Data Analyses, Field Sampling, Input-Output Budgets, Modeling, Single-Factor Analyses
Processes:	Base Cation Exchange, Base Cation Supply, Chronic Acidification, Sulfate Adsorption, Sulfur Retention

PPA: E-07 **EPA Code:** E-07.4 **NAPAP Code:** 6C-2.10

Element: Program Element

Contributing to: E-05, E-06, E-09

Cross Reference: Program: Direct/Delayed Response Project (E-07)

Status: Ongoing **Period of Performance:** 1984 to 1990

Contact: M. Robbins Church

TITLE: Sulfate Adsorption: Time to Sulfur Steady State

SHORT TITLE: Sulfate Adsorption

REGION(S)/STATE(S): Mid-Appalachians (DE, MD, PA, VA, WV), Northeast (CT, MA, ME, NH, NY, PA, RI, VT), Southern Blue Ridge Province (GA, NC, SC, TN, VA)

GOAL(S)/OBJECTIVE(S): To determine the relationship between soil solution and surface water sulfate concentrations. To estimate time for watershed sulfate concentrations to reach steady state in Direct/Delayed Response Project study areas.

RATIONALE: This project, representing one of the Single-Factor Analyses for the Direct/Delayed Response Project, is designed to quantify sulfate partitioning between soil solution and adsorbed phases. The data are then used to estimate how long sulfate is retained by soils on a net basis, and the resulting time over which surface water chemical changes are moderated by sulfate adsorption.

Sulfate is the dominant anion in acidic deposition, and is the principal mobile anion mediating the rate of cation leaching from soils. Consequently, the extent to which sulfate is immobilized by soil reactions, primarily adsorption, plays a major role in determining whether, and at what rate, surface water acidification by acidic deposition will occur. It has been hypothesized that there are major regional differences in sulfate retention between the northeastern and southeastern United States (Northeast at steady state, Southeast with high sulfate retention); thus, there may be major regional differences in the extent and rate of future effects on surface water chemistry. This hypothesis to date has not been evaluated on a regional scale, using soils data collected in large-scale, uniform soil surveys. Sulfate analyses in the Direct/Delayed Response Project will provide such an assessment at intra- and interregional scales, and will estimate response time (time to steady state) for sulfate on a watershed and regional basis. This analysis will also include the Mid-Appalachians.

APPROACH: For all soils collected in the Direct/Delayed Response Project soil survey, present sulfate content of the soil has been measured, and adsorption isotherms, which define the ability of soils to retain additional sulfate, have been determined. For each soil, the concentration of sulfate in soil water will be estimated from isotherm data; isotherm data are also being used to compute coefficients for a partitioning equation that forecasts dynamics of sulfate added to the soil. Data will be aggregated from values for individual soils to weighted averages for sampling classes and then for watersheds. Average watershed values for soil solution sulfate will be compared with measured surface water sulfate concentrations to determine the relationship between soil water and surface water sulfate (and by implication, the extent to which soil processes control surface water sulfate concentration). Aggregated watershed data for adsorption isotherms will be used with a dynamic watershed model subroutine to forecast the temporal response of the watershed to sulfate deposition, and specifically to forecast time to steady state for sulfate at current or altered deposition loading rates.

KEY WORDS:

Medium:	Chemistry, Lakes, Soils, Streams, Watersheds
Chemicals:	Sulfate
Approach:	Aggregation, Existing Data Analyses, Input-Output Budgets, Modeling, Single-Factor Analyses
Processes:	Chronic Acidification, Sulfate Adsorption, Sulfur Retention

PPA: E-07 **EPA Code:** E-07.4A **NAPAP Code:** 6C-2.10A

Element: Project

Contributing to: E-05, E-06, E-09

Cross Reference: Program: Direct/Delayed Response Project (E-07)
Program Element: Single-Factor Analyses (E-07.4)

Status: Ongoing **Period of Performance:** 1984 to 1990

Contact: M. Robbins Church

TITLE: Base Cation Response to Acidic Deposition in Soils from the Northeast and Southern Blue Ridge Province

SHORT TITLE: Base Cation Supply

REGION(S)/STATE(S): Mid-Appalachians (DE, MD, PA, RI, VA, WV), Northeast (CT, MA, ME, NH, NY, PA, RI, VT), Southern Blue Ridge Province (GA, NC, SC, TN, VA)

GOAL(S)/OBJECTIVE(S): Within watersheds, base cation exchange processes in soils have been identified as one of the primary mechanisms for mitigating the effects of acidic deposition. Details regarding the extent to which this process is actually involved in acid neutralization within watersheds in the eastern United States, however, are not currently available. The goals of this study, therefore, are to determine (1) whether base cation exchange is, in fact, a dominant soil process for neutralizing acidic deposition inputs, (2) whether this capacity is now changing in response to acidic deposition, and (3) the rate of base cation depletion, if it is occurring.

RATIONALE: The depletion of exchangeable base cations in soils is hypothesized to be a major factor delaying acidification of surface waters in regions receiving acidic deposition. Very little is currently known about cation supply and exchange processes in those regions, however. To understand the effects of acidic deposition in the context of an ecosystem's ability to neutralize acidic inputs over the long term (e.g., 100 years), it is essential to improve the understanding of neutralization mechanisms and of the ecosystem's existing capacities. Addressing these issues will provide the information required to determine long-term impacts of acidic deposition, at various loading levels, on a variety of ecosystems.

APPROACH: Input data for existing soil genesis/soil chemistry models are being developed, using soils data (cation exchange capacity, percent base saturation, exchangeable bases, exchange coefficients, pH, etc.) collected as part of the soil surveys in the Direct/Delayed Response Project, precipitation data from the National Trends Network, chemistry data from the National Surface Water Survey, and U.S. Geological Survey runoff data. The models will address two questions: (1) Can observed soil chemical parameters be used to forecast parameters in the study watersheds? and (2) Assuming that parameters can be successfully forecast, what changes would be expected to occur in both soil and surface water chemistries over the course of the next century under acidic loading scenarios? As part of the study, sensitivity analyses of the models will be conducted.

Data were gathered so that the exchangeable cation resource could be estimated regionally, and reliability estimates quantified. These data and information on sulfate chemistry will be used to project the future impact of acidic deposition, at various acid loading levels, on watersheds located in potentially sensitive regions of the country.

KEY WORDS:

Medium:	Chemistry, Soils, Watersheds
Chemicals:	Base Cations, Cation Exchange Complex, Clay Minerals
Approach:	Aggregation, Existing Data Analyses, Field Sampling, Modeling, Single-Factor Analyses
Processes:	Base Cation Exchange, Base Cation Supply, Chronic Acidification

PPA: E-07 **EPA Code:** E-07.4B **NAPAP Code:** 6C-2.10B

Element: Project

Contributing to: E-05, E-09

Cross Reference: Program: Direct/Delayed Response Project (E-07)
Program Element: Single-Factor Analyses (E-07.4)

Status: Ongoing **Period of Performance:** 1984 to 1990

Contact: M. Robbins Church

TITLE: Forecasting the Effects of Acidic Deposition on Surface Water Acidification

SHORT TITLE: Forecasting Surface Water Acidification

REGION(S)/STATE(S): Mid-Appalachians (DE, MD, PA, VA, WV), Northeast (CT, MA, ME, NH, NY, PA, RI, VT), Southern Blue Ridge Province (GA, NC, SC, TN, VA)

GOAL(S)/OBJECTIVE(S): To estimate the number of aquatic systems that might become acidic in the future at current levels of acidic deposition. Two primary objectives are (1) to estimate the relative importance of key watershed processes in controlling surface water chemistry across the regions of concern, and (2) to forecast watershed responses to current levels of deposition over the next 50 years and extrapolate these results from the sample of watersheds to the regions of concern. The regions in which the Direct/Delayed Response Project is being conducted are the Northeast, the Southern Blue Ridge Province, and the Mid-Appalachians.

RATIONALE: The National Surface Water Survey estimated the current regional status and extent of acidic lakes and streams plus the aquatic systems potentially susceptible to acidic deposition. With this estimate of the current regional status of lakes and streams, the next question is how many of these lakes and streams might become acidic in the future at current levels of acidic deposition. This program element, as part of the Direct/Delayed Response Project, is designed to forecast the change in surface water chemistry over the next 50 years for lakes in the Northeast and streams in the Southern Blue Ridge Province and the Mid-Appalachians, assuming current levels of deposition. The Mid-Appalachian area represents a transition zone between the Northeast and Southeast.

APPROACH: The Direct/Delayed Response Project is designed to forecast the effects of acidic deposition on surface water chemistry over the next 50 years using several approaches. One of these approaches, Level III (this program element), uses three dynamic watershed acidification models – Enhanced Trickle Down, Integrated Lake/Watershed Acidification Study, and Model for Acidification of Groundwaters in Catchments – to make these forecasts. A Level III modeling protocol for the Direct/Delayed Response Project has been developed that includes model calibration, sensitivity analyses, long-term consistency checks, future 50-year forecasts, and regionalization of the individual watershed modeling results to the Northeast, Southern Blue Ridge Province, and Mid-Appalachian Region. Three northeastern lakes (Woods, Panther, and Clear Pond) and three streams (Coweeta Watersheds 34 and 36 and White Oak Run) are being used for model calibration and confirmation. Similar watersheds are currently being evaluated for the Mid-Appalachians. Sensitivity analyses will include both single-parameter and multiparameter perturbations. The long-term consistency check will use a constant, annual precipitation/deposition record from nearby National Oceanic and Atmospheric Administration and National Atmospheric Deposition Program/National Trends Network stations reflecting a typical year; watershed data from the Direct/Delayed Response Project Soil Surveys; and water chemistry data from the National Surface Water Survey for each of 145 watersheds in the Northeast and 35 watersheds in the Southern Blue Ridge Province. Thirty-six watersheds in the Mid-Appalachian Region are being studied. The Direct/Delayed Response Project was designed within a statistical frame similar to the National Surface Water Survey, permitting extrapolation of the individual watershed responses to the target population of lakes in the Northeast and streams in the Southern Blue Ridge Province and the Mid-Appalachians. Uncertainty estimates will be provided for the regional extrapolations.

KEY WORDS: Medium: Chemistry, Deposition, Lakes, Soils, Streams, Watersheds, Wetlands
Chemicals: Sulfate
Approach: Modeling
Processes: Base Cation Supply, Mineral Weathering, Sulfate Adsorption

PPA: E-07 **EPA Code:** E-07.5 **NAPAP Code:** 6B-1.01

Element: Program Element

Contributing to: E-03, E-05, E-06, E-09

Cross Reference: Program: Direct/Delayed Response Project (E-07)

Status: Ongoing **Period of Performance:** 1984 to 1990

Contact: M. Robbins Church

2.4 WATERSHED PROCESSES AND MANIPULATIONS – PROGRAM E-05

[Program/Program Element/Project]

TITLE: Factors Controlling the Response of Surface Waters to Acidic Deposition

SHORT TITLE: Watershed Processes and Manipulations

REGION(S)/STATE(S): Canada (Sudbury), Mid-Appalachians (MD, PA, VA, WV), Middle Atlantic (DE, MD, NJ, NY, PA, RI, VA, WV), Northeast (CT, MA, ME, NH, NY, PA, RI, VT), Norway, Southeast (AL, AR, FL, GA, KY, NC, TN, VA), Southern Blue Ridge Province (GA, NC, TN), Upper Midwest (MI, MN, WI)

GOAL(S)/OBJECTIVE(S): To investigate and quantify watershed systems and subsystems that influence the acidity of surface waters, to determine the effect acidic deposition has on the function of these systems. To evaluate those watershed processes that play a role in regulating surface water recovery.

RATIONALE: The response to a major policy question being addressed within the Aquatic Effects Research Program depends on forecasting future acidification effects, the primary aim of the Direct/Delayed Response Project (Program E-07). That project bases such estimates on the processes of sulfate adsorption and base cation supply. However, other processes such as sulfur cycling and desorption, cation loss, nutrient cycling, organic acids, and hydrologic flow paths are also important in determining the response of watersheds to acidic inputs. Aquatic systems within these watersheds respond to acidic inputs by changes in water chemistry, within-lake processes, and biota. To determine the uncertainties and limitations associated with forecasting future status of surface waters, all these processes must be investigated. Therefore, the biogeochemical response of watershed systems or subsystems must be evaluated and understood before properly assessing the consequences of alternative policy decisions.

APPROACH: Watershed studies within the Aquatic Effects Research Program are using three approaches to further understand the effects of acidic deposition on surface waters: process-oriented research on natural systems, watershed manipulation studies, and surface water acidification model development and testing. The watershed manipulations focus on understanding the integrated response of the biogeochemical processes that operate within a watershed and contribute to surface water quality. The process-oriented research aims to improve our understanding of the nature and function of specific watershed mechanisms that contribute to surface water acidification. Modeling combines current understandings of surface water acidification with the results of the other two areas of research to help quantify the uncertainties met when forecasting future surface water chemistries with models. These approaches are designed to increase our understandings of effects, with the process studies contributing primarily to hypothesis development, the manipulation studies to hypothesis testing, and modeling studies to evaluating policy and deposition alternatives.

KEY WORDS:

Medium: Biology, Chemistry, Groundwater, Lakes, Seepage Lakes, Soils, Streams, Vegetation, Watersheds

Chemicals: Acid Neutralizing Capacity, Aluminum, Base Cations, Clay Minerals, Major Ions, Mercury, Nitrate, Organics, pH, Primary Minerals, Sulfate, Total Nitrogen, Trace Metals

Approach: Field Manipulation, Field Sampling, Ion Balance, Laboratory, Literature, Modeling, Statistical Analyses

Processes: Aluminum Mobilization, Aluminum Solubility, Base Cation Exchange, Base Cation Mobilization, Base Cation Supply, Chronic Acidification, Community Response, Denitrification, Hydrology, Indirect Effects, Mineral Weathering, Nitrification, Nitrogen Cycling, Nutrient Cycling, Organic Acidification, Organic Chelation, Organics Cycling, Primary Productivity, Recovery, Sulfate Adsorption, Sulfate Desorption, Sulfate Reduction, Sulfur Cycling, Tissue Mercury Accumulation, Trophic Interactions, Within-Lake Acid Neutralizing Capacity Generation

PPA: E-05 **EPA Code:** E-05 **NAPAP Code:** 6C

Element: Program

Contributing to: E-03, E-04, E-06, E-07, E-08, E-09

Cross Reference: None

Status: Ongoing **Period of Performance:** 1983 to 1990 +

Contact: Daniel McKenzie

TITLE: Whole System Manipulations – Artificial Acidification of Watersheds

SHORT TITLE: Watershed Acidification - Maine

REGION(S)/STATE(S): Northeast (ME)

GOAL(S)/OBJECTIVE(S): To investigate and quantify watershed systems and subsystems that influence the acidity of surface waters through field manipulation studies. To determine the impact that acidic deposition has on the functioning of these systems.

RATIONALE: A major policy question being addressed within the Aquatic Effects Research Program concerns forecasting future acidification effects, a primary goal of the Direct/Delayed Response Project (Program E-07). That project bases its estimates primarily on surface water acidification models that simulate the processes of sulfate adsorption and base cation supply. In addition, other processes such as sulfur cycling, cation loss, nutrient cycling, and hydrologic flow paths are represented in some of the models and are hypothesized to be important in determining the response of watersheds to acidic inputs. Aquatic systems within these watersheds also respond to acidic inputs through changes in water chemistry, within-lake processes, and biota, and in general, are less well represented in the Direct/Delayed Response Project models. To determine the uncertainties and limitations of forecasting future status of surface waters, all these processes must be investigated at the whole-system level. Therefore, the comparative response of watershed systems or subsystems must be evaluated and understood to assess properly the consequences of alternative policy decisions.

APPROACH: The primary approach in this program area is to study the response of watershed systems to altered or manipulated acidic inputs. The program is based on field manipulations at the system or subsystem level to evaluate their integrated response to the individual processes and mechanisms. At present, a watershed manipulation project has been implemented in Maine. At the site, atmospheric inputs are being monitored, annual budgets for major ions developed, and chemical transformations in soils and vegetation quantified; elevational stream sampling transects will allow characterization of spatial variation of stream chemistry patterns. Using a paired watershed approach, one of the watersheds at the site will be manipulated by controlled addition of acidic substances. Watershed responses will be determined and interpreted in light of biogeochemical processes. Small-scale pilot studies are also being conducted at the site. One additional watershed site, in the Mid-Appalachian region, has been established and will be manipulated in January of 1989 using a similar, but simpler, experimental design to gain additional information on watershed response to altered sulfate deposition.

KEY WORDS:

Medium:	Chemistry, Soils, Streams, Watersheds
Chemicals:	Aluminum, Base Cations, Nitrate, Organics, Sulfate
Approach:	Field Manipulation, Field Sampling, Laboratory
Processes:	Aluminum Mobilization, Base Cation Supply, Chronic Acidification, Hydrology, Mineral Weathering, Nitrogen Cycling, Organic Acidification, Sulfate Adsorption, Sulfate Desorption, Sulfur Cycling

PPA: E-05 **EPA Code:** E-05.1 **NAPAP Code:** 6C-3.01

Element: Program Element

Contributing to: E-03, E-06, E-07, E-08

Cross Reference: Program: Watershed Processes and Manipulations (E-05)

Status: Ongoing **Period of Performance:** 1987 to 1990 +

Contact: Timothy Strickland

TITLE: Whole-System Manipulations – Artificial Acidification of Surface Waters

SHORT TITLE: Surface Water Acidification

REGION(S)/STATE(S): Upper Midwest (WI)

GOAL(S)/OBJECTIVE(S): The goal of this program element is to refine the understanding of the effects of acidification on the chemistry and biology of surface waters through artificial acidification of a warmwater lake in Wisconsin. Project objectives include (1) identifying subtle and dramatic responses of the biotic community to decreased pH, (2) comparing direct (chemically mediated) and indirect (food chain-, habitat-mediated) effects on fish, (3) quantifying the effects on in-lake alkalinity generation by sulfate-reducing microbes, and (4) evaluating the ability to extrapolate these findings to lakes in the Upper Midwest and in other geographic areas.

RATIONALE: The effects of acidic deposition on surface water chemistry and biotic communities have been documented largely on the basis of correlative analyses. The complex interactions of acidic deposition in watersheds, differences in the susceptibility among aquatic ecosystems to acidification, fisheries management manipulations, the possible influence of other contaminants, and other variables generally preclude direct cause-and-effect conclusions regarding the response of lakes to anthropogenic acid inputs. The experimental, whole-lake, manipulation study at Little Rock Lake, WI, provides data on direct chemical and biological responses to mineral acid addition. This type of data alleviates uncertainties associated with studies that rely on assumptions necessitated by the inability to quantify or hold constant key variables related to surface water acidification. The results of this program element, although site-specific, will improve the understanding of the acidification phenomenon, particularly when the regional applicability of the conclusions are evaluated.

APPROACH: Baseline biological and chemical data were collected for two years from a warmwater seepage lake (Little Rock Lake, WI), before sulfuric acid was added to one half to decrease lakewater pH incrementally. Changes in lakewater chemistry and in fish, plankton, and benthic communities are being monitored throughout the six-year acidification experiment. Rates of bacterial sulfate reduction in response to decreased pH are being measured in situ to quantify the effects of decreased pH on within-lake generation of acid neutralizing capacity. The end product of the reduction is being identified (i.e., iron sulfide or hydrogen sulfide) to determine if it is oxidizable; if it is, no net hydrogen ion reduction will occur. Effects of acidification on the accumulation of mercury in fish tissues are also being examined. To alleviate the problems associated with the fact that the acidification experiment is not replicated, a third approach involves cross-calibrating the unacidified lake basin in Little Rock Lake with seven lakes serving as Long-Term Ecological Research sites. Establishing relationships between these lakes and the control basin in Little Rock Lake will allow an experimental design to be developed, which in turn will allow the significance of whole-system manipulation results to be tested statistically.

KEY WORDS:

Medium:	Biology, Chemistry, Seepage Lakes
Chemicals:	Major Ions, Mercury, pH, Sulfate, Trace Metals
Approach:	Field Manipulation, Field Sampling, Ion Balance, Laboratory, Statistical Analyses
Processes:	Base Cation Exchange, Chronic Acidification, Community Response, Hydrology, Indirect Effects, Mineral Weathering, Nutrient Cycling, Primary Productivity, Sulfate Reduction, Tissue Mercury Accumulation, Trophic Interactions, Within-Lake Acid Neutralizing Capacity Generation

PPA: E-05 **EPA Code:** E-05.2 **NAPAP Code:** 6C-3.02

Element: Program Element

Contributing to: E-01, E-03, E-04, E-09

Cross Reference: Program: Watershed Processes and Manipulations (E-05)

Status: Ongoing **Period of Performance:** 1983 to 1991

Contact: John Eaton

TITLE: Warmwater Lake Community Responses to Artificial Acidification

SHORT TITLE: Little Rock Lake

REGION(S)/STATE(S): Upper Midwest (WI)

GOAL(S)/OBJECTIVE(S): The major objectives of this project are (1) to determine the subtle (early indicator) as well as more dramatic responses of a non-trout, warmwater fish-dominated lake community to lakewater pH decreases; (2) to determine and compare the significance of direct (water chemistry-mediated) and indirect (food chain-, habitat-, etc., mediated) effects of increasing acidity on fish populations in Little Rock Lake; (3) to evaluate state-of-the-art capabilities for forecasting acidification impacts in systems like the one being studied from existing laboratory and field data; (4) to determine the mechanisms of response of various ecosystem biotic components through detailed chemical and biological observation, in-situ experimentation, and directly related laboratory testing; (5) to relate the observed effects of Little Rock Lake to possible acidic precipitation impacts on other lakes, with the aid of the many hydrological, limnological, and biotic studies (both short-term and long-term) being conducted in the area; and (6) to determine the degree of generality of biological effects from acidic deposition on lakes in different geographic areas (Canadian Shield, Adirondack Mountains, Upper Midwest, etc.).

RATIONALE: Although the effects of acidic precipitation on stream and lakewater chemistry have been documented, the response of fish and other biota, especially in warmwater systems, to altered water chemistry due to acidic deposition has been examined primarily through field surveys and laboratory bioassay experiments, both of which provide only indirect evidence of cause-and-effect relationships in the field. One reason that few acidification field experiments have been conducted is that they are difficult to carry out on scales large enough to provide a meaningful evaluation of population-level responses. This project is designed to collect these needed data.

APPROACH: A multidisciplinary, integrated research project involving artificial acidification of a 45-acre lake in north central Wisconsin was started in the summer of 1983. The study design has followed a two-year preacidification period in which baseline conditions and variability were observed in the lake. In-situ (limnocorral) and laboratory experiments were conducted during the second year to help refine hypotheses and analysis techniques and to define the nature, rate, and duration of acidification. After dividing the lake into two sections with a plastic curtain, acidification started in one-half of the lake during the third year and will progress from pH 6.0 to 4.5 over six years in a two-year stepped approach.

KEY WORDS:

Medium:	Biology, Chemistry, Seepage Lakes
Chemicals:	Major Ions, Mercury, pH, Sulfate, Trace Metals
Approach:	Field Manipulation, Field Sampling, Ion Balance, Laboratory
Processes:	Base Cation Exchange, Chronic Acidification, Community Response, Hydrology, Indirect Effects, Mineral Weathering, Nutrient Cycling, Primary Productivity, Sulfate Reduction, Tissue Mercury Accumulation, Trophic Interactions, Within-Lake Acid Neutralizing Capacity Generation

PPA: E-05 **EPA Code:** E-05.2A **NAPAP Code:** 6C-3.02A

Element: Project

Contributing to: E-01, E-03, E-04, E-09

Cross Reference: Program Area: Watershed Processes and Manipulations (E-05)
Program Element: Surface Water Acidification (E-05.2)

Status: Ongoing **Period of Performance:** 1983 to 1991

Contact: John Eaton

TITLE: *Effects of Acidification on Bacterial Sulfate Reduction in a Warmwater Lake*

SHORT TITLE: Within-Lake Alkalinity Generation (Sulfate Reduction)

REGION(S)/STATE(S): Upper Midwest (WI)

GOAL(S)/OBJECTIVE(S): To establish baseline values for bacterial sulfate reduction in lakes. To determine the influence of acidification in bacterial sulfate reduction using water column enclosures (limnocorrals).

RATIONALE: Within-lake alkalinity generation, particularly in seepage lakes, has been proposed as an important way for mitigating the effects of acidic deposition on surface waters. If iron sulfide, a product of bacterial sulfate reduction, is not reoxidized, an equivalent net neutralization of hydrogen ion results. Little data exist on the direct effects of acidification on the rates of this process or on the quantitative importance of the process in neutralizing acidic inputs.

APPROACH: Two approaches are used in this study: (1) baseline studies of the whole lake and (2) limnocorral (*in situ*) experiments. The baseline studies are conducted to determine rates of bacterial sulfate reduction, investigate the form of sulfur being produced, and quantify this process relative to other acid neutralizing processes. Limnocorral experiments (in which portions of the water column and underlying sediment are isolated) are being conducted while the rates of sulfate reduction in sediments are being monitored in response to various loadings of sulfuric acid. Hydrogen ion mass balance budgets for the enclosures are being calculated. Models are being developed and tested for extrapolating limnocorral results to the entire lake and subsequently to similar lakes in the region of study.

KEY WORDS:

Medium:	Chemistry, Seepage Lakes
Chemicals:	pH, Sulfate
Approach:	Field Sampling, Ion Balance
Processes:	Base Cation Exchange, Mineral Weathering, Sulfate Reduction, Within-Lake Acid Neutralizing Capacity Generation

PPA: E-05 **EPA Code:** E-05.2B **NAPAP Code:** 6C-3.02B

Element: Project

Contributing to: E-01, E-03, E-09

Cross Reference: Program: Watershed Processes and Manipulations (E-05)
Program Element: Surface Water Acidification (E-05.2)

Status: Concluding **Period of Performance:** 1984 to 1988

Contact: M. Robbins Church

TITLE: Cross-Calibration of Little Rock Lake and Long-Term Ecological Research Sites as a Means for Replicating Whole-Lake Manipulation Results

SHORT TITLE: Comparative Analyses of an Acidified Lake

REGION(S)/STATE(S): Upper Midwest (WI)

GOAL(S)/OBJECTIVE(S): To develop a series of analytical comparisons involving the two lake basins that are currently being investigated in the Little Rock Lake Experimental acidification project and the seven lakes currently being studied at the Northern Lakes Long-Term Ecological Research (LTER) site.

RATIONALE: Although major insights into ecosystem-scale processes have been gained by whole-system manipulations, the interpretation of such experiments is confounded by lack of replication in either manipulated or reference systems. Difficulty in interpreting experimental results can be particularly great when subtle rather than dramatic effects of manipulations are addressed This situation presents a dilemma to ecosystem scientists who seek to determine the early effects of anthropogenic contaminants within the range of conditions represented by natural systems. The Little Rock Lake project is being conducted to examine the effects of acidification on aquatic organisms and to document the mechanisms by which such effects occur. The experimental approach to date has involved a standard design involving a control and reference basin in an hourglass-shaped lake. This approach, however, suffers from lack of replication. Seven lakes within 7 km of Little Rock are currently being studied with the LTER project and thus have the potential to serve as additional references for the experimental system. This has suggested the possibility of an innovative design in the whole-lake experiment in which the acid additions in one lake basin are repeated in the second basin with a four-year lag, thus providing some element of replication. A critical element in this design is the use of the LTER lakes as references; this requires a cross calibration of the LTER lakes with the present Little Rock Lake reference basin.

APPROACH: The establishment of the LTER lakes as references requires the availability of parallel data for these systems and Little Rock Lake and the development of analytical procedures for comparisons. In many cases, such data are already available; however, in the case of zooplankton, samples from the LTER lakes have been archived for future use, but not yet counted. Since biological parameters are most likely to provide difficulty in interpreting the unreplicated Little Rock Lake experiment, comparisons of these samples are critical. Processing of the archived LTER samples to provide a zooplankton data set has been proposed. The early development of analytical procedures for comparisons between LTER and Little Rock Lake has been completed. This work, however, will require a number of extensive tests of varied analytical procedures. Such tests will be conducted to develop an appropriate analytical scheme. The primary value of this proposed work will be in testing a significantly different and potentially powerful experimental design for whole-ecosystem manipulation experiments.

KEY WORDS:

Medium:	Biology, Chemistry, Seepage Lakes
Chemicals:	pH, Sulfate
Approach:	Field Manipulation, Field Sampling, Laboratory, Statistical Analyses
Processes:	Chronic Acidification, Community Response

PPA: E-05 **EPA Code:** E-05.2C **NAPAP Code:** 6C-3.02C

Element: Project

Contributing to: E-01, E-03, E-09

Cross Reference: Program: Watershed Processes and Manipulations (E-05)
Program Element: Surface Water Acidification (E-05.2)

Status: Ongoing **Period of Performance:** 1987 to 1989

Contact: John Eaton

TITLE: Investigating Soil and Hydrologic Processes Controlling Surface Water Response to Acidic Deposition

SHORT TITLE: Soil/Hydrologic Processes

REGION(S)/STATE(S): Northeast (ME)

GOAL(S)/OBJECTIVE(S): To determine the soil and hydrologic processes, rates, and interactions that control the response of surface waters to acidic deposition. To establish appropriate ways to represent critical soil processes within static and dynamic models.

RATIONALE: The Aquatic Effects Research Program, through the National Surface Water Survey, has established the status and extent of surface water chemistry for regions of the United States potentially susceptible to acidic deposition. The Direct/Delayed Response Project is forecasting the time needed for surface waters to become acidic at current rates of deposition. Unfortunately, an understanding of the soil and hydrologic processes that control surface water acidification is incomplete, resulting in uncertainties regarding accurate representation of these processes in models used for forecasting future acidic status of surface waters. Activities in this program are designed to increase understanding of key processes that control acidification and consequently improve forecasting capabilities.

APPROACH: The processes that are hypothesized to be the most important in surface water acidification, including sulfate mobility, cation supply and mineral weathering, aluminum mobility, hydrologic routing, organic acid interactions, and nitrate mobility, are being studied through a series of plot-level and watershed-level artificial acidification experiments at the Bear Brook Watersheds in Maine (see "Watershed Acidification - Maine" program element). For each of these processes, cooperating scientists are testing hypotheses in laboratory, plot, and watershed-scale experiments to determine the controlling reactions and interactions of acidification. In addition, laboratory experiments are being conducted on cation supply and sulfate adsorption and desorption.

KEY WORDS:

Medium:	Chemistry, Groundwater, Soils, Streams, Vegetation, Watersheds
Chemicals:	Aluminum, Base Cations, Clay Minerals, Nitrate, Organics, Primary Minerals, Sulfate, Total Nitrogen
Approach:	Field Manipulation, Field Sampling, Laboratory, Modeling
Processes:	Aluminum Mobilization, Aluminum Solubility, Base Cation Exchange, Base Cation Mobilization, Base Cation Supply, Denitrification, Hydrology, Mineral Weathering, Nitrification, Nitrogen Cycling, Organic Acidification, Organic Chelation, Organics Cycling, Sulfate Adsorption, Sulfate Desorption, Sulfate Reduction, Sulfur Cycling

PPA: E-05 **EPA Code:** E-05.3 **NAPAP Code:** 6C-2

Element: Program Element

Contributing to: E-03, E-06, E-07, E-08, E-09

Cross Reference: Program: Watershed Processes and Manipulations (E-05)

Status: Ongoing **Period of Performance:** 1985 to 1990 +

Contact: Timothy Strickland

TITLE: Soil Characteristics and Processes Affecting Sulfate Mobility in Watersheds

SHORT TITLE: Sulfate Mobility in Soils

REGION(S)/STATE(S): Northeast (ME)

GOAL(S)/OBJECTIVE(S): To identify major processes and soil parameters affecting sulfur mobility in watersheds. To verify sulfate dynamics of existing watershed chemistry models, and to provide data to revise models as necessary. To determine response time of watershed sulfur mobility at current and altered deposition levels.

RATIONALE: Sulfate, a principal anion in acidic deposition, is the primary mobile anion associated with cation leaching from soils and with surface water acidification. Existing watershed chemistry models assume that adsorption is the only process significantly affecting sulfate mobility in watersheds, and further assume that adsorption would be completely reversible under conditions of reduced sulfur deposition. It has been well documented that other processes affect sulfur cycling in terrestrial and aquatic systems (e.g., organic reactions in soils, reduction in wetlands and sediments, and mineral precipitation). The net effect of these processes is basically unknown; their role could be significant, especially during periods when sulfur deposition is changing. Similarly, laboratory data indicate that sulfate desorption from soils varies widely, depending on soil type, aging, and other (poorly understood) factors. Policy decisions regarding controls on sulfur emissions likely will rely on model forecasts of future watershed chemistry; given the critical role of sulfate mobility in determining watershed and surface water response to acidic deposition, it is imperative that watershed chemistry models accurately represent sulfate dynamics.

APPROACH: Activities are under way or planned at several scales to identify and quantify key processes affecting sulfate mobility. Field monitoring is under way, with plans for manipulating plot and whole catchment scales. The Bear Brook Watershed in Maine (see "Watershed Acidification - Maine" program element) will be treated with sulfate; watershed inputs and outputs will be quantified to assess total system response, and sulfate pools and internal fluxes will be measured at plots within the treated and adjacent control catchments. Multiple levels of sulfate will be applied to replicated field plots adjacent to the Bear Brook site to provide more detailed data on sulfur cycling within the soil; stable isotopes of sulfur will be included in plot treatments to provide additional data on transfers among soil sulfur pools. Laboratory studies are being planned to characterize effects of pH, temperature, and other soil variables on sulfate adsorption, and to assess desorption of sulfate from soils. Laboratory studies are also planned to evaluate methods issues, such as methods comparison and development of improved laboratory methods.

KEY WORDS:

Medium:	Chemistry, Soils, Watersheds
Chemicals:	Sulfate
Approach:	Field Manipulation, Field Sampling, Laboratory
Processes:	Sulfate Adsorption, Sulfate Desorption, Sulfate Reduction, Sulfur Cycling

PPA: E-05 **EPA Code:** E-05.3A **NAPAP Code:** 6C-2 03

Element: Project

Contributing to: E-06, E-07, E-08, E-09

Cross Reference: Program: Watershed Processes and Manipulations (E-05)
Program Element: Soil/Hydrologic Processes (E-05.3)

Status: Ongoing **Period of Performance:** 1986 to 1990 +

Contact: Timothy Strickland

TITLE: The Role of Base Cation Supply and Mineral Weathering in Soil Neutralization Processes

SHORT TITLE: Cation Supply and Mineral Weathering in Soils

REGION(S)/STATE(S): Northeast (ME)

GOAL(S)/OBJECTIVE(S): Within watershed ecosystems, soil base cation exchange processes and primary mineral weathering have been identified as primary mechanisms for mitigating the effects of acidic deposition. The goals of this project are (1) to determine the extent of base cation exchange and mineral weathering at the watershed manipulation site (Bear Brook, ME), (2) to characterize soil exchange processes in a thermodynamically consistent manner, and (3) to determine the rate at which these processes respond to inputs of acidic meteoric waters. If these resources are being depleted by acidic deposition, a further goal will be to evaluate the rate of depletion and the size of the remaining resource.

RATIONALE: Both cation exchange processes and mineral weathering have been identified as mechanisms for neutralizing acidic deposition. However, the extent to which these processes are actually involved in acid neutralization, especially in relation to other soil processes, is not well known. To evaluate the importance of these processes in regulating observed surface water composition, it is necessary to develop an internally consistent and defensible procedure for describing these processes as they occur in the soil environment. This project is directed toward that goal.

APPROACH: Soil samples, collected at the Bear Brook watershed manipulation site, are being examined in process-oriented studies with the goal of addressing specific hypotheses regarding the relationship between certain soil chemical and physical properties and surface water chemistry as described above. The research will combine laboratory experiments, field-plot manipulation, and watershed manipulation experiments to examine cation supply/mineral weathering processes.

KEY WORDS:
Medium: Chemistry, Soils
Chemicals: Base Cations, Clay Minerals, Primary Minerals
Approach: Field Manipulation, Field Sampling, Laboratory
Processes: Base Cation Exchange, Base Cation Supply, Mineral Weathering

PPA: E-05 EPA Code: E-05.3B NAPAP Code: 6C-2.04

Element: Project

Contributing to: E-07, E-09

Cross Reference: Program: Watershed Processes and Manipulations (E-05)
Program Element: Soil/Hydrologic Processes (E-05.3)

Status: Ongoing Period of Performance: 1985 to 1990 +

Contact: Timothy Strickland

TITLE: Factors Controlling Aluminum Mobility in Soils

SHORT TITLE: Aluminum Mobility in Soils

REGION(S)/STATE(S): Northeast (ME)

GOAL(S)/OBJECTIVE(S): To determine the influence of acidic deposition on the mobility and release of aluminum and associated base cations. To determine the controls of aluminum mobility and solubility in soils.

RATIONALE: Concern over surface water acidification in the United States has focused largely on the Northeast, a region experiencing elevated loading of acidic substances. Spodosolic soils in the northeastern United States are acidic and have limited capacity to retain sulfate. If pools of exchangeable or easily weatherable base cations are limited in these soils, then strong acidic inputs will be incompletely neutralized. Incomplete neutralization can cause acidic cations, hydrogen, and aluminum to be transported from terrestrial to aquatic environments. Some of the first effects on fish and other biota is toxicity associated with aluminum leached from soils.

APPROACH: As a component of the Watershed Manipulation Project, this project will combine laboratory experiments, field-plot manipulations, and watershed manipulation experiments to ascertain the influence of acidic deposition on mobility of aluminum and cations in soils and water. Specific techniques include laboratory batch titration studies, potentiometric titrations, and soil column leaching experiments, as well as analyses of solutions and soils gathered at the field plots and catchments.

KEY WORDS:
Medium: Chemistry, Soils, Watersheds
Chemicals: Aluminum, Base Cations
Approach: Field Manipulation, Field Sampling, Laboratory
Processes: Aluminum Mobilization, Aluminum Solubility, Base Cation Mobilization, Base Cation Supply

PPA: E-05 **EPA Code:** E-05.3C **NAPAP Code:** 6C-2.05

Element: Project

Contributing to: E-06, E-07, E-08, E-09

Cross Reference: Program: Watershed Processes and Manipulations (E-05)
Program Element: Soil/Hydrologic Processes (E-05.3)

Status: Ongoing **Period of Performance:** 1986 to 1990 +

Contact: Timothy Strickland

TITLE: Examining the Role of Hydrologic Pathways and Water Residence Times in Altering Acidic Deposition Inputs

SHORT TITLE: Hydrologic Pathways/Residence Times

REGION(S)/STATE(S): Northeast (ME)

GOAL(S)/OBJECTIVE(S): To determine the pathways of water flowing within the soil mantle and regolith of upland catchments, typical of those susceptible to acidic deposition. To determine the flow processes or domains (e.g., micropore versus macropore flow) by which water moves within watersheds. To establish classes of watersheds, based on runoff and physical watershed characteristics, that reflect the pathway and process by which water reaches bodies of water.

RATIONALE: Many watershed processes collectively determine the chemical responses of surface water chemistry to acidic deposition. Watershed hydrology critically links the response of watersheds to acidic deposition. The route and mechanism by which water moves determines which particles of soil or regolith come in contact with water and for how long. Traditionally, engineering hydrology has emphasized forecasting flood peaks without regarding the means by which the water reached streams and lakes. This project seeks to answer these important questions for upland catchments.

APPROACH: Hillslope-scale sprinkler plots were established at the Bear Brook watershed manipulation site to determine the relative contribution of micropore and macropore flow to streamflow. Tracers were used to evaluate the relative contribution of regions within the watershed to streamflow. Extensive measures of flowpath using, for example, crest piezometers and recording piezometers are being implemented on the two watersheds.

KEY WORDS:
Medium: Chemistry, Groundwater, Soils, Streams, Watersheds
Chemicals: N/A
Approach: Field Manipulation, Field Sampling, Modeling
Processes: Hydrology

PPA: E-05 **EPA Code:** E-05.3D **NAPAP Code:** 6C-2.06

Element: Project

Contributing to: E-06, E-07, E-08, E-09

Cross Reference: Program: Watershed Processes and Manipulations (E-05)
Program Element: Soil/Hydrologic Processes (E-05.3)

Status: Ongoing **Period of Performance:** 1986 to 1990 +

Contact: Timothy Strickland

TITLE: The Influence of Organic Acids on Acidification and Aluminum and Sulfur Dynamics

SHORT TITLE: Organic Acid Influence on Acidification

REGION(S)/STATE(S): Northeast (ME)

GOAL(S)/OBJECTIVE(S): To determine how organic acid mobilization is influenced by acidic deposition. To evaluate the effect of organic acids on aluminum mobilization and toxicity. To determine the effect of organic acids and changes in organic acids due to acidic deposition on sulfate sorption dynamics.

RATIONALE: In those natural systems unaffected by acidic deposition, organic acids originating from plants decomposing within the ecosystem are a natural source of acidity. These acids substantially influence the mobility of metals, such as aluminum, and strong acid anions, such as sulfate. These influences must be quantified accurately to forecast watershed acidic deposition responses.

APPROACH: As a component of the Watershed Manipulation Project, the general approach in this project is to combine laboratory experiments, field-plot manipulations, and watershed manipulation experiments to ascertain the role of organic anions in regulating surface water acidity. Specific analyses include determining total carbon and humic and fulvic acids in watershed soils. Titrations of dissolved organic carbon samples are being made for lysimeter, throughfall, and streamflow samples. Laboratory studies are used to assess carbon dynamics and mobilization-mineralization under controlled conditions using soil columns and batch experiments.

KEY WORDS:
Medium: Chemistry, Soils, Streams
Chemicals: Organics
Approach: Field Manipulation, Field Sampling, Laboratory
Processes: Organic Acidification, Organic Chelation, Organics Cycling

PPA: E-05 **EPA Code:** E-05.3E **NAPAP Code:** 6C-2.07

Element: Project

Contributing to: E-06, E-07, E-08, E-09

Cross Reference: Program: Watershed Processes and Manipulations (E-05)
Program Element: Soil/Hydrologic Processes (E-05.3)

Status: Ongoing **Period of Performance:** 1986 to 1990 +

Contact: Timothy Strickland

TITLE: Nitrate Uptake and Leaching in Soils in Response to Acidic Deposition

SHORT TITLE: Nitrate Mobility in Soils

REGION(S)/STATE(S): Northeast (ME)

GOAL(S)/OBJECTIVE(S): To determine if nitrogen amendment (an analog for increased acidic deposition) will cause mineral nitrogen to accumulate in soils that will, after a delay of one or more years, induce nitrification even at low soil pH values. To determine if nitrification causes nitrate leaching. To determine if chronic nitrogen additions will cause a relatively small increase in foliar biomass and nitrogen concentration, and if, when the systems become non-nitrogen limited, higher rates of nitrogen mineralization and nitrogen cycling occur. To determine if losses due to nitrate leaching rise near input rates as the biological uptake capacity becomes saturated.

RATIONALE: Acidic deposition primarily involves two strong acids, sulfuric acid and nitric acid. Nitrate is one of the strong acid anions that serves as a carrier to remove hydrogen ions from soils. To quantify the response of watersheds to acidic deposition, the nitrogen cycle must be understood. This cycle is driven largely by biological processes that modify or dominate the nitrate derived from deposition. This project relates nitrate response in soils to acidic deposition.

APPROACH: As a component of the Watershed Manipulation Project, this project combines laboratory experiments, field-plot manipulations, and watershed manipulation experiments to determine the role of nitrate in soils to regulate surface water acidity. Specific analyses include measuring total nitrogen in vegetation and soils. Nitrogen mineralization and nitrification will be measured using soil cores, while litter decay rates and nitrogen release will be measured using nylon mesh bags.

KEY WORDS:
Medium: Chemistry, Soils, Vegetation, Watersheds
Chemicals: Nitrate, Total Nitrogen
Approach: Field Manipulation, Field Sampling, Laboratory
Processes: Denitrification, Nitrification, Nitrogen Cycling

PPA: E-05 **EPA Code:** E-05.3F **NAPAP Code:** 6C-2.08

Element: Project

Contributing to: E-03, E-06, E-07, E-08, E-09

Cross Reference: Program: Watershed Processes and Manipulations (E-05)
Program Element: Soil/Hydrologic Processes (E-05.3)

Status: Ongoing **Period of Performance:** 1986 to 1990 +

Contact: Timothy Strickland

TITLE: Validating Surface Water Acidification Models Used in Forecasting Regional-Scale Responses to Acidic Deposition

SHORT TITLE: Acidification/Recovery Model Development and Testing

REGION(S)/STATE(S): Canada (Sudbury), Middle Atlantic (DE, MD, NJ, NY, PA, RI, VA, WV), Northeast (CT, MA, ME, NH, NY, PA, RI, VT), Norway, Southeast (AL, AR, FL, GA, KY, NC, TN, VA), Upper Midwest (MI, MN, WI)

GOAL(S)/OBJECTIVE(S): To evaluate and validate the surface water acidification models being applied within the Direct/Delayed Response Project. To identify and quantify model sensitivities and uncertainties including identification of the bounds within which the model forecasts can be considered to be reliable forecasts of future conditions.

RATIONALE: Significant aquatic and terrestrial resources, particularly in the Northeast, may be at risk from current levels of acidic deposition. Therefore, to develop sound environmental policy, it is important to determine if potentially sensitive watersheds are at or near steady-state conditions, or if further acidification of lakes is likely to occur at current deposition levels. Likewise, it is important to evaluate the probable effect of increasing and decreasing emissions over the next few decades on the surface water chemistries of potentially sensitive lakes.

Because of the complexity of watershed systems, dynamic models of natural phenomena are essential for testing process-level hypotheses at the watershed scale. This is particularly true for forecasting the probable future consequences of current or reduced acidic deposition loadings on surface waters. However, the models used for forecasting must be adequately evaluated and tested to provide the necessary assurance of their reliability. Because adequate long-term records for validation do not exist, the ability of these models to simulate important processes must be determined. Similarly, it is necessary to evaluate their behavior under conditions of inadequate data for calibration. The sensitivity of response variables (e.g., acid neutralizing capacity and pH) to the interrelationships among variables and to changes in input values also must be understood. Because previous studies on watershed acidification models have been directed primarily toward forecasting acidification, it is important also to test the capability of the models to forecast recovery under reduced deposition loadings.

APPROACH: The principal hypothesis to be tested is that those hydrologic, geochemical, and biological processes that are important in watershed acidification can be simulated with sufficient reliability to be useful in interpreting manipulation experiments and in forecasting the future course of watershed acidification and recovery for particular acidic deposition scenarios. The modeling studies are integrated with the watershed manipulation and soil process studies to test more detailed hypotheses at the catchment and plot scale.

Three approaches are being employed: (1) evaluation of model behavior, (2) model sensitivity analysis, and (3) experimental and observational field studies. Efforts will be made in the first category to review and evaluate the process formulations, comparisons of process formulations among models and with the literature, testing of model behavior, uncertainty analysis, and consequences of alternative calibration procedures. Sensitivity analysis will determine the interrelationships among input variables, changes in model output resulting from alternative input variables, and initial conditions. Experimental and observational studies will evaluate the forecasting model capabilities by comparison of results with observed data from field studies. These field studies will include the manipulation experiments being conducted in Maine and other available data sets (e.g., lakes near Sudbury, RAIN project).

KEY WORDS: Medium: Chemistry, Lakes, Soils, Streams, Watersheds
Chemicals: Acid Neutralizing Capacity, pH
Approach: Literature, Modeling
Processes: Recovery

PPA: E-05 **EPA Code:** E-05.4 **NAPAP Code:** 6B-1.02

Element: Program Element

Contributing to: E-06, E-07, E-08, E-09

Cross Reference: Program: Watershed Processes and Manipulations (E-05)

Status: Ongoing **Period of Performance:** 1987 to 1990 +

Contact: Kent Thornton

TITLE: Sensitivity Analyses of Direct/Delayed Response Project Models to Inputs and Parameters

SHORT TITLE: Acidification Model Sensitivity Analysis

REGION(S)/STATE(S): Middle Atlantic (DE, MD, NJ, NY, PA, RI, VA, WV), Northeast (CT, MA, ME, NH, NY, PA, RI, VT), Southeast (AL, AR, FL, GA, KY, NC, TN, VA)

GOAL(S)/OBJECTIVE(S): To investigate and evaluate the sensitivity and behavior of the Direct/Delayed Response Project model forecasts of future water chemistry to the accuracy and uncertainties in data, model inputs, parameter values, process formulations, and calibration procedures.

RATIONALE: Because of the complexity of watershed systems, dynamic models of natural phenomena are essential for forecasting the probable future consequences of current or reduced acidic deposition loadings on surface waters. However, the models used for forecasting must be evaluated and tested adequately to provide the necessary assurance of their reliability. The sensitivity of variables (e.g., acid neutralizing capacity and pH) upon which the forecasts are based must be understood with respect to the interrelationships among variables and to uncertainties of input values. In addition, it is essential to evaluate model behavior under conditions of limited data for calibration, and thereby provide guidance or bounds on the situations that produce reliable forecasts.

APPROACH: The three models that were evaluated were Model for Acidification of Groundwaters in Catchments, Enhanced Trickle Down, and Integrated Lake/Watershed Acidification Study. Three Direct/Delayed Response Project watersheds (Woods, Panther, and Clear Pond) were used for the behavioral evaluation and sensitivity analysis studies because sufficient time-series data were available. The initial step in these studies was to identify all input data, all computed variables, and all output variables. The input variables, boundary conditions, and initial data were classified to provide the following identification: model compartment, temporal nature, estimation procedure, and units of measurement. This effort is being followed by an estimation of the realistic ranges and interdependence among variables. The behavior evaluation and comparison study will address the following: a review of the process formulations of each model, comparisons of process formulations among models and with alternative approaches in the literature, testing of model behavior, uncertainty analysis, and consequences of alternative calibration procedures. The sensitivity analysis will address the following: interrelationships among the model inputs, sensitivity of model output to changes in data-derived input variables, and initial boundary conditions. These results will permit a thorough evaluation of the model forecasts and their associated uncertainty and reliability within the Direct/Delayed Response Project application.

KEY WORDS:

Medium:	Chemistry, Watersheds
Chemicals:	Acid Neutralizing Capacity, pH
Approach:	Modeling
Processes:	N/A

PPA: E-05 **EPA Code:** E-05.4A **NAPAP Code:** 6B-1.02A

Element: Project

Contributing to: E-06, E-07, E-08, E-09

Cross Reference: Program: Watershed Processes and Manipulations (E-05)
Program Element: Acidification/Recovery Model Development and Testing (E-05.4)

Status: Completed **Period of Performance:** 1987 to 1988

Contact: Kent Thornton

TITLE: Modeling the Recovery of Sensitive Surface Waters Following Decreased Acidic Deposition

SHORT TITLE: Modeling Recovery of Surface Waters

REGION(S)/STATE(S): Canada (Sudbury), Middle Atlantic (DE, MD, NJ, NY, PA, RI, VA, WV), Northeast (CT, MA, ME, NH, NY, PA, RI, VT), Norway, Southeast (AL, AR, FL, GA, KY, NC, TN, VA), Upper Midwest, (MI, MN, WI)

GOAL(S)/OBJECTIVE(S): To test and develop, or enhance, forecasts of surface water recovery associated with decreases in deposition that result from the application of existing surface water acidification models.

RATIONALE: One of the forecasted benefits from a policy decision resulting from reduction of acidic deposition is that some currently acidic surface waters would recover, i.e., become less acidic. The current Direct/Delayed Response Project models were developed to simulate surface water chemistry under either constant or increasing deposition. The sources of data for model building, testing, and forecasting have been derived from areas receiving nearly constant deposition. The ability of these models to represent adequately the processes and changes associated with reduced acidification has not been tested and evaluated. Proper evaluation of policy alternatives that reduce deposition requires that this aspect of current models be tested and the uncertainties understood.

APPROACH: The approach within this project area is twofold. Initially, the project is compiling existing data from sites where documented reductions in emissions have occurred and where surface water recovery has been observed. These data bases then will be used to calibrate the models, using the data prior to the emission reduction, and evaluating the model forecasts during the post-reduction period. Direct/Delayed Response Project modeling approaches and protocols will be followed to the maximum extent possible during this effort.

The second line of investigation will examine the current literature to develop relationships and hypotheses relevant to the processes involved in recovery. These relationships and processes then will be examined through existing or modified models. Iterative interactions are anticipated between this effort and efforts within the Soil/Hydrologic Processes program element (E-05.3) to estimate parameters and to test hypotheses and model forecasts.

KEY WORDS:
Medium: Chemistry, Lakes, Soils, Streams, Watersheds
Chemicals: Acid Neutralizing Capacity, pH
Approach: Literature, Modeling
Processes: Recovery

PPA: E-05 **EPA Code:** E-05.4B **NAPAP Code:** 6B-1.02B

Element: Project

Contributing to: E-06, E-07, E-08, E-09

Cross Reference: Program: Watershed Processes and Manipulations (E-05)
Program Element: Acidification/Recovery Model Development and Testing (E-05.4)

Status: Ongoing **Period of Performance:** 1987 to 1990

Contact: Jeff Lee

TITLE: Coordinating Watershed Studies as a Means for Implementing an Integrated Environmental Monitoring Program

SHORT TITLE: Watershed Studies Coordination

REGION(S)/STATE(S): Mid-Appalachians, Middle Atlantic, Midwest, Northeast, Southeast, Upper Midwest, West

GOAL(S)/OBJECTIVE(S): To establish an interagency, integrated watersheds research effort that will allow ongoing and proposed studies to be coordinated into a long-term environmental monitoring research program. To identify sites presently being studied and, through the agency sponsoring the research, evaluate the potential for including the sites as part of a research program that addresses environmental issues including and beyond those associated with acidic deposition.

RATIONALE: Many presently ongoing watersheds studies have periods of record dating to the early 1980s. Although the research is part of the National Acid Precipitation Assessment Program, and therefore the focus has been primarily on acidic deposition effects, most of the project's objectives also are relevant to environmental issues that extend beyond acidification issues. Because long-term data records are few, though extremely valuable in assessing trends, coordinating these and future research activities into a program with a common goal and set of objectives would allow the maximum opportunity to assess how and to what degree aquatic ecosystems are being affected by anthropogenic activities.

APPROACH: The first task is to select a mutually agreeable set of research questions that most or all sites can address in the near future that remain relevant to the National Acid Precipitation Assessment Program. The selected questions will consider the benefits of combining information from all sites without jeopardizing the success of the present mission. The second approach will be to identify, as a coordinated agency effort, the key goals and objectives for a long-term environmental monitoring program. Contacts will be established for the U.S. Geological Survey, the U.S. Department of Agriculture-Forest Service, the U.S. Department of Interior-National Park Service, the U.S. Environmental Protection Agency, and others involved in environmental monitoring. Periodic meetings and correspondence will help facilitate this coordination effort.

KEY WORDS:
Medium: N/A
Chemicals: N/A
Approach: N/A
Processes: N/A

PPA: E-05 **EPA Code:** E-05.5 **NAPAP Code:** 6C-4

Element: Program Element

Contributing to: E-06, E-09

Cross Reference: Program: Watershed Processes and Manipulations (E-05)

Status: Ongoing **Period of Performance:** 1987 to 1990 +

Contact: Daniel McKenzie

TITLE: Watershed Processes Regulating Surface Water Recovery from Acidic Deposition

SHORT TITLE: Watershed Recovery Project

REGION(S)/STATE(S): Mid-Appalachians (MD, PA, VA, WV), Northeast (CT, ME, NH, NY, VT), Southern Blue Ridge Province (GA, NC, TN)

GOAL(S)/OBJECTIVE(S): To assess error inherent in measurement of sulfate adsorption isotherms utilizing air-dry vs. field-moist soils. To assess the feasibility of using adsorption isotherms to model desorption during watershed recovery.

RATIONALE: The models used within the Direct/Delayed Response Project assume soil sulfate adsorption to regulate the potential for buffering acidic inputs to surface waters. Due to the logistical constraints imposed upon the sampling scheme employed by the Direct/Delayed Response Project, air-dry soil samples were subjected to analysis. Evidence indicates that sulfate adsorption potentials may be overestimated as an artifact of this sample preparation procedure. Ongoing efforts within the National Acid Precipitation Assessment Program include a modeling exercise to determine the utility of using Direct/Delayed Response Project models to forecast recovery rates at Clearwater Lake near Sudbury, Canada. Implicit in that effort is the assumption that sulfate concentrations in surface waters will be controlled solely by the desorption rate from the soil, and that desorption is kinetically equivalent to adsorption.

APPROACH: Selected watersheds representative of dominant soil groupings from each region of interest will be sampled during the Fall of 1988. For each watershed and horizon, sulfate adsorption and desorption isotherms will be determined on both field-moist and air-dry samples. A statistical model will be developed and validated, providing a framework within which existing Direct/Delayed Response Project soils data can be enhanced to reflect field-moist conditions. Desorption experiments also will be conducted that will determine the utility of Direct/Delayed Response Project model formulations (i.e., adsorption reversibility and kinetics parameters) in the forecasting of watershed recovery.

KEY WORDS:

Medium:	Chemistry, Soils, Watersheds
Chemicals:	Sulfate
Approach:	Field Sampling, Laboratory, Statistical Analyses
Processes:	Chronic Acidification, Recovery, Sulfate Adsorption, Sulfate Desorption

PPA: E-05 **EPA Code:** E-05.6 **NAPAP Code:** 6C-5

Element: Program Element

Contributing to: E-07, E-08, E-09

Cross Reference: Watershed Processes and Manipulations (E-05)

Status: Initiating **Period of Performance:** 1988 to 1989

Contact: Jeff Lee

TITLE: Determination of Sulfate Adsorption and Desorption Potentials: Error Inherent in the Use of Air Dry Samples

SHORT TITLE: Adsorption and Desorption of Sulfate by Soils

REGION(S)/STATE(S): Mid-Appalachians (MD, PA, VA, WV), Northeast (CT, ME, NH, NY, VT), Southern Blue Ridge Province (GA, NC, TN)

GOAL(S)/OBJECTIVE(S): To assess error inherent in measurement of sulfate adsorption isotherms utilizing air-dry vs. field-moist soils. To assess the feasibility of using adsorption isotherms to model desorption during watershed recovery.

RATIONALE: The formulation of models used within the Direct/Delayed Response Project assume soil sulfate adsorption to regulate the potential for buffering acidic inputs to surface waters. Due to the logistical constraints imposed upon the sampling scheme employed by the Direct/Delayed Response Project, air-dry soil samples were subjected to analysis. Evidence indicates that sulfate adsorption potentials may be overestimated as an artifact of this sample preparation procedure. Ongoing efforts within the National Acid Precipitation Assessment Program include a modeling exercise to determine the utility of using Direct/Delayed Response Project models to forecast recovery rates at Clearwater Lake near Sudbury, Canada. Implicit in that effort is the assumption that sulfate concentrations in surface waters will be controlled solely by the desorption rate from the soil, and that desorption is kinetically equivalent to adsorption.

APPROACH: Selected watersheds representative of dominant soil groupings from each region of interest will be sampled during the Fall of 1988. For each watershed and horizon, sulfate adsorption and desorption isotherms will be determined on both field-moist and air-dry samples. A statistical model will be developed and validated, providing a framework within which existing Direct/Delayed Response Project soils data can be enhanced to reflect field-moist conditions. Desorption experiments also will be conducted that will determine the utility of Direct/Delayed Response Project model formulations (i.e., adsorption reversibility and kinetics parameters) in the forecasting of watershed recovery.

KEY WORDS:
Medium: Chemistry, Soils, Watersheds
Chemicals: Sulfate
Approach: Field Sampling, Laboratory, Statistical Analyses
Processes: Chronic Acidification, Recovery, Sulfate Adsorption, Sulfate Desorption

PPA: E-05 **EPA Code:** E-05.6A **NAPAP Code:** 6C-5.01

Element: Project

Contributing to: E-07, E-08, E-09

Cross Reference: Program: Watershed Processes and Manipulations (E-05)
Program Element: Watershed Recovery Project (E-05.6)

Status: Initiating **Period of Performance:** 1988 to 1989

Contact: Jeff Lee

2.5 EPISODIC RESPONSE PROJECT – PROGRAM E-08

[Program/Program Element/Project]

TITLE: Effects of Snowmelt and Storm Episodes on Surface Water Acidification

SHORT TITLE: Episodic Response Project

REGION(S)/STATE(S): Middle Atlantic (DE, MD, NJ, NY, PA, RI, VA, WV), Northeast (CT, MA, ME, NH, NY, PA, RI, VT)

GOAL(S)/OBJECTIVE(S): To determine the magnitude, duration, and frequency of episodic chemical changes that accompany hydrologic events To determine the critical site factors and forcing functions including deposition and hydrologic flowpath. To determine whether episodes can potentially impact long-term fish survival. To develop a model to forecast the regional extent of episodic chemical changes in the United States

RATIONALE: The National Surface Water Survey was designed and implemented to characterize the extent of "chronic" acidic conditions that may adversely affect aquatic biota in lake and stream ecosystems Because these population estimates pertain only to index conditions (seasonal, hydrologic, etc.), they do not provide an estimate of the "worst-case" chemical conditions from an acidification perspective, such as short-term acidification of lakes and streams that accompanies snowmelt and rainstorm events. Preliminary analyses using simple conceptual and empirical models of episodic acidification indicate that lake acidification in the Adirondacks during snowmelt and stream acidification in the Middle Atlantic region may be underestimated significantly if based solely on index conditions.

APPROACH: Several approaches to acidic episodes in surface waters have been only marginally successful for several reasons. Both intensive studies and survey approaches have been generally data-limited, primarily as a result of the unpredictable nature of snowmelt and rainstorm events. Most of these studies have employed manual sampling as the principal field sampling approach, and thus episodes that begin on weekends or at night are typically missed. Survey approaches have failed because of logistical difficulties associated with sampling unfamiliar systems. Therefore, a more intensive approach is being employed at 10-15 streams in Pennsylvania and New York. Biological and chemical characterization will be conducted during snowmelt and rainstorm events through means of automated and manual sampling techniques. In addition, a watershed manipulation experiment is being conducted in West Virginia to examine the influence of altered acidic deposition on chronic and episodic surface water acidification.

KEY WORDS:

Medium:	Biology, Chemistry, Deposition, Soils, Streams, Watersheds
Chemicals:	Acid Neutralizing Capacity, Aluminum, Ammonium, Base Cations, Major Ions, Nitrate, pH, Sulfate
Approach:	Field Sampling, Modeling
Processes:	Episodic Acidification, Hydrology, Nitrification, Nitrogen Retention, Sulfur Retention

PPA: E-08 **EPA Code:** E-08 **NAPAP Code:** 6A-2

Element: Program

Contributing to: E-01, E-03, E-05, E-06, E-07

Cross Reference: None

Status: Ongoing **Period of Performance:** 1987 to 1991

Contact: Parker J. Wigington, Jr

TITLE: Regional Episodic and Acidic Manipulation Studies

SHORT TITLE: Regional Episodic and Acidic Manipulations

REGION(S)/STATE(S): Middle Atlantic (WV)

GOAL(S)/OBJECTIVE(S): To determine the surface water chemical responses, at both chronic and episodic time scales, of regionally representative watersheds and associated streams to altered deposition of sulfur and/or nitrogen. To determine the important site factors and forcing functions that control chronic and episodic response of watersheds and associated streams, including the importance of deposition. To test the behavior of the Direct/Delayed Response Project models, evaluate model forecasts of manipulation outcomes, and refine model structure to improve reliability of forecasts. To determine the magnitude, duration, and frequency of episodic chemical changes that accompany hydrologic events in regionally representative streams.

RATIONALE: Results from the National Surface Water Survey and the Direct/Delayed Response Project have revealed a critical need for testing acidification hypotheses – formulated using regional water chemistry and soils data bases – through application of watershed-based research. The Episodic Response Project and the Watershed Manipulation Project were designed and implemented to test these hypotheses. Conducting the two projects independently would be a costly duplication of effort, given their similar logistical, analytical, and quality assurance needs. Therefore, the Regional Episodic and Acidic Manipulation studies were designed to integrate the objectives of both projects.

APPROACH: The overall approach of this project from the Watershed Manipulation Project perspective is to provide additional tests of acidification hypotheses that have been formulated from regional data bases and mechanistic hydrochemical models. Each of these hypotheses deals with the response of a calibrated catchment to an increased loading of an acidic substance relative to the response of a control system. The acidic manipulations will be applied as ammonium sulfate over at least a three-year period, during which time the response will be determined through quantification of the chemical output in streamflow. From the Episodic Response Project perspective, streams from both the experimental and the control catchment will be monitored to determine the extent to which short-term chemical changes in water chemistry (particularly pH and acid neutralizing capacity) occur. These data will be integrated with comparable episodes data (collected under E-08.2) from a group of larger streams located in regions of the eastern United States to formulate an empirical or conceptual model of episodic acidification that could potentially be used in a regionalization context.

KEY WORDS:

Medium:	Chemistry, Soils, Streams
Chemicals:	Acid Neutralizing Capacity, Ammonium, Nitrate, pH, Sulfate
Approach:	Field Sampling
Processes:	Episodic Acidification, Hydrology, Nitrification, Nitrogen Retention, Sulfur Retention

PPA: E-08 **EPA Code:** E-08.1 **NAPAP Code:** 6A-2.01

Element: Program Element

Contributing to: E-01, E-05, E-06, E-07

Cross Reference: Program: Episodic Response Project (E-08)

Status: Ongoing **Period of Performance:** 1987 to 1990 +

Contact: Timothy Strickland

TITLE: Monitoring Episodic Acidification in Surface Waters

SHORT TITLE: Monitoring of Episodic Events

REGION(S)/STATE(S): Middle Atlantic (NY, PA)

GOAL(S)/OBJECTIVE(S): To determine the magnitude, duration, and frequency of episodic chemical changes that accompany hydrologic events. To determine the critical site factors and forcing functions including deposition and hydrologic flowpath. To determine whether episodes can potentially impact long-term fish survival.

RATIONALE: The National Surface Water Survey was designed and implemented to characterize the extent of "chronic" acidic conditions that may adversely affect aquatic biota in lake and stream ecosystems. Because these population estimates pertain only to index conditions (seasonal, hydrologic, etc.), they do not provide an estimate of the "worst-case" chemical conditions from an acidification perspective, such as short-term acidification of lakes and streams that accompanies snowmelt and rainstorm events. Preliminary analyses using simple conceptual and empirical models of episodic acidification indicate that lake acidification in the Adirondacks during snowmelt and stream acidification in the Middle Atlantic region may be significantly underestimated if based solely on index conditions. In addition, impacts of episodic acidification on fishery resources and other biota are not well established.

APPROACH: Several approaches to acidic episodes in surface waters have been only marginally successful for several reasons. Both intensive studies and survey approaches have been generally data-limited, primarily as a result of the unpredictable nature of snowmelt and rainstorm events. Most of these studies have employed manual sampling as the principal field sampling approach, and thus episodes that begin on weekends or at night are typically missed. Survey approaches have failed because of logistical difficulties associated with unfamiliar sampling systems. In addition, any regional interpretation of many intensive studies is limited because it is not known what population or subpopulation of surface waters were "represented" by the intensive systems. Therefore, a more intensive approach is being employed in the Catskills, Northern Appalachian Plateau, and the Adirondacks. Three to five streams in each region will be monitored, and the episodic acidification potential of each site will be assessed from these complete, continuous chemistry data bases. Fish population responses to episodes also will be characterized through repeated stream-reach surveys. Biological studies are being conducted as part of E-03.3, Biological Effects of Acidic Episodes.

KEY WORDS:
Medium: Biology, Chemistry, Streams
Chemicals: Acid Neutralizing Capacity, Aluminum, Base Cations, Nitrate, pH, Sulfate
Approach: Field Sampling
Processes: Episodic Acidification

PPA: E-08 **EPA Code:** E-08.2 **NAPAP Code:** 6A-2.02

Element: Program Element

Contributing to: E-01, E-03, E-05, E-07

Cross Reference: Program: Episodic Response Project (E-08)

Status: Ongoing **Period of Performance:** 1988 to 1991

Contact: Parker J Wigington, Jr.

TITLE: Monitoring the Episodic Chemical Response and Associated Biological Impacts of Streams in the Catskills, New York

SHORT TITLE: Episodic Stream Monitoring in the Catskills

REGION(S)/STATE(S): Middle Atlantic (NY)

GOAL(S)/OBJECTIVE(S): To determine the magnitude, duration, and frequency of episodic chemical changes that accompany hydrologic events. To determine the site factors and forcing functions (including deposition and hydrologic flowpath) that affect the characteristics of acidic episodes. To determine the impact of episodic acidification on aquatic biota with an emphasis on fish.

RATIONALE: The National Surface Water Survey estimates of the status and extent of aquatic resources pertain to "index" conditions, and thus do not correspond to the "worst-case" chemical conditions from an acidification perspective. Short-term (episodic) acidification significantly affects the interpretation of status and extent. In addition, the actual impacts of episodic acidification on fishery resources and other biota are not well established for the United States, including the Middle Atlantic (one of the regions of the United States most likely to experience episodic acidification).

APPROACH: Because, by definition, episodic acidification is transient in nature, survey approaches have been unsuccessful in characterizing the significance of episodes. Therefore, a more intensive approach is being employed in the Catskills. Three to five streams, of sufficient size to support sport fisheries, are being studied using a variety of physical, chemical, and biological monitoring approaches. Stream discharge, pH, temperature, and conductance are measured continuously. Automated samplers are used to collect water samples during rainstorm- and snowmelt-driven hydrologic events. These samples are then analyzed for a complete set of chemical parameters. Stable isotopes are used to separate hydrologic flowpaths. At each stream, fish population responses to episodes are characterized through repeated stream-reach surveys. In addition, in-stream bioassays and electro-tagging of fish are used to measure individual fish responses.

KEY WORDS:
Medium: Biology, Chemistry, Streams
Chemicals: Acid Neutralizing Capacity, Aluminum, Base Cations, Nitrate, pH, Sulfate
Approach: Field Sampling
Processes: Episodic Acidification

PPA: E-08 **EPA Code:** E-08.2A **NAPAP Code:** 6A-2.02A

Element: Project

Contributing to: E-01, E-03, E-05, E-07

Cross Reference: Program: Episodic Response Project (E-08)
Program Element: Monitoring of Episodic Events (E-08.2)

Status: Initiating **Period of Performance:** 1988 to 1991

Contact: Parker J. Wigington, Jr.

TITLE: Monitoring the Episodic Chemical Response and Associated Biological Impacts of Streams in the Northern Appalachian Plateau, Pennsylvania

SHORT TITLE: Episodic Stream Monitoring in the Northern Appalachian Plateau

REGION(S)/STATE(S): Middle Atlantic (PA)

GOAL(S)/OBJECTIVE(S): To determine the magnitude, duration, and frequency of episodic chemical changes that accompany hydrologic events. To determine the site factors and forcing functions (including deposition and hydrologic flowpath) that affect the characteristics of acidic episodes. To determine the impact of episodic acidification on aquatic biota with an emphasis on fish.

RATIONALE: The National Surface Water Survey estimates of the status and extent of aquatic resources pertain to "index" conditions, and thus do not correspond to the "worst-case" chemical conditions from an acidification perspective. Short-term (episodic) acidification significantly affects the interpretation of status and extent. In addition, the actual impacts of episodic acidification on fishery resources and other biota are not well established for the United States, including the Middle Atlantic (one of the regions of the United States most likely to experience episodic acidification).

APPROACH: Because, by definition, episodic acidification is transient in nature, survey approaches have been unsuccessful in characterizing the significance of episodes. Therefore, a more intensive approach is being employed in the Northern Appalachian Plateau. Three to five streams, of sufficient size to support sport fisheries, are being studied using a variety of physical, chemical, and biological monitoring approaches. Stream discharge, pH, temperature, and conductance are measured continuously. Automated samplers are used to collect water samples during rainstorm- and snowmelt-driven hydrologic events. These samples are then analyzed for a complete set of chemical parameters. Stable isotopes are used to separate hydrologic flowpaths. At each stream, fish population responses to episodes are characterized through repeated stream-reach surveys. In addition, in-stream bioassays and electro-tagging of fish are used to measure individual fish responses.

KEY WORDS:
Medium: Biology, Chemistry, Streams
Chemicals: Acid Neutralizing Capacity, Aluminum, Base Cations, Nitrate, pH, Sulfate
Approach: Field Sampling
Processes: Episodic Acidification

PPA: E-08 **EPA Code:** E-08.2B **NAPAP Code:** 6A-2.02B

Element: Project

Contributing to: E-01, E-03, E-05, E-07

Cross Reference: Program: Episodic Response Project (E-08)
Program Element: Monitoring of Episodic Events (E-08.2)

Status: Initiating **Period of Performance:** 1988 to 1991

Contact: Parker J. Wigington, Jr.

TITLE: Monitoring the Episodic Chemical Response and Associated Biological Impacts of Streams in the Adirondacks

SHORT TITLE: Episodic Stream Monitoring in the Adirondacks

REGION(S)/STATE(S): Middle Atlantic (NY)

GOAL(S)/OBJECTIVE(S): To determine the magnitude, duration, and frequency of episodic chemical changes that accompany hydrologic events. To determine the site factors and forcing functions (including deposition and hydrologic flowpath) that affect the characteristics of acidic episodes. To determine the impact of episodic acidification on aquatic biota with an emphasis on fish.

RATIONALE: The National Surface Water Survey estimates of the status and extent of aquatic resources pertain to "index" conditions, and thus do not correspond to the "worst-case" chemical conditions from an acidification perspective. Short-term (episodic) acidification significantly affects the interpretation of status and extent. In addition, the actual impacts of episodic acidification on fishery resources and other biota are not well established for the United States, including the Middle Atlantic (one of the regions of the United States most likely to experience episodic acidification).

APPROACH: Because, by definition, episodic acidification is transient in nature, survey approaches have been unsuccessful in characterizing the significance of episodes. Therefore, a more intensive approach is being employed in the Adirondacks. Three to five streams, of sufficient size to support sport fisheries, are being studied using a variety of physical, chemical, and biological monitoring approaches. Stream discharge, pH, temperature, and conductance are measured continuously. Automated samplers are used to collect water samples during rainstorm- and snowmelt-driven hydrologic events. These samples are then analyzed for a complete set of chemical parameters. Stable isotopes are used to separate hydrologic flowpaths. At each stream, fish population responses to episodes are characterized through repeated stream-reach surveys. In addition, in-stream bioassays and electro-tagging of fish are used to measure individual fish responses.

KEY WORDS:
Medium: Biology, Chemistry, Streams
Chemicals: Acid Neutralizing Capacity, Aluminum, Base Cations, Nitrate, pH, Sulfate
Approach: Field Sampling
Processes: Episodic Acidification

PPA: E-08 **EPA Code:** E-08.2C **NAPAP Code:** 6A-2.02C

Element: Project

Contributing to: E-01, E-03, E-05, E-07

Cross Reference: Program: Episodic Response Project (E-08)
Program Element: Monitoring of Episodic Events (E-08.2)

Status: Initiating **Period of Performance:** 1988 to 1991

Contact: Parker J. Wigington, Jr.

TITLE: Development and Application of Models to Quantify the Importance of Episodes in Surface Water Acidification on Regional Scales

SHORT TITLE: Regional Modeling of Episodic Acidification

REGION(S)/STATE(S): Middle Atlantic (DE, MD, NJ, NY, PA, RI, VA, WV), Northeast (CT, MA, ME, NH, NY, PA, RI, VT)

GOAL(S)/OBJECTIVE(S): The National Surface Water Survey, through application of an "index" sampling protocol and a statistically rigorous design, allowed the extent of "chronic" acidic conditions in target populations of lakes and streams in regions of interest to be quantified. Because "acute" or "episodic" acidification is by definition transient, the data requirements and logistical constraints of making direct regional estimates would be prohibitive. Such approaches undertaken as part of the National Surface Water Survey were deemed infeasible An alternative method is the application of simple empirical or conceptual models that can forecast the occurrence of episodic acidification with more readily available data. The objective of this project is to develop such models from existing data bases, and to calibrate and verify them using data that will be collected as part of the Episodes Monitoring and Regional Episodic and Acidic Manipulation research efforts.

RATIONALE: Understanding the importance and causes of episodic acidification is crucial to a complete assessment program, because of the possibility that biological effects are associated with transient acidic conditions, rather than with "index" conditions. Acute toxicity to fish has been documented under both laboratory and field conditions, and preliminary analyses suggest that the number of acidic systems in the eastern United States is significantly underestimated using the "index" sample approach. Forecast models of episodic acidification would ultimately permit estimation of the "target loadings" for systems, given some objective criteria are provided.

APPROACH: The technical approach will include a formulation of both empirical and deterministic mathematical models using existing data from a variety of episodes studies. In some cases, existing deterministic models will be used (decreasing the time steps); more hydrologically realistic models will presumably be easier to calibrate, however, and several of these models are already in the development stage. Several empirical models have also been proposed, and these will also be tested using data from the Regional Episodic and Acidic Manipulation and Episodes Monitoring studies. Regional forecasts using the empirical techniques will be made, and the deterministic models will be used for estimating target loadings.

KEY WORDS:
Medium: Chemistry, Deposition, Streams, Watersheds
Chemicals: Major Ions, Nitrate, Sulfate
Approach: Modeling
Processes: Episodic Acidification

PPA: E-08 **EPA Code:** E-08.3 **NAPAP Code:** 6A-2.03

Element: Program Element

Contributing to: E-01, E-03, E-05, E-06, E-07

Cross Reference: Program: Episodic Response Project (E-08)

Status: Ongoing **Period of Performance:** 1987 to 1991

Contact: Parker J. Wigington, Jr

TITLE: Event Wet Deposition Monitoring in Support of Episodes Research

SHORT TITLE: Deposition Monitoring for Episodes

REGION(S)/STATE(S): Middle Atlantic (NY, PA)

GOAL(S)/OBJECTIVE(S): To provide event-based measurements of wet-deposition chemistry to support episodic stream research.

RATIONALE: A significant effort is being made to determine the magnitude, duration, and frequency of episodes and the associated biological effects in 15 streams in New York and Pennsylvania. A major part of the research is determine the site factors and forcing functions that control episodic acidification. To accomplish this task, event-based wet deposition chemistry measurements are required.

APPROACH: The 15 streams that are being studied within the Episodic Response Project are located in three clusters of 5 streams each. The clusters are located in the Catskills, the Adirondacks, and the Northern Appalachian Plateau of Pennsylvania. One Aerochem Metrics wet deposition sampler will be centrally located within each of the clusters. Wet deposition samples will be collected on a rain or snow event basis.

KEY WORDS:
Medium: Chemistry, Deposition
Chemicals: Major Ions
Approach: Field Sampling
Processes: Episodic Acidification

PPA: E-08 EPA Code: E-08.4 NAPAP Code: 6A-2.04

Element: Program Element

Contributing to: E-01, E-03, E-05, E-07

Cross Reference: Program: Episodic Response Project (E-08)

Status: Initiating Period of Performance: 1988 to 1991

Contact: Parker J. Wigington, Jr.

2.6 BIOLOGICALLY RELEVANT CHEMISTRY – PROGRAM E-03

[Program/Program Element/Project]

TITLE: Determining the Regional Risk of Aquatic Biota in Response to Acidic Deposition

SHORT TITLE: Biologically Relevant Chemistry

REGION(S)/STATE(S): Middle Atlantic (DE, MD, NJ, NY, PA, RI, VA, WV), Northeast (CT, MA, ME, NH, NJ, NY, PA, RI, VT), Southeast (AL, AR, FL, GA, KY, NC, OK, SC, TN, VA), Upper Midwest (MI, MN, WI), West (CA, CO, ID, MT, NM, NV, OR, UT, WA, WY)

GOAL(S)/OBJECTIVE(S): To provide the information necessary to assess at a regional level the risk that acidic deposition poses to aquatic biota, focusing on past and future potential impacts on fish populations.

RATIONALE: Acidification of surface waters is of concern principally to the degree that biological processes and communities are adversely affected. Public interest centers on potential losses or decline in the fishery resource resulting from acidic deposition.

APPROACH: Biological responses to acidic deposition and acidification are complex and varied. As a result, the program emphasis is to identify those chemical characteristics and changes in surface waters that cause "undesirable" biological effects, rather than to define in detail the specific nature and mechanisms of biological response. These analyses draw primarily upon the existing literature, and thus are derived from a broad range of studies: laboratory bioassays, field bioassays, field experiments, and field surveys. Several modeling approaches are being pursued, based on data from field surveys and laboratory bioassays, to quantify levels of key chemical parameters associated with the loss of fish populations in lakes and streams as a result of acidic deposition. The existing literature and data are being supplemented by several major field studies that address uncertainties. Surveys of fish populations focus on selected subregions with little existing data but relatively large numbers of acidic or potentially sensitive surface waters (e.g., Upper Peninsula of Michigan and Florida), providing additional information on the current status of the fishery resource and levels of acidity associated with fish population loss or absence. In addition, the role and importance of acidic episodes in determining fish population response to acidification are being investigated as part of field studies associated with the Episodic Response Project in streams across the eastern United States.

KEY WORDS:

Medium:	Biology, Chemistry, Lakes, Seepage Lakes, Streams
Chemicals:	Acid Neutralizing Capacity, Aluminum, Base Cations, Calcium, Fluoride, Major Ions, Mercury, Metals, Nitrate, Organics, pH, Silica, Sulfate
Approach:	Existing Data Analyses, Field Manipulation, Field Sampling, Laboratory, Literature, Modeling
Processes:	Biological Response, Chronic Acidification, Community Response, Episodic Acidification

PPA: E-03 **EPA Code:** E-03 **NAPAP Code:** 6D-1

Element: Program

Contributing to: E-01, E-04, E-05, E-06, E-08, E-09

Cross Reference: None

Status: Ongoing **Period of Performance:** 1985 to 1991

Contact: Dixon Landers

TITLE: Current Status of Fish and Other Biotic Communities in Surface Waters

SHORT TITLE: Current Status of Biological Communities

REGION(S)/STATE(S): Middle Atlantic (MD, NJ, PA, VA, WV), Northeast (CT, MA, ME, NH, PA, RI, VT), Southeast (FL, GA, NC, TN), Upper Midwest (MI, WI)

GOAL(S)/OBJECTIVE(S): To establish the current status of and possible effects on fish populations and other selected biological communities (e.g., zooplankton) in lakes and streams considered potentially sensitive to acidic deposition.

RATIONALE: Survey data provide a baseline for the design and implementation of long-term monitoring and information on levels of acidity associated with observed biological effects, e.g., the absence or loss of fish populations. Surveys of zooplankton communities provide a reliable means to examine relationships between biological resources and water chemistry.

APPROACH: Field surveys and literature review focus on the status of fish populations, with more limited attention on other biological communities such as zooplankton. Regions to be surveyed are those with little existing data, but relatively large numbers of acidic waters or waters considered potentially sensitive to acidic deposition, e.g., lakes in Florida and the Upper Peninsula of Michigan. Waters selected for biological sampling represent a subset of those sampled during the National Surface Water Survey, thereby contributing to regional assessments of the current status of biological communities. Lake and stream survey data are used to quantify regional distributions of biological parameters of interest (e.g., estimate the number of lakes without fish) and to develop and test models of biological response to acidification and estimates of critical values for effects.

KEY WORDS:

Medium:	Biology, Chemistry, Lakes, Streams
Chemicals:	Acid Neutralizing Capacity, Aluminum, Base Cations, Calcium, Fluoride, Major Ions, Mercury, Metals, Nitrate, Organics, pH, Silica, Sulfate
Approach:	Existing Data Analyses, Field Sampling, Literature, Modeling
Processes:	Biological Response, Community Response, Episodic Acidification

PPA: E-03 **EPA Code:** E-03.1 **NAPAP Code:** 6D-1.01

Element: Program Element

Contributing to: E-01, E-04, E-05, E-06, E-08, E-09

Cross Reference: Program: Biologically Relevant Chemistry (E-03)

Status: Ongoing **Period of Performance:** 1985 to 1990

Contact: Dixon Landers

TITLE: Present Status of the Fishery Resource in Three Areas of Florida

SHORT TITLE: Fish Populations of Florida Lakes

REGION(S)/STATE(S): Southeast (FL)

GOAL(S)/OBJECTIVE(S): To assess the current status of fish communities and fish populations in selected lakes in three areas of Florida (Ocala National Forest, Trail Ridge, and Florida Panhandle).

RATIONALE: In the Eastern Lake Survey, the Florida subregion was identified as having the highest percentage of acidic lakes in the target population surveyed. Relatively few data exist on the status of the fishery resource in this subregion regarding potential effects of acidic deposition. The data acquired in this project will continue to improve the understanding of the current status of biological communities in an area with a high proportion of acidic lakes and also receiving relatively high levels of acidic deposition.

APPROACH: Four lakes, covering a range of pH levels and dissolved organic carbon concentrations, in each of the three areas were selected for sampling. Fish populations in the lakes are being sampled by electrofishing, gill netting, and blocknets. A mark-recapture study in each lake is being conducted in conjunction with the electrofishing technique. Results of the mark-recapture technique will provide information on species composition and abundance population size structure, condition factor coefficients, and fish age and growth rates.

KEY WORDS:
Medium: Biology, Chemistry, Lakes
Chemicals: Organics, pH
Approach: Field Sampling
Processes: N/A

PPA: E-03 **EPA Code:** E-03.1A **NAPAP Code:** 6D-1.01A

Element: Project

Contributing to: E-01, E-05, E-06, E-09

Cross Reference: Program: Biologically Relevant Chemistry (E-03)
Program Element: Current Status of Biological Communities (E-03.1)

Status: Ongoing **Period of Performance:** 1986 to 1989

Contact: Joan Baker

TITLE: Present Status of the Fishery Resource in the Upper Peninsula of Michigan

SHORT TITLE: Surface Water Chemistry and Fish Presence (MI)

REGION(S)/STATE(S): Upper Midwest (MI, WI)

GOAL(S)/OBJECTIVE(S): To assess the current status of fish communities and fish populations in lakes in the Upper Peninsula of Michigan.

RATIONALE: In the Eastern Lake Survey-Phase I, three subregions were identified as having the highest percentages of acidic lakes in the target populations of lakes surveyed – the Adirondacks, Florida, and the Upper Peninsula of Michigan. Of these three subregions, extensive data on the current status of fishery resources exist only for the Adirondack Subregion. The current status of the fishery resource in Florida is being addressed in a separate project, Fish Populations of Florida Lakes E-03.1A). This project will provide information on the present status of fish populations in the Upper Peninsula of Michigan.

APPROACH: A variable probability, systematic sample of 50 lakes was selected from the Eastern Lake Survey-Phase I frame in Region 2. Lake selection was optimized to include those lakes with a range of key chemical parameters affecting fish, including pH, calcium, and dissolved organic carbon. A number of chemical parameters will be measured in conjunction with fish sampling by use of gill nets, fish nets, and beach seines. Results of these efforts will provide information on fish species presence/absence and estimates of population abundance (through calculations of catch per unit effort). The project is also being conducted in cooperation with a mercury study to determine the concentrations and regional distribution of mercury in fish tissues.

KEY WORDS:
Medium: Biology, Chemistry, Lakes
Chemicals: Aluminum, Calcium, Fluoride, Mercury, Metals, Organics, pH
Approach: Field Sampling
Processes: N/A

PPA: E-03 **EPA Code:** E-03.1B **NAPAP Code:** 6D-1.01B

Element: Project

Contributing to: E-01, E-04, E-05, E-06, E-09

Cross Reference: Program: Biologically Relevant Chemistry (E-03)
Program Element: Current Status of Biological Communities (E-03.1)

Status: Ongoing **Period of Performance:** 1986 to 1989

Contact: Dixon Landers

TITLE: Relationship between Zooplankton Distributions and Surface Water Chemistry in the Northeastern United States

SHORT TITLE: Surface Water Chemistry and Plankton Distributions

REGION(S)/STATE(S): Northeast (CT, MA, ME, NH, PA, RI, VT)

GOAL(S)/OBJECTIVE(S): To characterize summer zooplankton communities. To examine relationships between zooplankton and water chemistry. To evaluate zooplankton community structure with respect to existing data on fish populations and lake basin characteristics. To assess potential of acidification to alter structure and function of zooplankton communities. To evaluate project results in light of application to long-term monitoring.

RATIONALE: Zooplankton are a component of aquatic biological communities, and their assemblages are particularly sensitive to direct (chemical) and indirect (food web interactions) effects of acidification. Surveys of zooplankton communities can provide a sensitive, reliable, and accurate means to examine relationships between biological resources and water chemistry, contributing to an overall assessment of biological status of lakes at risk to acidic deposition effects.

APPROACH: Zooplankton samples were collected in conjunction with the Northeastern Seasonal Variability Study during the spring, summer, and fall by vertical tows from 150 lakes statistically selected from the Eastern Lake Survey-Phase I in the Northeast. Taxonomic composition, species abundance, size class abundance, and feeding category abundance are being determined on each zooplankton sample. Data analysis includes a number of statistical evaluations between zooplankton community structure and regional patterns of zooplankton distribution.

KEY WORDS:
Medium: Biology, Chemistry, Lakes
Chemicals: Acid Neutralizing Capacity, Aluminum, Calcium, Major Ions, Nitrate, Organics, pH, Sulfate
Approach: Field Sampling, Literature
Processes: Community Response

PPA: E-03 **EPA Code:** E-03.1C **NAPAP Code:** 6D-1.01C

Element: Project

Contributing to: E-01, E-05, E-09

Cross Reference: Program: Biologically Relevant Chemistry (E-03)
Program Element: Current Status of Biological Communities (E-03.1)

Status: Concluding **Period of Performance:** 1986 to 1988

Contact: Dixon Landers

TITLE: Regional Assessment of Acidification Effects on Fish in Streams

SHORT TITLE: Regional Assessment of Acidification Effects on Fish in Streams

REGION(S)/STATE(S): Middle Atlantic (MD, NJ, PA, VA, WV), Southeast (GA, NC, TN)

GOAL(S)/OBJECTIVE(S): To compile and analyze the existing information on fish populations in streams in subregions surveyed by the National Stream Survey to evaluate potential effects on fish communities from acidification.

RATIONALE: As part of the National Stream Survey, chemical conditions in streams were assessed for nine subregions of the eastern United States. Comparable information on biological status, and estimates of effects of acidity on fish populations in these target streams, are not, however, currently available. Three major assessment questions are of primary interest:

1. What is the resource at risk, i.e., what fish species occur in streams with present-day low pH and low acid neutralizing capacity, or in streams projected to acidify in the future?

2. Is there any evidence of effects on fish communities to date?

3. What are the regional extent and magnitude of effects on fish populations, presently and with projected future changes in stream chemistry?

This project will use existing information to address each of these above questions to the degree possible within the limitations of the available data.

APPROACH: The work will be conducted in three phases:

Phase 1, Project Scoping -- to identify the types of data available and evaluate alternative approaches to data analysis and assessment.

Phase 2, Model Development -- to develop and test the specific tools and models necessary for regional assessments of potential effects on fish populations in National Stream Survey streams.

Phase 3, Model Application -- to apply the selected techniques and models for each National Stream Survey subregion, with the output from these analyses to be used in the National Acid Precipitation Assessment Program final assessment in 1990.

Four specific tasks are underway as part of Phase 1:

Task 1 -- Contact local experts to determine the nature, extent, and format of existing fish survey data for the National Stream Survey subregions; computerized data bases will be acquired.

Task 2 -- Compile and evaluate existing bioassay data (laboratory and field) for the fish species of interest in the National Stream Survey subregions.

Task 3 -- Develop a proposed framework for using bioassay data to forecast acidification "stress" on fish populations in the field.

Task 4 -- Evaluate existing methods and models for defining habitat suitability and fish distribution in National Stream Survey streams.

Based on results from Phase 1, specific plans for Phases 2 and 3 will be prepared.

KEY WORDS: Medium: Biology, Streams
Chemicals: Acid Neutralizing Capacity, Aluminum, Calcium, pH
Approach: Existing Data Analyses, Literature, Modeling
Processes: Biological Response

PPA: E-03 **EPA Code:** E-03.1D **NAPAP Code:** 6D-1.01D

Element: Project

Contributing to: E-01, E-05, E-09

Cross Reference: Program: Biologically Relevant Chemistry (E-03)
Program Element: Current Status of Biological Communities (E-03.1)

Status: Initiating **Period of Performance:** 1988 to 1990

Contact: Joan Baker

TITLE: Fish Population Status in Maine Streams

SHORT TITLE: Fish Population Status in Maine Streams

REGION(S)/STATE(S): Northeast (ME)

GOAL(S)/OBJECTIVE(S): To determine the influence of precipitation chemistry, precipitation amount and character, and stream hydrologic components on biologically important stream chemistry parameters To determine the response of fish to episodic and chronic changes in these parameters in Maine streams.

RATIONALE: Streams are an important aquatic resource, yet, relative to lakes, little is known regarding fish population responses to chronic and episodic acidification in streams. Thus, a two-year intensive joint investigation of stream chemistry and effects on fish was initiated in 1985 on six streams in eastern Maine.

APPROACH: Six small (first-order) streams in eastern Maine were monitored for stream chemistry and fish community characteristics over a two-year period. The streams support populations of Atlantic salmon, brook trout, and several forage species. Population parameters measured include fish abundance, growth, production, and survival. Precipitation amounts and chemistry were monitored from samples collected by a centrally located NADP-protocol site. Stream discharge was recorded continuously for each stream. Stream chemistry was measured at least biweekly; samples were analyzed for pH, acid neutralizing capacity, conductance, color, dissolved organic carbon, dissolved inorganic carbon, major cations and anions, aluminum, exchangeable aluminum, silica, and ammonium.

In addition to the routine stream monitoring studies, six artificial stream channels were constructed adjacent to one stream and used to test the effects of chemically manipulated stream water on the physiology, growth, and survival of Atlantic salmon early life stages (embryos, fry, and smolts). Exposures simulated episodic pH depressions, accompanied by increased aluminum levels, and chronic exposure to sublethal levels of acidic stress. Physiological response variables or indices examined included blood plasma and whole-body ion content and histological analysis of gill tissues.

KEY WORDS:
Medium: Biology, Chemistry, Streams
Chemicals: Acid Neutralizing Capacity, Aluminum, Base Cations, Major Ions, pH, Silica
Approach: Field Sampling
Processes: Biological Response, Episodic Acidification

PPA: E-03 **EPA Code:** E-03.1E **NAPAP Code:** 6D-1.01E

Element: Project

Contributing to: E-05, E-08

Cross Reference: Program: Biologically Relevant Chemistry (E-03)
Program Element: Current Status of Biological Communities (E-03.1)

Status: Completed **Period of Performance:** 1985 to 1988

Contact: Joan Baker

TITLE: Model Development and Testing: Identifying Values of Chemical Variables Critical to Fish Populations

SHORT TITLE: Biological Model Development and Testing

REGION(S)/STATE(S): Middle Atlantic (DE, MD, NJ, NY, PA, RI, VA, WV), Northeast (CT, MA, ME, NH, NJ, NY, PA, RI, VT), Southeast (AL, AR, FL, GA, KY, NC, OK, SC, TN, VA), Upper Midwest (MI, MN, WI), West (CA, CO, ID, MT, NM, NV, OR, UT, WA, WY)

GOAL(S)/OBJECTIVE(S): To quantify the relationship between surface water acidification and key biological responses, in particular the loss of fish populations. To identify critical values for effects (e.g., levels of pH, aluminum, and calcium at which adverse effects are likely to occur).

RATIONALE: Acidification of surface waters is of concern principally to the degree that biological processes and communities are adversely affected. Public interest centers on the potential loss or decline in the fisheries resource. Thus, it is important to define what chemical characteristics and levels of key chemical parameters are associated with adverse biological effects, in particular, effects on fish populations.

APPROACH: Three alternative approaches were examined: (1) qualitative evaluation and integration of the existing literature, (2) empirical models based on field survey data, and (3) response models based on both field surveys and laboratory bioassay data. The existing literature includes data derived from laboratory bioassays, field bioassays, field experiments, and field surveys. Critical pH values for effects observed or tested were identified and combined across studies to estimate the critical pH range for effects. Empirical models rely on the spatial association between water chemistry and biological status (e.g., fish presence or absence) to quantify critical levels for effects. In addition to models of biological response to acidification, empirical models are being developed to assess the likelihood that fish occur, or do not occur, for reasons other than acidity, termed the baseline probability of fish presence. The third approach quantitatively integrates bioassay data with field survey data, using bioassay data to define the interactive effects of pH, aluminum, and calcium, and survey data to identify levels of stress (e.g., decreased reproductive potential) that result in population extinction. Results from these three alternative approaches will be compared directly, in terms of estimated critical values or ranges for effects, and as they influence regional forecasts of responses to acidic deposition.

KEY WORDS:
Medium: Biology, Chemistry, Lakes, Streams
Chemicals: Aluminum, Calcium, Organics, pH
Approach: Literature, Modeling
Processes: Biological Response, Community Response

PPA: E-03 EPA Code: E-03.2 NAPAP Code: 6D-1.02

Element: Program Element

Contributing to: E-01, E-05, E-06, E-09

Cross Reference: Program Area: Biologically Relevant Chemistry (E-03)

Status: Ongoing Period of Performance: 1987 to 1990

Contact: Joan Baker

TITLE: Development of Empirical Models for Estimating the Baseline Probability of Fish Presence

SHORT TITLE: Baseline Probability

REGION(S)/STATE(S): Northeast (ME, NH, NY, VT)

GOAL(S)/OBJECTIVE(S): To develop empirical models for forecasts of fish species distribution among lakes in the northeastern United States as a function of factors *other than* lake acidity or acidification.

RATIONALE: Models of the "baseline probability" of fish presence are eventually to be coupled with models of fish response to acidification and forecasts of lake chemistry in order to estimate regional impacts from acidic deposition. Although it is expected that these models of baseline probability will be rather crude, such models are needed to supplement and integrate existing survey data to quantify patterns of fish species distribution in waters considered potentially sensitive to acidic deposition

APPROACH: Models for forecasting the baseline probability of fish presence will be strictly empirical, based on the observed spatial association between fish species distribution and physical and chemical lake characteristics other than lake acidity. The models will be developed and tested, for the most part, using fish survey data collected in 1984 and 1985 in the Adirondack region of New York by the Adirondack Lakes Survey Corporation. The Adirondack Lakes Survey Corporation data set ($n = 842$) will be subdivided into data for model development (two-thirds) and model testing (one-third). Models also will be evaluated with limited survey data for Maine ($n = 87$), Vermont ($n = 29$), and New Hampshire ($n = 20$). Models will focus initially on forecasting the distribution of brook trout and other important game fish. Independent factors considered will include lake area, lake depth, elevation, watershed area, hydrologic type, temperature, dissolved oxygen, and fish stocking. Model development principally will involve logistic regression analysis. Data sets may be restricted, initially, to only lakes with $pH \geq 6.0$, to eliminate potential confounding effects due to lake acidity. Colinearity among independent parameters will be assessed using linear regression (PROCREG), colinearity diagnostics, the Mallows Cp statistic, and other criteria. Depending on the utility of the results for lakes in the Northeast, future projects may apply similar techniques for streams or lakes in other regions of the United States.

KEY WORDS:
Medium: Biology, Chemistry, Lakes
Chemicals: Organics
Approach: Literature
Processes: Biological Response

PPA: E-03 **EPA Code:** E-03.2A **NAPAP Code:** 6D-1.02A

Element: Project

Contributing to: E-05, E-06, E-09

Cross Reference: Program Area: Biologically Relevant Chemistry (E-03)
Program Element: Biological Model Development and Testing (E-03.2)

Status: Ongoing **Period of Performance:** 1987 to 1990

Contact: Joan Baker

TITLE: Defining Critical Values for Effects of Acidification on Aquatic Biota

SHORT TITLE: Defining Critical Values

REGION(S)/STATE(S): Middle Atlantic (DE, MD, NJ, NY, PA, RI, VA, WV), Northeast (CT, MA, ME, NH, NJ, NY, PA, RI, VT), Southeast (AL, AR, FL, GA, KY, NC, OK, SC, TN, VA), Upper Midwest (MI, MN, WI), West (CA, CO, ID, MT, NM, NV, OR, UT, WA, WY)

GOAL(S)/OBJECTIVE(S): To define best possible estimates of levels of acidity (and associated parameters) that cause significant damage to aquatic biota, in particular, fish populations and zooplankton communities.

RATIONALE: Acidification of surface waters is of concern principally to the degree that biological processes and communities are adversely affected. Public interest centers on the potential loss or decline in the fishery resource. Thus, it is important to define what chemical characteristics and levels of key chemical parameters are associated with adverse biological effects, in particular effects on fish populations.

APPROACH: Three alternative approaches were examined: (1) qualitative evaluation of the existing literature, (2) empirical models based on field survey data, and (3) response models based on both field surveys and laboratory bioassay data. The existing literature includes data derived from laboratory bioassays, field bioassays and experiments, and field surveys. Literature reviews covered all aspects of effects of acidification on aquatic biota and biological communities. Critical pH values for effects observed or tested were identified from individual studies, and then combined to estimate a critical pH range for effects. Empirical models rely on the spatial association between water chemistry and biological status (e.g., fish presence or absence) to quantify acidity levels for effects. Logistic regression models were developed for selected species of fish and zooplankton. The third approach quantitatively integrates bioassay data with field survey data, using bioassay data to define the interactive effects of pH, aluminum, and calcium, and survey data to identify levels of stress (e.g., decreased reproductive potential) that result in population extinction. This third approach was applied for fish populations only, based largely on efforts funded by the Electric Power Research Institute as part of the Lake Acidification and Fisheries Project. Results from these three alternative approaches were compared directly, in terms of estimated critical values or ranges for effects, and as they influence regional forecasts of responses to acidic deposition.

KEY WORDS:
Medium: Biology, Chemistry, Lakes, Streams
Chemicals: Aluminum, Calcium, Organics, pH
Approach: Literature
Processes: Biological Response, Community Response

PPA: E-03 **EPA Code:** E-03.2B **NAPAP Code:** 6D-1.02B

Element: Project

Contributing to: E-05, E-06, E-09

Cross Reference: Program Area: Biologically Relevant Chemistry (E-03)
Program Element: Biological Model Development and Testing (E-03.2)

Status: Completed **Period of Performance:** 1987 to 1988

Contact: Joan Baker

TITLE: Modeling the Effects of Acidification on Fish Population Status

SHORT TITLE: Modeling Fish Population-Level Responses

REGION(S)/STATE(S): Northeast (CT, MA, ME, NH, NJ, NY, PA, RI, VT), Upper Midwest (MI, MN, WI)

GOALS(S)/OBJECTIVE(S): To develop models of fish population response to acidification for use in estimating the regional effects of acidic deposition.

RATIONALE: Estimation of the regional extent and severity of effects of acidic deposition of fish populations is a primary goal of the Aquatic Effects Research Program. Models that express changes in fish population status as a function of changes in surface water chemistry and acidity provide a framework for quantifying potential effects on fish populations. These models may then be used with results from the National Surface Water Survey (E-01) and the Direct/Delayed Response Project (E-07), translating regional estimates of changes in chemical status into regional estimates of biological effects.

APPROACH: The primary approach used for model development is empirical, relying on the spatial association between fish population status and water chemistry among surface waters across a broad geographic region. Given the limited field data available for streams, modeling efforts to date have focused on lakes, principally lakes in the Adirondack region of New York and in Ontario. Data sets for model calibration have been restricted to those lakes with historical survey data (or other information) indicating the presence of the fish species of interest in the past. Fish population status is defined simply as fish species catch or no catch in field surveys as an indicator of fish species presence/absence. Models are defined based on logistic regression analysis relating fish presence/absence as a function of lake pH, calcium, aluminum, elevation, area or other chemical and physical characteristics. Exploratory analyses using Bayesian statistical techniques to pool information across regions or to pool field data with expert judgment have also been initiated.

KEY WORDS:
Medium: Biology, Chemistry, Lakes
Chemicals: Aluminum, Calcium, Organics, pH
Approach: Modeling
Processes: Biological Response

PPA: E-03 **EPA Code:** E-03.2C **NAPAP Code:** 6D-1.02C

Element: Project

Contributing to: E-01, E-09

Cross Reference: Program: Biologically Relevant Chemistry
Program Element: Biological Model Development and Testing

Status: Ongoing **Period of Performance:** 1987 to 1990

Contact: Joan Baker

TITLE: Empirical Bayes Models of Fish Population Response to Acidification: Linking Laboratory Bioassay and Empirical Modeling Studies

SHORT TITLE: Empirical Bayes Models of Fish Population Response

REGION(S)/STATE(S): Northeast (ME, NH, NY, VT)

GOALS(S)/OBJECTIVE(S): To develop models of fish population response to acidification that take advantage of results from both laboratory bioassays (defining the functional relationship between fish survival and pH, aluminum, and calcium levels) and field surveys (i.e., the observed spatial association between fish population status and water chemistry).

RATIONALE: Modeling efforts to date to forecast changes in fish populations with acidification have relied principally on field survey data and the observed spatial association between fish population status and the chemical (and physical) characteristics of the surface water. These empirical approaches have several inherent problems, in particular, problems related to multicolinearity, or correlations among the independent forecast variables that make it difficult to distinguish causal relationships based on field survey data alone. Bioassays provide another major source of information on effects of acidic conditions on fish. The pooling of laboratory bioassay data and empirical field observations is expected to result in improved forecast models.

APPROACH: Four tasks are planned: (1) compile and review existing data sets from laboratory bioassays, (2) use appropriate statistical methods (e.g., Bayesian techniques or weighting schemes) for pooling among bioassay data sets from different investigators or for different life stages, (3) develop a Bayesian model for combining laboratory bioassay and empirical models (E-03.2C) of fish response to acidification, and (4) statistically compare the resultant model parameter estimates and forecasts with existing models. Models are to be developed for brook trout and lake trout populations in lakes. A particularly critical issue to be explored is the nature of the relationship between the bioassay survival data or model and observed responses in field surveys. Several alternative strategies will be explored that incorporate the concept of compensatory reserve, i.e., mechanisms by which the population may compensate for increases in acid -induced mortality.

KEY WORDS:
Medium: Biology, Chemistry, Lakes
Chemicals: Aluminum, Calcium, Organics, pH
Approach: Modeling
Processes: Biological Response

PPA: E-03 **EPA Code:** E-03.2D **NAPAP Code:** 6D-1.02D

Element: Project

Contributing to: E-01, E-09

Cross Reference: Program: Biologically Relevant Chemistry
Program Element: Biological Model Development and Testing

Status: Ongoing **Period of Performance:** 1987 to 1989

Contact: Joan Baker

TITLE: Determining the Effects of Acidic Episodes on the Status of Populations of Aquatic Biota

SHORT TITLE: Biological Effects of Acidic Episodes

REGION(S)/STATE(S): Middle Atlantic (PA), Northeast (NY)

GOAL(S)/OBJECTIVE(S): To determine whether acidic episodes have definitive, long-term effects on fish populations. To determine the general characteristics of episodes (i.e., magnitude, duration, frequency) associated with adverse effects.

RATIONALE: While it has been demonstrated that chronic acidification can result in the loss of fish populations and other adverse biological effects, the specific role and influence of short-term acidic episodes remains uncertain. Acidic episodes occur in many lakes and streams, including surface waters experiencing no measurable chronic acidification. Thus, an understanding of the importance of acidic episodes is required for improved assessments of the regional extent of biological effects related to acidic deposition.

APPROACH: Laboratory and field bioassays have demonstrated that short-term exposures to acidic conditions typical of those that occur during acidic episodes can kill individual fish. Uncertainties remain, however, regarding the long-term effects of episodes on fish population status. Thus, studies of episodic effects will concentrate on population-level responses in the field environment, evaluating key processes and parameters such as behavioral avoidance, reproductive success, and changes in population abundance over time. Studies will be conducted in 3-5 streams per region, in 3 regions (Adirondacks, Catskills, and Northern Appalachians), in conjunction with chemical monitoring, as part of the Episodic Response Project (E-08).

KEY WORDS:
Medium: Biology, Chemistry, Streams
Chemicals: Aluminum, Calcium, Organics, pH
Approach: Field Sampling, Field Manipulation
Processes: Biological Response, Episodic Acidification

PPA: E-03 **EPA Code:** E-03.3 **NAPAP Code:** 6D-1.03

Element: Program Element

Contributing to: E-08, E-09

Cross Reference: Program: Biologically Relevant Chemistry (E-03)

Status: Initiating **Period of Performance:** 1987 to 1991

Contact: Joan Baker

TITLE: Mechanisms of Fish Population Responses to Episodic Acidification

SHORT TITLE: Mechanisms of Fish Population Response

REGION(S)/STATE(S): Middle Atlantic (PA), Northeast (NY)

GOALS(S)/OBJECTIVE(S): To improve understanding of mechanisms of fish population response to episodic acidification. To define key characteristics of episodes that determine the severity of effects on fish populations. To aid in interpretation of fish survey data and evaluation of models of fish population responses to episodic acidification.

RATIONALE: The effects of episodic acidification on fish communities and fish population status are uncertain. Numerous laboratory and field bioassays have demonstrated that short-term exposures to acidic conditions can cause increased mortality and other adverse effects on fish. Yet, definitive population-level effects on fish from short-term depressions in pH or acid neutralizing capacity have been demonstrated in few systems. Ideally, chemical characterization of the extent and severity of episodes should focus on those features that determine or influence biological response. Unfortunately, our understanding of these factors is incomplete. These uncertainties contribute to uncertainties in models of fish population response and uncertainties in regional estimates of the effects of acidic episodes and acidic deposition.

APPROACH: Intensive field studies of fish population responses to acidic episodes are being conducted in 3-5 streams per region, in three regions (Adirondacks, Catskills, and Northern Appalachians). Existing fish in the study reach will be removed with electrofishing, and each study reach will be restocked with a known number of brook trout and a forage species common to the region and likely to be sensitive to stream acidification. These fish transplant experiments are to be initiated in late summer/fall 1988 and will continue through late 1990/early 1991. Response variables to be measured or estimated include (1) patterns of fish movement into and out of the study reach, (2) changes in fish abundance over time in the study reach, (3) population-level mortality rates (estimated from observed changes in fish abundance corrected from outmigration and inmigration), (4) reproductive success and behavior, and (5) fish growth rates. Values for these response variables will be assessed as a function of changes in chemical conditions through time in any one stream, particularly with respect to potential effects from acidic episodes, and also as a function of differences in water chemistry (and the severity of episodes) among streams.

KEY WORDS:
Medium: Biology, Chemistry, Streams
Chemicals: Aluminum, Calcium, Organics, pH
Approach: Field Sampling, Field Manipulation
Processes: Biological Response, Episodic Acidification

PPA: E-03 **EPA Code:** E-03.3C **NAPAP Code:** 6D-1.03A

Element: Project

Contributing to: E-08, E-09

Cross Reference: Program: Biologically Relevant Chemistry
Program Element: Biological Effects of Episodes

Status: Initiating **Period of Performance:** 1987 to 1991

Contact: Joan Baker

TITLE: Investigating Physiological and Population-Level Responses of Aquatic Organisms Resulting from Changes in Surface Water Chemistry

SHORT TITLE: Organismal Development/Physiology

REGION(S)/STATE(S): Upper Midwest (MN, WI)

GOAL(S)/OBJECTIVE(S): To determine changes in the structure and function of gills and other organs in fish exposed to low pH water.

RATIONALE: Although low pH has been documented to be detrimental to fish and fish populations, many of the direct effects are poorly understood. Careful examination of the histological, anatomical, and physiological effects of low pH on fish will help refine our understanding of how acidification of surface waters might adversely affect physiology and population structure of an important biotic component of aquatic ecosystems.

APPROACH: The projects in this program element are being conducted in conjunction with the artificial acidification of Little Rock Lake, WI (E-05.2A). Warmwater fish are being collected from Little Rock Lake as the pH declines in response to incremental additions of sulfuric acid. One study is focusing on anatomical changes in fish gills and the consequent effects on blood osmoregulatory control. The second focuses on examining histological and histopathological changes in fish gills, kidneys, and ovaries, and evaluating if such changes can be used reliably to detect early acidification effects on fish.

KEY WORDS:
Medium: Biology, Chemistry, Lakes, Seepage Lakes, Streams
Chemicals: pH
Approach: Field Manipulation, Laboratory
Processes: Biological Response, Chronic Acidification, Episodic Acidification

PPA: E-03 **EPA Code:** E-03.4 **NAPAP Code:** 6D-2

Element: Program Element

Contributing to: E-01, E-06, E-08, E-09

Cross Reference: Program: Biologically Relevant Chemistry (E-03)

Status: Concluding **Period of Performance:** 1987 to 1988

Contact: Howard McCormick

TITLE: Loss of Osmoregulatory Control in Warmwater Fish in Response to Artificial Acidification

SHORT TITLE: Osmoregulation – Loss/Recovery

REGION(S)/STATE(S): Upper Midwest (MN, WI)

GOAL(S)/OBJECTIVE(S): To define the types of gill anatomical changes associated with exposure to lethal pH of sublethal duration. To relate such changes to the loss of blood osmoregulatory control and its recovery when neutral pH is restored.

RATIONALE: Brief pulses of low pH conditions have been documented for lakes and streams during spring snowmelt and storm events and reportedly are responsible for fish morbidity and mortality. No studies have been published, however, that document (1) concurrent effects of an acute pH reduction on osmotic balance and histopathological changes in ionoregulatory organs of fish, or (2) recovery of osmoregulatory tissues and ionoregulatory control when pH returns to circumneutral levels.

APPROACH: The fish species being examined are three of the four prevalent in Little Rock Lake: largemouth bass, black crappie, and rock bass, plus the acid-sensitive fathead minnow. Work conducted to date with largemouth bass, black crappie, and rock bass has shown that osmoregulatory control is maintained over a wide range of pH values from 8.0 to 4.5, but that at pH 4.0 control is lost and death ensues. Recovery occurs, however, if pH 7.0 is restored in time. Current research is focused on the recovery process, documenting the sequence of anatomical, histological, and cytological changes taking place in the key osmoregulatory organ system, the gills, as the experiment progresses from pH exposure through recovery. Samples were collected from a complete set of exposures, for which blood osmolalities of each individual of each species has already been determined. Histological analyses are ongoing.

KEY WORDS:
Medium: Biology, Chemistry, Lakes, Streams
Chemicals: pH
Approach: Field Manipulation, Laboratory
Processes: Biological Response, Episodic Acidification

PPA: E-03 **EPA Code:** E-03.4A **NAPAP Code:** 6D-2.01G

Element: Project

Contributing to: E-01, E-06, E-08, E-09

Cross Reference: Program: Biologically Relevant Chemistry (E-03)
Program Element: Organismal Development/Physiology (E-03.4)

Status: Concluding **Period of Performance:** 1987 to 1988

Contact: Howard McCormick

TITLE: Effects of Acidification in Osmoregulatory and Reproductive Organs in Warmwater Fish

SHORT TITLE: Effects on Osmoregulatory/Reproductive Organs

REGION(S)/STATE(S): Upper Midwest (MN, WI)

GOAL(S)/OBJECTIVE(S): To document histological and histopathological changes in fish gills and other organs during the experimental sulfuric acid acidification of Little Rock Lake, WI (E-05.2A).

RATIONALE: In addition to performing a vital respiratory function, gills are the chief organs of ionic and acid-base regulation in fish. Thus, they are a principal organ likely to be affected by acidification. Kidneys and ovaries also may be affected by chronic acid exposure. Examining how progressive acidification affects these organs (1) may provide an indication as to how fish are directly harmed by acidification (e.g., direct damage to ionocytes in gills and kidneys may adversely affect ionoregulatory ability) and (2) may allow development of simple microscopic methods (or indicators) for detecting acid-associated stress before measurable decreases in fish population abundance are observed.

APPROACH: Gills, kidneys, and ovaries of yellow perch and largemouth or rock bass from Little Rock Lake are being examined by light and electron microscopy. Fish samples were collected for analysis when the pH in Little Rock Lake was 5.5 (1985 and 1986) and when it was 5.0 (1987). Observations of histological or histopathological changes in these organs will be related to the population status or health (e.g., breeding success, blood osmolality, and other parameters being measured as part of the whole-lake experiment). In particular, the outputs will focus on the occurrence of acid-stressed tissue changes that may affect the health of the fish first, what these changes are, and whether histopathological methods represent a reliable means of detecting early effects of acidification on fish.

KEY WORDS:
Medium: Biology, Chemistry, Lakes, Seepage Lakes
Chemicals: pH
Approach: Field Manipulation, Laboratory
Processes: Biological Response, Chronic Acidification

PPA: E-03 **EPA Code:** E-03.4B **NAPAP Code:** 6D-2.01H

Element: Project

Contributing to: E-01, E-06, E-09

Cross Reference: Program: Biologically Relevant Chemistry (E-03)
Program Element: Organismal Development/Physiology (E-03.4)

Status: Concluding **Period of Performance:** 1987 to 1988

Contact: Howard McCormick

2.7 SYNTHESIS AND INTEGRATION – PROGRAM E-09

[Program/Program Element/Project]

TITLE: Synthesis and Integration of Data to Understand Past, Current, and Future Effects of Acidic Deposition on Aquatic Resources

SHORT TITLE: Synthesis and Integration

REGION(S)/STATE(S): Canada, Mid-Appalachians, Northeast (ME, NH, NY, VT), Norway, Southeast (FL, GA, NC, SC, TN, VA), Southern Blue Ridge Province, Upper Midwest (MI, MN, WI), West (CA, CO, ID, MT, NM, NV, OR, UT, WA, WY)

GOAL(S)/OBJECTIVE(S): To provide a comprehensive and integrated interpretation of data on the understanding of effects of acidic deposition on surface waters, including the extent of past change, current status, future forecasts, and exposure-response relationships.

RATIONALE: The complexity of the questions surrounding the regional-scale effects of acidic deposition on surface waters has mandated investigation via several regionalized, integrated projects in the Aquatic Effects Research Program (e.g., the National Surface Water Survey, the Direct/Delayed Response Project, the Episodic Response Project, and Watershed Process and Manipulation Studies). Informed policy decisions require that the results and forecasts from these component projects be integrated to allow comprehensive assessments of past, current, and future aquatic effects.

APPROACH: Several approaches are being used to fulfill the above goal. One ongoing effort is that of integrating National Surface Water Survey results with other data sets and synthesizing them into Regional Case Studies. A second effort involves the synthesis of research results, including documents, reports, and data bases, for dissemination to the public, to state and federal agencies, and to universities. The major effort in Synthesis and Integration is the Aquatic Effects Research Program's contribution to the National Acid Precipitation Assessment Program's 1990 State of Science and Integrated Assessment. These documents will consist of a comprehensive series of reports on the state of science of aquatic effects resulting from acidic deposition (along with associated uncertainties) and an integrated assessment based on the state of science results and approaches.

KEY WORDS:

Medium:	Biology, Chemistry, Deposition, Lakes, Sediments, Seepage Lakes, Snowpack, Soils, Streams, Vegetation, Watersheds, Wetlands
Chemicals:	Acid Neutralizing Capacity, Aluminum, Nitrate, Organics, Sulfate
Approach:	Correlative Analyses, Existing Data Analyses, Literature, Modeling, Single-Factor Analyses, Statistical Analyses, Trends Analyses
Processes:	Biological Response, Chronic Acidification, Episodic Acidification, Mineral Weathering, Nitrogen Cycling, Organic Acidification, Recovery, Sulfate Adsorption, Sulfate Desorption

PPA: E-09 EPA Code: E-09 NAPAP Code: 6G

Element: Program

Contributing to: N/A

Cross Reference: None

Status: Ongoing Period of Performance: 1987 to 1990

Contact: Daniel McKenzie

TITLE: Regionalized, Integrated Evaluation of the Current and Potential Future Effects of Acidic Deposition on Surface Waters in Low Alkalinity Regions – Regional Case Studies

SHORT TITLE: Regional Case Studies

REGION(S)/STATE(S): Northeast (ME, NH, NY, VT), Southeast (FL, GA, NC, SC, TN, VA), Upper Midwest (MI, MN, WI), West (CA, CO, ID, MT, NM, NV, OR, UT, WA, WY)

GOAL(S)/OBJECTIVE(S): To provide an integrated assessment of current and potential effects of acidic deposition on aquatic ecosystems in regions with large proportions of surface waters with low acid neutralizing capacity. To characterize important factors controlling surface water chemistry. To examine past and current status of biological communities. To compare and contrast regional characteristics of surface waters; to assess the effects of changes in acidic deposition loadings. To summarize, synthesize, and integrate the results of acidic deposition-related research funded by the National Acid Precipitation Assessment Program and other agencies and institutions.

RATIONALE: Since acidic deposition was identified in the late 1970s as an important issue relative to aquatic effects, much research by a variety of agencies, institutions, and universities has been conducted. The analysis of this wide body of information has not been conducted on an integrated, regional-scale basis. The Regional Case Studies project will synthesize previously existing information and newly acquired information from the Aquatic Effects Research Program to provide regional comparisons of surface water quality (including chemistry and biology) in areas of the United States identified as being potentially sensitive to or at risk due to acidic deposition.

APPROACH: The primary outputs from this project will be a book and journal articles emphasizing intra- and inter-regional descriptions and characterizations of surface waters. Individual book chapters will be authored by individuals with expertise in particular regions or on particular processes, or directly involved with ongoing research programs. The completion of this project involves extensive planning and coordination among a diversity of groups and institutions, including government laboratories, universities, state agencies, and private industry.

KEY WORDS:
Medium: Biology, Chemistry, Deposition, Lakes, Sediments, Seepage Lakes, Soils, Streams, Watersheds, Wetlands
Chemicals: Aluminum, Nitrate, Organics, Sulfate
Approach: Existing Data Analyses, Literature
Processes: N/A

PPA: E-09 **EPA Code:** E-09.1 **NAPAP Code:** 6G-1

Element: Program Element

Contributing to: N/A

Cross Reference: Program: Synthesis and Integration (E-09)

Status: Ongoing **Period of Performance:** 1987 to 1990

Contact: Donald Charles

TITLE: The 1990 State of Science and Integrated Assessment for the Aquatic Effects Task Group–National Acid Precipitation Assessment Program

SHORT TITLE: 1990 NAPAP Report

REGION(S)/STATE(S): Canada, Mid-Appalachians, Northeast, Norway, Southeast, Southern Blue Ridge Province, Upper Midwest, West

GOAL(S)/OBJECTIVE(S): To provide a comprehensive, integrated report on the state of science regarding the effects of acidic deposition on aquatic resources in the United States. To perform an integrated assessment and uncertainty analysis based on the following four questions: (1) What are the effects of concern and what is the relationship between acidic deposition and these effects? (2) What is the sensitivity to change in effects with selected incremental changes in deposition relative to a selected base case? (3) What are the estimates of future conditions (categorized by conservation parameters), given (a) no changes in current policy or legislation on air quality issues, and (b) given various (illustrative) control strategies? and (4) What are the comparative evaluations of the illustrative control strategies based on conservation benefits?

RATIONALE: As a major component of the National Acid Precipitation Assessment Program's Aquatic Effects Task Group (VI), EPA's Aquatic Effects Research Program has conducted research since 1980 on the chemical and biological status of surface waters in response to acidic deposition in various regions of the United States. The Congressional mandate that established the National Acid Precipitation Assessment Program requires the interagency task force to prepare an integrated report on the result of the Task Group's research as well as on relevant results not funded under the auspices of National Acid Precipitation Assessment Program. Successful completion of this two-phased program element will satisfy this Congressional requirement.

APPROACH: The goals/objectives of this program element will be satisfied in two phases: (1) completion of a series of related reports on the state of science regarding acidic deposition effects on lakes and streams and (2) completion of an integrated assessment. Methods and results of Task Group and related research projects will be presented in several papers, on such topics as processes controlling surface water acidification, biological effects, status of surface water chemistry (current, historical, and future), episodes, and mitigation. Comprehensive literature evaluations, uncertainty analyses, and full documentation of data analysis procedures in the State of Science will form the basis for the Integrated Assessment. The Integrated Assessment will provide answers for the four questions presented above, along with uncertainty analyses. Effects of concern in aquatic systems and their relationship to acidic deposition will be analyzed using various models, algorithms, and empirical relationships. These analyses as well as the information upon which they are based will be ranked according to their level of certainty. Sensitivity of aquatic resources to increases and decreases in deposition relative to current levels will be evaluated using three types of models: steady-state; empirical, time-varying; and dynamic watershed models. Estimates of future condition will be based on an evaluation of natural trends in surface waters and the results of various models or algorithms, such as source-receptor relationship models and exposure-response functions, relating deposition to effects. Comparative evaluations of the illustrative control strategies will be presented as a matrix of the estimated responses of aquatic resources relative to reference scenarios (without policy changes) and scenarios described in various illustrative control strategies.

KEY WORDS:
Medium: Biology, Chemistry, Deposition, Lakes, Sediments, Seepage Lakes, Snowpack, Soils, Streams, Vegetation, Watersheds, Wetlands
Chemicals: Acid Neutralizing Capacity, Aluminum, Nitrate, Organics, Sulfate
Approach: Correlative Analyses, Existing Data Analyses, Literature, Modeling, Single-Factor Analyses, Statistical Analyses, Trends Analyses
Processes: Biological Response, Chronic Acidification, Episodic Acidification, Mineral Weathering, Nitrogen Cycling, Organic Acidification, Recovery, Sulfate Adsorption, Sulfate Desorption

PPA: E-09 **EPA Code:** E-09.2 **NAPAP Code:** 6G-2

Element: Program Element

Contributing to: N/A

Cross Reference: Program: Synthesis and Integration (E-09)

Status: Ongoing **Period of Performance:** 1987 to 1990

Contact: Kent Thornton

TITLE: The Effects of Acidic Deposition on Aquatic Resources: State of Science

SHORT TITLE: Aquatics State of Science

REGION(S)/STATE(S): Canada, Mid-Appalachians, Northeast, Norway, Southeast, Southern Blue Ridge Province, Upper Midwest, West

GOAL(S)/OBJECTIVE(S): To provide a comprehensive series of reports on the state of science regarding the effects of acidic deposition on the chemical and biological status of aquatic resources.

RATIONALE: The Congressional mandate that resulted in the establishment of the National Acid Precipitation Assessment Program in 1980 stipulated that a final assessment of the Program's research would be produced in 1990. The State of Science for the Aquatic Effects Task Group fulfills, in part, this obligation.

APPROACH: Published literature and peer-reviewed data bases generated within the Task Group since 1979, as well as results of relevant research outside the Task Group, will be used to produce a series of integrated reports on the state of science of aquatic effects. Topics to be addressed in the reports include watershed and lake processes controlling surface water acidification; biological effects; current status, historical change, and forecasts of future change in surface water chemistry; episodic acidification; and mitigation. Data analysis procedures include modeling (steady-state; empirical; empirical time-varying; dynamic; process); correlative, single-factor, and multivariate analyses; spatial and temporal trends analyses; and paleoecological analyses.

KEY WORDS:

Medium:	Biology, Chemistry, Deposition, Lakes, Sediments, Seepage Lakes, Snowpack, Soils, Streams, Vegetation, Watersheds, Wetlands
Chemicals:	Acid Neutralizing Capacity, Aluminum, Nitrate, Organics, Sulfate
Approach:	Correlative Analyses, Existing Data Analyses, Literature, Modeling, Single-Factor Analyses, Statistical Analyses, Trends Analyses
Processes:	Biological Response, Chronic Acidification, Episodic Acidification, Mineral Weathering, Nitrogen Cycling, Organic Acidification, Recovery, Sulfate Adsorption, Sulfate Desorption

PPA: E-09 **EPA Code:** E-09.2A **NAPAP Code:** 6G-2.01

Element: Project

Contributing to: N/A

Cross Reference: Program: Synthesis and Integration (E-09)
Program Element: 1990 NAPAP Report (E-09.2)

Status: Ongoing **Period of Performance:** 1987 to 1990

Contact: Kent Thornton

TITLE: The Effects of Acidic Deposition on Aquatic Resources: Integrated Assessment

SHORT TITLE: Integrated Assessment

REGION(S)/STATE(S): Canada, Mid-Appalachians, Northeast, Norway, Southeast, Southern Blue Ridge Province, Upper Midwest, West

GOAL(S)/OBJECTIVE(S): To perform an Integrated Assessment and uncertainty analysis, using the approaches and results presented in the Aquatics State of Science, to answer the following four questions: (1) What are the effects of concern in aquatic resources, and what is the relationship between acidic deposition and these effects? (2) What is the sensitivity to change in effects with selected incremental changes in deposition relative to a selected base case? (3) What are estimates of future conditions (categorized by conservation parameters), given (a) no change in current policy or legislation on air quality issues, and (b) given various (illustrative) control strategies? and (4) What are the comparative evaluations of the illustrative control strategies based on conservation benefits?

RATIONALE: The Congressional mandate that resulted in the establishment of the National Acid Precipitation Assessment Program in 1980 stipulated that a final assessment of the Program's research would be produced in 1990. The Task Group's contribution to the Integrated Assessment, in part, fulfills this obligation.

APPROACH: The Integrated Assessment will provide answers to the above four questions along with uncertainty analyses. Various models, algorithms, and empirical analyses will be used to evaluate effects of acidic deposition on aquatic resources identified to be of concern, and the outcome of these analyses will be ranked according to their level of certainty. Steady-state, dynamic, and empirical, time-varying models will be used to evaluate the sensitivity of aquatic resources with regard to increased and decreased deposition (relative to current levels). Estimates of future conditions will be based on comparative evaluation of natural trends in surface waters with future forecasts based on the results of various models or algorithms (such as source-receptor relationship models and exposure-response functions) relating deposition to effects. Comparative evaluations of illustrative control strategies will be presented as a matrix of estimated responses of aquatic resources relative to reference scenarios (without policy changes) and scenarios described in various illustrative control strategies

KEY WORDS:

Medium:	Biology, Chemistry, Deposition, Lakes, Sediments, Seepage Lakes, Snowpack, Soils, Streams, Vegetation, Watersheds, Wetlands
Chemicals:	Acid Neutralizing Capacity, Aluminum, Nitrate, Organics, Sulfate
Approach:	Correlative Analyses, Existing Data Analyses, Literature, Modeling, Single-Factor Analyses, Statistical Analyses, Trends Analyses
Processes:	Biological Response, Chronic Acidification, Episodic Acidification, Mineral Weathering, Nitrogen Cycling, Organic Acidification, Recovery, Sulfate Adsorption, Sulfate Desorption

PPA: E-09 **EPA Code:** E-09.2B **NAPAP Code:** 6G-2.02

Element: Program Element

Contributing to: N/A

Cross Reference: Program: Synthesis and Integration (E-09)
Program Element: 1990 NAPAP Report Activities (E-09.2)

Status: Ongoing **Period of Performance:** 1988 to 1990

Contact: Kent Thornton

TITLE: Dissemination of Information and Technology from the Aquatic Effects Research Program

SHORT TITLE: Technology Transfer

REGION(S)/STATE(S): N/A

GOAL(S)/OBJECTIVE(S): To transfer effectively and efficiently technology and information emanating from the Aquatic Effects Research Program to the users of that technology and information. To establish communication lines from the user to the Environmental Protection Agency.

RATIONALE: Since its implementation in 1983, the Aquatic Effects Research Program has produced extensive technical information including data bases, analytical methods and quality assurance manuals, field and laboratory operating plans, data reports, and scientific publications. To maximize the use of this information requires that an effective communications and dissemination plan be developed. Active transmittal of Aquatic Effects Research Program products to federal and state agencies, universities, the private sector, and other parties interested in or conducting research on environmental issues will afford maximal opportunity for all to benefit from the knowledge gained in executing this program.

APPROACH: Identify categories of users for the information and design mechanisms by which the information can be distributed in a timely and efficient manner. Also, establish a communication channel for users to distribute information to the Environmental Protection Agency.

KEY WORDS:
Medium: N/A
Chemicals: N/A
Approach: Literature
Processes: N/A

PPA: E-09 **EPA Code:** E-09.3 **NAPAP Code:** 6G-3

Element: Program Element

Contributing to: E-01, E-03, E-04, E-05, E-06, E-07, E-08

Cross Reference: Program: Synthesis and Integration (E-09)

Status: Ongoing **Period of Performance:** 1987 to 1990

Contact: Deb Chaloud

2.8 LONG-TERM MONITORING – PROGRAM E-06

[Program/Program Element/Project]

TITLE: Long-Term Monitoring of Surface Waters to Verify Forecasts of Surface Water Response to Various Levels of Acidic Deposition

SHORT TITLE: Long-Term Monitoring

REGION(S)/STATE(S): Middle Atlantic (DC, DE, MD, MO, MS, NJ, NY, PA, RI, VA, WV), Midwest (IN, OH), Northeast (CT, MA, ME, NH, NJ, NY, PA, RI, VT), Southeast (AL, AR, FL, GA, KY, MS, NC, OK, SC, TN, TX, VA), Upper Midwest (MI, MN, WI), West (AK, AZ, CA, CO, ID, MT, NM, NV, OR, UT, WA, WY)

GOAL(S)/OBJECTIVE(S): To provide an early and ongoing indication of regional trends in surface water acidification or recovery, using the most appropriate techniques to detect such trends. To quantify, with known certainty for defined subpopulations of lakes and streams, the rate at which chemical and biological changes are occurring, the subpopulation characteristics of these affected lakes and/or streams, and the subregional extent of these systems. To compare patterns and trends in local and regional atmospheric deposition with patterns and trends in surface water quality.

RATIONALE: Forecasts of surface water response to future changes in acidic loadings can be corroborated only through the long-term collection and analysis of chemical and biological data. Informed policy decisions to implement or continue emissions controls can be made only with an understanding of trends in aquatic ecosystems.

APPROACH: Long-term monitoring has two program elements – the Temporally Integrated Monitoring of Ecosystems (TIME) and Site-Specific Long-Term Monitoring. Within the first program element, the TIME Project, six projects are identified: (1) Monitoring (to collect long-term chemical and biological data records), (2) Optimizing Trends Detection (essential for completion of an optimal design for the project), (3) Methods Development (essential for development and refinement of analytical methods), (4) Quality Assurance/Quality Control Interpretation (analyses of extensive quality assurance data to quantify error associated with environmental sampling), (5) Paleolimnological Studies (a study of Adirondack lake chemistry using paleolimnological techniques to infer historical water chemistry from sediment records), and (6) Long-Term Biomonitoring (to assess feasibility of incorporating biological parameters in the long-term monitoring program) Within the second program element, Site-Specific Long-Term Monitoring, six other projects are identified. These projects focus on the continuation of data collection and analysis at low acid neutralizing capacity lakes in six different regions: the Upper Midwest, Vermont, Adirondacks, Maine, Catskills, and Southern Rocky Mountains. These studies will provide valuable information on natural variability of these systems over a range of annual hydrologic cycles, as well as preliminary insights into whether and where trends in acidification or recovery are occurring.

The basis for selecting lakes and streams for monitoring is derived from the results of the National Surface Water Survey in which regional lake and stream population characteristics were developed. Historical monitoring data are used to improve designs proposed for future studies. Methods proposed for monitoring activities will be compatible with those used in the National Surface Water Survey. Appropriate statistical analyses will be applied to the resulting data.

KEY WORDS:

Medium:	Biology, Chemistry, Deposition, Lakes, Sediments, Seepage Lakes, Soils, Streams, Watersheds
Chemicals:	Acid Neutralizing Capacity, Aluminum, Calcium, Chlorophyll, Color, Conductance, Conductivity, Discharge, Dissolved Organic Carbon, Major Ions, Mercury, Metals, Nitrate, Nutrients, Organics, pH, Speciated Aluminum, Sulfate, Total Aluminum
Approach:	Existing Data Analyses, Field Sampling, Ion Balance, Laboratory, Literature, Modeling, Paleolimnology, Remote Sensing, Single-Factor Analyses, Statistical Analyses, Trends Analyses
Processes:	Aluminum Speciation, Biological Response, Chronic Acidification, Community Response, Episodic Acidification, Metals Mobilization, Organic Acidification, Recovery

PPA: E-06 **EPA Code:** E-06 **NAPAP Code:** 6B-2

Element: Program

Contributing to: E-01, E-03, E-05, E-07, E-08, E-09

Cross Reference: None

Status: Ongoing **Period of Performance:** 1982 to 1990 +

Contact: Jesse Ford

TITLE: Temporally Integrated Monitoring of Ecosystems to Detect Trends in Surface Water Chemical Status and Acidification or Recovery Processes

SHORT TITLE: Temporally Integrated Monitoring of Ecosystems

REGION(S)/STATE(S): Middle Atlantic (DC, DE, MD, MO, MS, NJ, NY, PA, RI, VA, WV), Midwest (IN, OH), Northeast (CT, MA, ME, NH, NJ, NY, PA, RI, VT), Southeast (AL, AR, FL, GA, KY, MS, NC, OK, SC, TN, TX, VA), Upper Midwest (MI, MN, WI), West (AK, AZ, CA, CO, ID, MT, NM, NV, OR, UT, WA, WY)

GOAL(S)/OBJECTIVE(S): To provide an early indication of regional trends in surface water acidification or recovery. To quantify with known certainty for defined subpopulations of surface waters the rate of change in surface water quality and the geographical extent of these changes. To compare patterns and trends in local and regional deposition with regional patterns and trends in surface water quality. To evaluate usefulness of integrating biological parameters with chemical parameters.

RATIONALE: Forecasts of surface water response to future changes in acidic loadings can be corroborated only through the long-term collection and analysis of chemical and biological data. Informed policy decisions to implement or continue emissions controls can be made only with an understanding of trends in aquatic ecosystems.

APPROACH: Using the National Surface Water Survey data bases as a frame, lakes and streams will be selected for broad-scale seasonal or monthly monitoring. Smaller subsets of systems will be sampled to quantify mechanisms and to test regional-scale hypotheses, relating results back to the population of interest identified from the National Surface Water Survey. The project design is expected to be sufficiently flexible to accommodate the use of existing long-term data bases and research activities within relevant scientific areas such as forests, soils, and meteorology.

KEY WORDS:

Medium:	Biology, Chemistry, Deposition, Lakes, Sediments, Seepage Lakes, Soils, Streams, Watersheds
Chemicals:	Acid Neutralizing Capacity, Aluminum, Calcium, Conductance, Major Ions, Mercury, Metals, Nitrate, Organics, pH, Sulfate
Approach:	Existing Data Analyses, Field Sampling, Ion Balance, Laboratory, Literature, Modeling, Paleolimnology, Remote Sensing, Statistical Analyses, Trends Analyses
Processes:	Aluminum Speciation, Biological Response, Chronic Acidification, Community Response, Metals Mobilization, Organic Acidification, Recovery

PPA: E-06 **EPA Code:** E-06.1 **NAPAP Code:** 6B-2.01

Element: Program Element

Contributing to: E-01, E-03, E-05, E-07, E-08, E-09

Cross Reference: Program: Long-term Monitoring (E-06)

Status: Ongoing **Period of Performance:** 1982 to 1990 +

Contact: Jesse Ford

TITLE: Regional-scale Monitoring to Determine Long-term Trends in Surface Waters

SHORT TITLE: Monitoring for Regional Trends Assessment

REGION(S)/STATE(S): Middle Atlantic (DC, DE, MD, NJ, NY, PA, RI, VA, WV), Northeast (CT, MA, ME, NH, NJ, NY, PA, RI, VT), Southeast (AL, AR, FL, GA, KY, MS, NC, OK, SC, TN), Upper Midwest (MI, MN, WI), West (CA, CO, ID, MT, NM, NV, OR, UT, WA, WY)

GOAL(S)/OBJECTIVE(S): To determine, via an integrated aquatic ecosystem monitoring program, the long-term regional trends in acidification or recovery. To compare results of trends monitoring to the forecasts of surface water chemical change as determined by the Direct/Delayed Response Project. To analyze the relationship between patterns and trends in atmospheric deposition and trends in surface water chemistry for defined subpopulations of aquatic resources in areas particularly susceptible to acidification or recovery.

RATIONALE: Aquatic ecosystem change in both the near and distant future is likely to result from projected increases or decreases in emissions of SO_X and NO_X in the United States. If costly emission controls are installed, the efficiency of these measures in reversing surface water acidification is an important issue. Conversely, no action to curb current emissions or to limit increased emissions in the United States could result in changes in surface water chemistry that affect biological populations (e.g., fish) or human health (e.g., heavy metal availability). A coordinated, integrated regional monitoring program is the only way of determining the rate of change in potentially affected ecosystems on a time frame of years, rather than decades. In the case of deterioration or recovery, the regional nature of the problem translates into an important environmental issue affecting valuable resources.

APPROACH: Important acidic deposition effects are manifested as changes in biological populations, yet the direct measurement and interpretation of biota is not always straightforward. Chemical measurements are more easily obtained but cannot always be used as surrogate measures of probable biological effects. The proposed approach is to design a monitoring program in which both biological indicators and biologically relevant chemical parameters are measured over time. A balance between extensive and intensive monitoring will be struck and the design will be customized for the individual regions of the country and the expected change that would occur within them.

Seasonal or monthly samples from "rapid response" aquatic systems will form the core of the study and will provide an early detection of change in those systems most likely to demonstrate effects. Quantification of the proportion of the population that may also be changing could be accomplished by annual sampling of a statistically chosen subsample or by resampling a statistically chosen subsample after a change has been identified in a specific subpopulation.

KEY WORDS:

Medium:	Biology, Chemistry, Deposition, Lakes, Seepage Lakes, Soils, Streams, Watersheds
Chemicals:	Aluminum, Calcium, Mercury, Nitrate, Organics, Sulfate
Approach:	Field Sampling
Processes:	Chronic Acidification, Recovery

PPA: E-06 **EPA Code:** E-06.1A **NAPAP Code:** 6B-2.01A

Element: Project

Contributing to: E-05, E-07, E-09

Cross Reference: Program: Long-term Monitoring (E-06)
Program Element: Temporally Integrated Monitoring of Ecosystems (E-06.1)

Status: Ongoing **Period of Performance:** 1982 to 1990 +

Contact: Jesse Ford

TITLE: Optimizing Trends Detection for Long-term Monitoring of Surface Waters

SHORT TITLE: Optimizing Trends Detection

REGION(S)/STATE(S): Middle Atlantic (DC, DE, MD, MO, MS, NJ, NY, PA, RI, VA, WV), Midwest (IN, OH), Northeast (CT, MA, ME, NH, NJ, NY, PA, RI, VT), Southeast (AL, AR, FL, GA, KY, MS, NC, OK, SC, TN, TX, VA), Upper Midwest (MI, MN, WI), West (AK, AZ, CA, CO, ID, MT, NM, NV, OR, UT, WA, WY)

GOAL(S)/OBJECTIVE(S): To ensure that the design and implementation plan for the Temporally Integrated Monitoring of Ecosystems project adequately addresses the issues related to detecting subtle changes in chemistry and biology of surface waters that may have regional-scale significance in terms of recovery or acidification.

RATIONALE: Six key areas for which insufficient information exist have been identified that need to be addressed before the research plan and implementation plan of the Temporally Integrated Monitoring of Ecosystems project can be optimally developed. Completion of this project will improve the chances of implementing a well-designed, efficient, and appropriate monitoring program.

APPROACH: Investigators in the private sector, universities, and federal laboratories are being asked to contribute to six key tasks: (1) examining the effects of constituent variability on estimating temporal change in surface water quality, (2) developing protocols for analysis of detection limit data, (3) identifying and acquiring existing long-term data records, (4) evaluating the utility of diatom/chrysophyte data for examining long-term trends in chemistry, (5) devising robust statistical testing procedures for establishing trends, and (6) developing an inventory of emissions point sources likely to affect monitoring sites.

KEY WORDS:

Medium:	Chemistry, Deposition, Lakes, Streams, Watersheds
Chemicals:	Acid Neutralizing Capacity, Major Ions, pH, Sulfate
Approach:	Existing Data Analyses, Literature, Modeling, Statistical Analyses, Trends Analyses
Processes:	Chronic Acidification, Recovery

PPA: E-06 **EPA Code:** E-06.1B **NAPAP Code:** 6B-2.01B

Element: Project

Contributing to: E-05, E-07, E-09

Cross Reference: Program: Long-term Monitoring (E-06)
Program Element: Temporally Integrated Monitoring of Ecosystems (E-06.1)

Status: Ongoing **Period of Performance:** 1987 to 1989

Contact: Dixon Landers

TITLE: Methods Development for Long-term Monitoring of Surface Waters

SHORT TITLE: Methods Development

REGION(S)/STATE(S): West (NV)

GOAL(S)/OBJECTIVE(S): To provide analytical methods of sufficient accuracy, precision, and sensitivity to meet the requirements of the Temporally Integrated Monitoring of Ecosystems project.

RATIONALE: Detection and interpretation of trends in surface waters depend on the quality of the analytical measurements. Because many of the methods are state-of-the-art, the surface waters studied have relatively dilute chemical composition, data quality objectives were rigorously defined, and chemical data from the Aquatic Effects Research Program will contribute significantly to policy decisions on potential emissions controls, the methods selected for analyzing chemistry of surface waters were required to be of the highest quality possible. The emphasis of this project was on the use of inductively coupled plasma-mass spectrometry for monitoring trends in trace metal distributions, and on the development of automated methods such as flow injection analysis for measuring water quality parameters. Other methods evaluated include the aluminum/fluoride complex kinetic method, for determining aluminum species in surface waters, and remote sensing applications, for extending the results of water surveys to much larger areas.

APPROACH: Analytical methods requirements for research projects were identified. Initial research identified one (or more) method(s) that could be applied to the analysis. A protocol was developed, optimized, tested, and modified if necessary before incorporating the method into the program.

KEY WORDS:
Medium: Chemistry, Lakes, Sediments, Streams
Chemicals: Acid Neutralizing Capacity, Aluminum, Metals, pH
Approach: Field Sampling, Laboratory, Literature, Remote Sensing
Processes: Aluminum Speciation, Metals Mobilization

PPA: E-06 **EPA Code:** E-06.1C **NAPAP Code:** 6B-2.01C

Element: Project

Contributing to: E-01, E-07, E-08

Cross Reference: Program: Long-term Monitoring (E-06)
Program Element: Temporally Integrated Monitoring of Ecosystems (E-06.1)

Status: Completed **Period of Performance:** 1986 to 1988

Contact: Edward Heithmar

TITLE: Quality Assurance/Quality Control Interpretation for Application in Long-term Monitoring

SHORT TITLE: Quality Assurance/Quality Control Interpretation

REGION(S)/STATE(S): West (NV)

GOAL(S)/OBJECTIVE(S): To provide and define to data users and project planners quality assurance/quality control guidance that is technically correct, easily understood, cost effective, and based on Aquatic Effects Research Program experience.

RATIONALE: The effective application of quality assurance/quality control data is sometimes confounded by the complexity of its derivation and the diversity of the information that can be obtained from the data. This complexity can be especially true of environmental monitoring where analyte concentrations are often at the limits of detection and where numerous sources of variability are present through the sampling and analytical process. In addition, quality assurance project plans for environmental studies are to a great degree based on a number of assumptions and theoretical statistical manipulations.

The National Surface Water Survey data bases contain a wealth of quality assurance/quality control information not yet rigorously analyzed as part of the program. A unique opportunity exists to develop from these data bases practical quality assurance/quality control guidance for environmental scientists based on actual field experience. Such guidance can be essential for long-term monitoring activities in which knowledge of system imprecision is important for trends detection and for reducing uncertainties that impact policy decisions.

APPROACH: A team of university cooperators, contractors, and Environmental Protection Agency staff is examining all quality assurance/quality control aspects of the existing verified National Surface Water Survey data bases. Emphasis is on the efficiency of not only the procedures used to detect and estimate bias and variability, but also on procedures to reduce and control bias and variability, such as upfront quality control. Identification of the various components of variability (e.g., sampling, sample processing, analytical) is an important aspect of this task that will be particularly useful to project planners. The risk versus cost benefit of an increased or decreased number of quality assurance/quality control samples such as blanks, replicates, and audits for a study is being determined. Procedures for estimating the appropriate number and frequency of such samples during project planning is being described and is based on actual National Surface Water Survey field data.

Particular attention is being given to the problems of concentration-dependent precision in terms of use during data interpretation, and of the representativeness and use of audit samples. The National Surface Water Survey data are being used to develop and examine a variability model based on analyte concentration. The model should provide data users and project planners with a variability estimate based on actual or expected concentrations.

KEY WORDS:

Medium:	Chemistry, Lakes, Soils, Streams
Chemicals:	Acid Neutralizing Capacity, Aluminum, Conductance, Major Ions, Nitrate, Organics, Sulfate
Approach:	Existing Data Analyses, Ion Balance, Literature
Processes:	N/A

PPA: E-06 **EPA Code: E-06.1D** **NAPAP Code: 6B-2.01D**

Element: Project

Contributing to: E-01, E-05, E-07, E-08

Cross Reference: Program: Long-Term Monitoring (E-06)
Program Element: Temporally Integrated Monitoring of Ecosystems (E-06.1)

Status: Ongoing **Period of Performance:** 1986 to 1990

Contact: Jesse Ford, Robert Schonbrod

TITLE: Paleoecological Assessment of Changes in Adirondack Lake pH and Alkalinity, pre-1850 to the Present

SHORT TITLE: Paleolimnological Studies of Adirondack Lakes

REGION(S)/STATE(S): Northeast (NY)

GOAL(S)/OBJECTIVE(S): To determine the percentage of a representative set of Adirondack lakes with current pH <5.5 that were naturally acidic prior to 1850, and the extent to which these and other lakes have acidified since the onset of acidic deposition. To assess which lakes appear to have been most susceptible to acidic inputs and thus would be best candidates for long-term monitoring. To develop procedures and strategies for use of diatoms and chrysophytes in other studies.

RATIONALE: Although the National Lake Survey is providing an accurate estimate of the number and surface area of lakes with currently low pH (<5.5) and alkalinity (acid neutralizing capacity <25 μeq/L), the proportion of these lakes that were/are naturally acidic is unknown. Likewise, the extent to which different categories of lakes have acidified since the onset of acidic deposition is unknown. Limited historical water chemistry and fisheries data provide evidence of acidification, but interpretations are controversial. Analysis of diatom and chrysophyte remains in sediment cores, a technique that has developed rapidly in the past five years, has been used successfully in several European and U.S. studies. Studies have indicated significant recent acidification trends in several regions, and that many lakes were naturally acidic prior to 1850.

APPROACH: Diatom and chrysophyte assemblages in the top (0 to 1 cm) and bottom (below 20-30 cm; pre-1850) of sediment cores from 22 Adirondack lakes will be analyzed, and inferred pH and acid neutralizing capacity, using procedures and forecast equations developed in the PIRLA project (Paleoecological Investigation of Recent Lake Acidification) will be calculated. A representative set of study lakes (acid neutralizing capacity <25μeq/L) has been selected from a set of 30 that were cored but not analyzed for diatoms, and from lakes sampled as part of the Eastern Lake Survey. Estimates of the percent of naturally acidic lakes and magnitude of acidification trends will be based on these 22 lakes combined with comparable existing data on about 20 other Adirondack lakes. Conclusions based on analysis of tops and bottoms of cores will be compared with conclusions based on full stratigraphic analysis of previously studied cores. The characteristics of the best candidate lakes for long-term monitoring will be identified and incorporated into screening criteria for the Temporally Integrated Monitoring of Ecosystems Project.

KEY WORDS:
Medium: Biology, Chemistry, Lakes, Sediments
Chemicals: Sulfate
Approach: Field Sampling, Laboratory, Paleolimnology
Processes: Chronic Acidification, Organic Acidification

PPA: E-06 **EPA Code:** E-06.1E **NAPAP Code:** 6B-2.01E

Element: Project

Contributing to: E-03, E-07, E-09

Cross Reference: Program: Long-Term Monitoring (E-06)
Program Element: Temporally Integrated Monitoring of Ecosystems (E-06.1)

Status: Ongoing **Period of Performance:** 1987 to 1989

Contact: Don Charles

TITLE: Usefulness and Feasibility of Biomonitoring in the Context of a Long-Term Surface Water Monitoring Program

SHORT TITLE: Long-Term Biomonitoring

REGION(S)/STATE(S): Northeast, Southeast, Upper Midwest, West

GOAL(S)/OBJECTIVE(S): To assess the usefulness and feasibility of adding biological parameters to the long-term monitoring program. What would be gained? What (exactly) are the parameters (organisms, population/community measures) of interest? Is it cost-effective? Is it feasible, logistically and technically?

RATIONALE: Aquatic communities are sensitive to changes in their chemical environment. Because communities are complex and ecotypic variation within species can be significant, simple dose-response relationships between single chemical parameters and individual species are unreliable indicators of likely potential trajectories of real communities undergoing chemical stress Following the changes in regionally appropriate aspects of aquatic communities may provide an integrative measure of biologically relevant change that simple chemical sampling may miss (e.g., frequency and severity of transient episodes).

APPROACH: Following the recommendations of the joint U.S./Canadian workshop on Biomonitoring (3/88), several aspects of biological community structure will be studied, using existing data sets, to characterize their statistical properties. This is the first step in determining whether they can be useful in terms of trend assessment.

KEY WORDS:
Medium: Biology, Lakes, Streams
Chemicals: N/A
Approach: Literature, Statistical Analyses
Processes: Biological Response, Community Response, Recovery

PPA: E-06 **EPA Code:** E-06.1F **NAPAP Code:** 6B-2 01F

Element: Project

Contributing to: E-03, E-05

Cross Reference: Program: Long-Term Monitoring (E-06)
Program Element: Temporally Integrated Monitoring of Ecosystems (E-06.1)

Status: Ongoing **Period of Performance:** 1988 to 1990+

Contact: Jesse Ford

TITLE: Site-Specific Long-Term Monitoring

SHORT TITLE: Site-Specific Long-Term Monitoring

REGION(S)/STATE(S): Northeast (ME, NY, VT), Upper Midwest (MN, WI, MI), West (CO)

GOAL(S)/OBJECTIVE(S): Because the implementation schedule for the new Temporally Integrated Monitoring of Ecosystems (TIME) Project has been delayed, it has been decided to maintain the most relevant and feasible portions of the old Long-Term Monitoring Project network.

RATIONALE: The continuation of these sites ensures that 5-9 years of seasonal or monthly data will be available for over 80 low acid neutralizing capacity systems distributed throughout many of the regions of concern with respect to acidic precipitation. This will provide information on natural variability of these systems over a range of annual hydrologic cycles, as well as preliminary insights into whether and where trends in acidification or recovery are occurring.

APPROACH: Continuation of data collection by the same cooperators who have been studying these systems since the early- to mid-80's.

KEY WORDS:

Medium:	Lakes, Streams
Chemicals:	Acid Neutralizing Capacity, Chlorophyll, Color, Conductivity, Discharge, Dissolved Organic Carbon, Major Ions, Nutrients, pH, Speciated Aluminum, Total Aluminum
Approach:	Field Sampling, Laboratory, Single-Factor Analyses, Statistical Analyses, Trends Analyses
Processes:	Chronic Acidification, Episodic Acidification, Recovery

PPA: E-06 **EPA Code:** E-06.2 **NAPAP Code:** 6B-2.03

Element: Program Element

Contributing to: E-05, E-08, E-09

Cross Reference: Program: Long-Term Monitoring (E-06)

Status: Ongoing **Period of Performance:** 1988 to 1990 +

Contact: Jesse Ford

TITLE: Site-Specific Long-Term Monitoring in the Upper Midwest

SHORT TITLE: Site-Specific Monitoring in the Upper Midwest

REGION(S)/STATE(S): Upper Midwest (MN, WI, MI)

GOAL(S)/OBJECTIVE(S): To continue data collection and analysis at low acid neutralizing capacity lakes with five or more years of monitoring data In some cases, records extend back for an additional four years due to inclusion in a previous monitoring program.

RATIONALE: The continuation of these sites means that 5-9 years of seasonal or monthly data will be available for over 80 low acid neutralizing capacity systems distributed throughout many of the regions of concern with respect to acidic precipitation. This will provide information on natural variability of these systems over a range of annual hydrologic cycles, as well as preliminary insights into whether and where trends in acidification or recovery are occurring.

APPROACH: Spring, summer, and fall water samples and field measurements will be taken at 4 Minnesota lakes, 11 Wisconsin lakes, and 10 Michigan lakes. These lakes span a significant east/west deposition gradient. Ancillary biological data are available for many of these systems and are being used under Project E-06.1F, Long-Term Biomonitoring.

KEY WORDS:

Medium:	Lakes
Chemicals:	Acid Neutralizing Capacity, Chlorophyll, Color, Conductivity, Dissolved Organic Carbon, Major Ions, Nutrients, pH, Total Aluminum
Approach:	Field Sampling, Laboratory, Single-Factor Analyses, Statistical Analyses, Trends Analyses
Processes:	Chronic Acidification, Episodic Acidification, Recovery

PPA: E-06 **EPA Code:** E-06.2A **NAPAP Code:** 6B-2.03A

Element: Project

Contributing to: E-05, E-08, E-09

Cross Reference: Program: Long-Term Monitoring (E-06)
Program Element: Site-Specific Long-Term Monitoring (E-06.2)

Status: Ongoing **Period of Performance:** 1988 to 1990+

Contact: Jesse Ford

TITLE: Site-Specific Long-Term Monitoring in Vermont

SHORT TITLE: Site-Specific Monitoring in Vermont

REGION(S)/STATE(S): Northeast (VT)

GOAL(S)/OBJECTIVE(S): To continue data collection and analysis at low acid neutralizing capacity lakes with five or more years of monitoring data. In some cases, records extend back an additional three years due to inclusion in a previous program.

RATIONALE: The continuation of these sites means that 5-9 years of seasonal or monthly data will be available for over 80 low acid neutralizing capacity systems distributed throughout many of the regions of concern with respect to acidic precipitation. This will provide information on natural variability of these systems over a range of annual hydrologic cycles, as well as preliminary insights into whether and where trends in acidification or recovery are occurring.

APPROACH: Winter, spring, summer, and fall water samples and field measurements are being taken at 24 Vermont lakes of different levels of organic color. Ancillary precipitation quantity and pH data are available through Vermont's Acid Precipitation Monitoring Network. Ancillary biological data are available for many of these systems and may be used under Project E- 06.1F, Long-Term Biomonitoring.

KEY WORDS:

Medium:	Lakes
Chemicals:	Acid Neutralizing Capacity, Aluminum, Color, Conductivity, Major Ions, pH, Total Aluminum
Approach:	Field Sampling, Laboratory, Single-Factor Analyses, Statistical Analyses, Trends Analyses
Processes:	Chronic Acidification, Episodic Acidification, Recovery

PPA: E-06 **EPA Code:** E-06.2B **NAPAP Code:** 6B-2.03B

Element: Project

Contributing to: E-05, E-08, E-09

Cross Reference: Program: Long-Term Monitoring (E-06)
Program Element: Site-Specific Long-Term Monitoring (E-06.2)

Status: Ongoing **Period of Performance:** 1988 to 1990+

Contact: Jesse Ford

TITLE: Site-Specific Long-Term Monitoring in the Adirondack Mountains, NY

SHORT TITLE: Site-Specific Monitoring in the Adirondack Mountains, NY

REGION(S)/STATE(S): Northeast (NY)

GOAL(S)/OBJECTIVE(S): To continue data collection and analysis at low acid neutralizing capacity lakes with six years of monitoring data.

RATIONALE: The continuation of these sites means that 5-9 years of seasonal or monthly data will be available for over 80 low acid neutralizing capacity systems distributed throughout many of the regions of concern with respect to acidic precipitation. This will provide information on natural variability of these systems over a range of annual hydrologic cycles, as well as preliminary insights into whether and where trends in acidification or recovery are occurring.

APPROACH: Monthly water samples and field measurements are being taken at the outlets of 16 Adirondack lakes. At 11 sites, samples are taken weekly during spring snowmelt. These lakes cover a range of geologic, hydrologic, and limnological characteristics and also cover a significant gradient in bulk precipitation and, therefore, acid loadings. All of the sites were used in the Regionalization of the Integrated Lake Watershed Acidification Study funded by the Electric Power Research Institute, and have ancillary information on atmospheric deposition, surficial geology, mineralogy, vegetation, hydrology, and fish populations.

KEY WORDS:

Medium:	Lakes
Chemicals:	Acid Neutralizing Capacity, Speciated Aluminum, Color, Conductivity, Dissolved Organic Carbon, Major Ions, pH
Approach:	Field Sampling, Laboratory, Single-Factor Analyses, Statistical Analyses, Trends Analyses
Processes:	Chronic Acidification, Episodic Acidification, Recovery

PPA: E-06 **EPA Code:** E-06.2C **NAPAP Code:** 6B-2 03C

Element: Project

Contributing to: E-05, E-08, E-09

Cross Reference: Program: Long-Term Monitoring (E-06)
Program Element: Site-Specific Long-Term Monitoring (E-06.2)

Status: Ongoing **Period of Performance:** 1988 to 1990+

Contact: Jesse Ford

TITLE: Site-Specific Long-Term Monitoring in Maine

SHORT TITLE: Site-Specific Monitoring in Maine

REGION(S)/STATE(S): Northeast (ME)

GOAL(S)/OBJECTIVE(S): To continue data collection and analysis for low acid neutralizing capacity lakes with six years of monitoring data.

RATIONALE: The continuation of these sites means that 5-9 years of seasonal or monthly data will be available for over 80 low acid neutralizing capacity systems distributed throughout many of the regions of concern with respect to acidic precipitation. This will provide information on natural variability of these systems over a range of annual hydrologic cycles, as well as preliminary insights into whether and where trends in acidification or recovery are occurring.

APPROACH: Spring, summer, and fall water samples and field measurements are being taken from five lakes clustered in an area receiving deposition that is intermediate relative to that received by the Adirondacks and the Upper Midwest. Ancillary information is also available on fish species composition.

KEY WORDS:

Medium:	Lakes
Chemicals:	Acid Neutralizing Capacity, Color, Conductivity, Major Ions, pH, Total Aluminum
Approach:	Field Sampling, Laboratory, Single-Factor Analyses, Statistical Analyses, Trends Analyses
Processes:	Chronic Acidification, Episodic Acidification, Recovery

PPA: E-06 **EPA Code:** E-06.2D **NAPAP Code:** 6B-2.03D

Element: Project

Contributing to: E-05, E-08, E-09

Cross Reference: Program: Long-Term Monitoring (E-06)
Program Element: Site-Specific Long-Term Monitoring (E-06.2)

Status: Ongoing **Period of Performance:** 1988 to 1990+

Contact: Jesse Ford

TITLE: Site-Specific Long-Term Monitoring in the Catskill Mountains, NY

SHORT TITLE: Site-Specific Monitoring in the Catskill Mountains, NY

REGION(S)/STATE(S): Northeast (NY)

GOAL(S)/OBJECTIVE(S): To continue data collection and analysis in low acid neutralizing capacity, headwater streams with five years of monitoring data in an area of significant sulfate loadings.

RATIONALE: The continuation of these sites means that 5-9 years of seasonal or monthly data will be available for over 80 low acid neutralizing capacity systems distributed throughout many of the regions of concern with respect to acidic precipitation This will provide information on natural variability of these systems over a range of annual hydrologic cycles, as well as preliminary insights into whether and where trends in acidification or recovery are occurring.

APPROACH: Nine to twelve samples per year will be taken from four streams in a region of the state receiving sulfate deposition

KEY WORDS:

Medium:	Streams
Chemicals:	Acid Neutralizing Capacity, Conductivity, Discharge, Dissolved Organic Carbon, Major Ions, Total Aluminum
Approach:	Field Sampling, Laboratory, Single-Factor Analyses, Statistical Analyses, Trends Analyses
Processes:	Chronic Acidification, Episodic Acidification, Recovery

PPA: E-06 **EPA Code:** E-06.2E **NAPAP Code:** 6B-2.03E

Element: Project

Contributing to: E-05, E-08, E-09

Cross Reference: Program: Long-Term Monitoring (E-06)
Program Element: Site-Specific Long-Term Monitoring (E-06.2)

Status: Ongoing **Period of Performance:** 1988 to 1990+

Contact: Jesse Ford

TITLE: Site-Specific Long-Term Monitoring in the Southern Rocky Mountains

SHORT TITLE: Site-Specific Monitoring in the Southern Rocky Mountains

REGION(S)/STATE(S): West (CO)

GOAL(S)/OBJECTIVE(S): To continue data collection and analysis for low acid neutralizing capacity lakes in the Mt. Zirkel and Weminuche Wilderness Areas.

RATIONALE: The continuation of these sites means that 5-9 years of seasonal or monthly data will be available for over 80 low acid neutralizing capacity systems distributed throughout many of the regions of concern with respect to acidic precipitation. This will provide information on natural variability of these systems over a range of annual hydrologic cycles, as well as preliminary insights into whether and where trends in acidification or recovery are occurring

APPROACH: Three water samples will be collected during the ice-free season from 10 low acid neutralizing capacity lakes in a poorly characterized area that may be highly vulnerable should deposition increase.

KEY WORDS:

Medium:	Lakes
Chemicals:	Acid Neutralizing Capacity, Color, Conductivity, Major Ions, pH, Total Aluminum
Approach:	Field Sampling, Laboratory, Single-Factor Analyses, Statistical Analyses, Trends Analyses
Processes:	Chronic Acidification

PPA: E-06 **EPA Code:** E-06 2F **NAPAP Code:** 6B-2.03F

Element: Project

Contributing to: E-05, E-08, E-09

Cross Reference: Program: Long-Term Monitoring (E-06)
Program Element: Site-Specific Monitoring in the West (E-06.2)

Status: Ongoing **Period of Performance:** 1988 to 1990+

Contact: Jesse Ford

TITLE: Lake Acidification in the Front Range of Colorado

SHORT TITLE: Front Range Lake Acidification

REGION(S)/STATE(S): West (CO)

GOAL(S)/OBJECTIVE(S): To determine if literature references to lake acidification in the Front Range of Colorado are consistent with results from analyses of complete chemical data.

RATIONALE: Of the regions in the West receiving acidic deposition, the Front Range of Colorado is an area of concern because it is close to the Denver metropolitan area and because previous studies conducted in this area have concluded that lake acidification has occurred.

APPROACH: Approximately 43 lakes will be sampled annually, as per a previous study (1979), and 5-10 lakes will be sampled biweekly to determine if lake sulfate concentrations reflect acidification by acidic deposition. Complete chemical characterization will be performed. Maximum acidification will be estimated using a new method that differentiates estimated normal regional atmospheric deposition of sulfate from weathering of sulfur minerals in watersheds. The activities for this project with regard to the National Surface Water Survey have been completed under PPA E-01; some of these activities will now be conducted as part of the Long-Term Monitoring Program (E-06).

KEY WORDS:
Medium: Chemistry, Deposition, Lakes
Chemicals: Acid Neutralizing Capacity, Base Cations, Nitrate, pH, Sulfate
Approach: Field Sampling, Literature
Processes: Chronic Acidification, Mineral Weathering

PPA: E-06 **EPA Code:** E-06.2G **NAPAP Code:** 6B-2.03G

Element: Project

Contributing to: E-01, E-03, E-05, E-08, E-09

Cross Reference: Program: Long-Term Monitoring (E-06)
Program Element: Temporally Integrated Monitoring of Ecosystems (E-06.1)

Status: Ongoing **Period of Performance:** 1988 to 1990 +

Contact: Dixon Landers

TITLE: Chemistry of Lakes in High Elevation, Western Wilderness Areas

SHORT TITLE: Mt. Zirkel Lake Study

REGION(S)/STATE(S): West (CO)

GOAL(S)/OBJECTIVE(S): To characterize the chemistry of 10 high-elevation lakes in the Mount Zirkel and Weminuche Wilderness Areas during a summer index period; to determine temporal variability of key chemical parameters in four of the lakes; and to examine the relationship between major ions in precipitation and lake water.

RATIONALE: Concern about acidic deposition is growing in the western United States. Development of energy and metal resources is expected to increase atmospheric emissions of acid precursors and trace metals. Of particular note are developments near wilderness areas or national parks. Because federal permits are required for these areas, air quality is protected from degradation. This project will evaluate the present water quality of lakes in these areas to help develop emissions permits and control strategies, to establish a data base for monitoring long-term effects, and to evaluate selected monitoring methods.

APPROACH: Ten lakes (four in Mt. Zirkel Wilderness Area and six in Weminuche Wilderness Area) were selected for study because of their low alkalinity and sulfate concentrations. These lakes likely would exhibit strong trends in response to acidic inputs if sulfate deposition is the major source of acidity. Sampling is conducted in the summer at two depths for the Mt. Zirkel lakes and at the outflow for the Weminuche lakes. Samples from the Mt. Zirkel lakes are preserved and analyzed for a number of chemical properties, while samples from the Weminuche lakes are analyzed for major ions only. Yearly sampling will show long-term trends, if any occur. The activities for this project with regard to the National Surface Water Survey have been completed under PPA E-01; a portion of these activities will now be addressed as part of the Long-Term Monitoring Program (E-06).

KEY WORDS:
Medium: Chemistry, Deposition, Lakes
Chemicals: Conductance, Major Ions, pH, Sulfate
Approach: Field Sampling
Processes: Chronic Acidification

PPA: E-06 **EPA Code:** E-06.2H **NAPAP Code:** 6B-2.03H

Element: Project

Contributing to: E-01, E-03, E-05, E-08, E-09

Cross Reference: Program: Long-Term Monitoring (E-06)
Program Element: Temporally Integrated Monitoring of Ecosystems (E-06.1)

Status: Ongoing **Period of Performance:** 1988 to 1990+

Contact: Dixon Landers

TITLE: Seasonal and Episodic Water Quality Changes in Precipitation and Lake Water in Northern New Mexico

SHORT TITLE: New Mexico Lake Study

REGION(S)/STATE(S): West (NM)

GOAL(S)/OBJECTIVE(S): To monitor atmospheric deposition at a high altitude site characteristic of northern New Mexico. To determine the frequency, duration, and magnitude of acidic episodes in precipitation, snowmelt, and adjacent lakes.

RATIONALE: The Western Lake Survey provided only fall data for lakes in high mountainous regions. Very little is known of the possible effects of spring snowmelt or precipitation events on these dilute systems. Further, there are very few high altitude sites at which deposition chemistry is measured. The New Mexico Lake Study will provide needed information in both of these areas.

APPROACH: Precipitation chemistry will be monitored by an NADP-type deposition sampling station at the 3,110-foot level in the Sangre de Cristo Mountains in northern New Mexico. Snowpack chemistry at that location will be determined monthly during the winter, and snowmelt will be sampled using a 1.5-m diameter fiberglass snowmelt collector. The nine adjacent Latir lakes will be monitored for changes in water chemistry associated with snowmelt and precipitation. The activities for this project, with regard to the National Surface Water Survey, have been completed under PPA E-01; if these activities continue, depending on the results of the first year of study, they will be addressed as part of the Long-Term Monitoring Program (E-06).

KEY WORDS:

Medium:	Chemistry, Deposition, Lakes, Snowpack
Chemicals:	Acid Neutralizing Capacity, Aluminum, Ammonium, Major Ions, Organics, pH
Approach:	Field Sampling
Processes:	Episodic Acidification

PPA: E-06 **EPA Code:** E-06.2I **NAPAP Code:** 6B-2.03I

Element: Project

Contributing to: E-01, E-03, E-05, E-08, E-09

Cross Reference: Program: Long-Term Monitoring (E-06)
Program Element: Temporally Integrated Monitoring of Ecosystems (E-06.1)

Status: Ongoing **Period of Performance:** 1988 to 1990+

Contact: Dixon Landers

2.9 INDIRECT HUMAN HEALTH EFFECTS – PROGRAM E-04

[Program/Program Element/Project]

TITLE: Indirect Human Health Effects due to Acidic Deposition

SHORT TITLE: Indirect Human Health Effects

REGION(S)/STATE(S): Canada, Middle Atlantic, Netherlands Antilles (St. Maarten), Northeast (CT, MA, ME, NH, NJ, NY, PA, RI, VT), Scandinavia, Southeast (FL, GA, KY, NC, SC, TN, VA), United States, Upper Midwest (MI, MN, WI), West (CA, CO, ID, MT, NM, NV, OR, UT, WA, WY)

GOAL(S)/OBJECTIVE(S): Research on post-depositional health effects due to acidic deposition has two main areas of focus. One is the alteration of drinking water supplies in response to acidic inputs. The second is the accumulation of mercury and other potentially toxic metals in the muscle tissue of edible fish. The program objective is to determine the risk to human health due to acidic deposition through these two routes of exposure.

RATIONALE: Acidic water is known to mobilize certain metals that have been demonstrated to be toxic to humans. Because of its broad geographic scope, acidic deposition has the potential to adversely affect a significant proportion of the population through water-mediated effects.

APPROACH: The approach to assess the extent of acidic deposition effects on precipitation-dominated, noncommunity drinking water supplies (which are not federally regulated) and food sources (e.g., metals bioaccumulation in edible fish) included analyzing existing survey data, sampling in areas of high and low deposition, and quantifying the potentially exposed population.

KEY WORDS:
Medium: Biology, Chemistry, Cisterns, Groundwater, Lakes, Sediments, Watersheds
Chemicals: Acid Neutralizing Capacity, Conductance, Mercury, Metals, Nitrate, Organics, pH, Sulfate
Approach: Existing Data Analyses, Field Sampling, Literature
Processes: Aluminum Mobilization, Mercury Bioaccumulation, Mercury Cycling, Mercury Mobilization, Metals Bioaccumulation, Metals Mobilization, Organic Chelation

PPA: E-04 EPA Code: E-04 NAPAP Code: 6E

Element: Program

Contributing to: E-01, E-03, E-05, E-09

Cross Reference: None

Status: Completed Period of Performance: 1984 to 1988

Contact: Daniel McKenzie

TITLE: Effects of Acidic Deposition on Noncommunity Drinking Water Supplies

SHORT TITLE: Effects of Acidic Deposition on Drinking Water

REGION(S)/STATE(S): Middle Atlantic, Netherlands Antilles (St. Maarten), Northeast (CT, MA, ME, NH, NY, PA, RI, VT), Southeast (GA, KY, NC, TN), Upper Midwest, West

GOAL(S)/OBJECTIVE(S): To determine the extent of effects of acidic deposition on drinking water supplies, including cisterns, groundwater, and surface water. To determine the magnitude of the risk to human health.

[NOTE: All 1990 Assessment activities pertaining to this area will be discussed under the Human Health component of the Assessment. For more information, contact Ruth Allen at EPA, 401 M St. Washington, DC 20460]

RATIONALE: Acidic water is known to mobilize certain metals that have a demonstrated human toxicity. Federal regulations do not apply to noncommunity systems, many of which are precipitation-dominated drinking water supplies (cisterns, springs, shallow aquifers, surface waters).

APPROACH: Analyses of existing survey data and sampling of water supplies in areas receiving high acidic deposition were used to determine the extent of effects. The population potentially affected was also determined through survey data and additional surveys as needed.

KEY WORDS:

Medium:	Chemistry, Cisterns, Groundwater, Lakes
Chemicals:	Acid Neutralizing Capacity, Conductance, Metals, pH
Approach:	Existing Data Analyses, Field Sampling, Literature
Processes:	Metals Mobilization

PPA: E-04 **EPA Code:** E-04.1 **NAPAP Code:** 6E-1

Element: Program Element

Contributing to: E-01, E-09

Cross Reference: Program: Indirect Human Health Effects (E-04)

Status: Completed **Period of Performance:** 1984 to 1988

Contact: Daniel McKenzie

TITLE: Effects of Acidic Deposition on Chemistry of Cisterns and Groundwaters used for Drinking Water

SHORT TITLE: Cistern and Groundwater Drinking Supplies

REGION(S)/STATE(S): Netherlands Antilles (St. Maarten), Southeast (GA, KY, NC, TN)

GOAL(S)/OBJECTIVE(S): To determine the role of acidic deposition in modifying the quality of drinking water supplied by cisterns and groundwaters. The objectives of the cistern study were (1) to compare the water quality characteristics of cisterns in an area receiving acidic deposition to those in an area not receiving acidic deposition, and (2) to determine changes in water quality as the water passes from the collection device to the storage tank, through the plumbing system, to the tap. The objectives of the groundwater, or shallow aquifer study, was to investigate different well and spring designs and varying geology and to examine the relationship of these factors to trace contaminants in the shallow aquifer itself and in the home plumbing system.

[NOTE: All 1990 Assessment activities pertaining to this area will be discussed under the Human Health component of the Assessment. For more information, contact Ruth Allen at EPA, 401 M St. Washington, DC 20460]

RATIONALE: Acidic water is known to mobilize certain metals and trace substances that have been demonstrated as toxic to humans. Federal standards for these substances do not extend to noncommunity drinking water systems, including cisterns, springs, and shallow aquifers. Examining water quality of noncommunity drinking water supplies in areas receiving acidic deposition will help to evaluate the potential, indirect human health risk posed by anthropogenically induced acidification.

APPROACH: The cistern study involved deposition monitoring and cistern sampling for 19 water quality parameters at four points in each system. Sampling was conducted throughout the year in one area that receives acidic deposition and one that does not. The groundwater study used data from the Eastern Lake Survey and other sources to identify areas where the geology might indicate the presence of potentially sensitive water supplies. Within these areas, the presence of shallow wells and springs was identified, and the geologic characteristics of these sites was determined. Samples from home taps were collected and analyzed for various chemical constituents.

KEY WORDS:
Medium: Chemistry, Cisterns, Groundwater
Chemicals: Conductance, Metals, pH
Approach: Existing Data Analyses, Field Sampling, Literature
Processes: Metals Mobilization

PPA: E-04 EPA Code: E-04.1A NAPAP Code: 6E-1.01

Element: Project

Contributing to: E-01, E-09

Cross Reference: Program: Indirect Human Health Effects (E-04)
Program Element: Effects of Acidic Deposition on Drinking Water (E-04.1)

Status: Completed Period of Performance: 1984 to 1988

Contact: Daniel McKenzie

TITLE: Investigating Potential Indirect Human Health Effects in Surface Waters Used as Drinking Water Supplies

SHORT TITLE: Surface Water Drinking Supplies

REGION(S)/STATE(S): Middle Atlantic, Northeast (CT, MA, ME, NH, NY, PA, RI, VT), Southeast, Upper Midwest, West

GOAL(S)/OBJECTIVE(S): The goals of this project were to evaluate the potential effects of acidic deposition in modifying the chemistry of surface waters used as drinking water supplies and the potential risk that such changes might pose to the population relying on these sources of drinking water. One objective was to determine whether the water quality of noncommunity systems used for drinking water is related to patterns of acidic deposition. A second was to determine if metals concentrations in lakes in the National Lake Survey (E-01.1) exceed federally established standards, and if so, whether these lakes are used as drinking water supplies.

[NOTE: All 1990 Assessment activities pertaining to this area will be discussed under the Human Health component of the Assessment. For more information, contact Ruth Allen at EPA, 401 M St. Washington, DC 20460]

RATIONALE: Acidic water is known to mobilize certain metals that have been demonstrated to be toxic to humans. Federal standards for the metals do not extend to noncommunity drinking water systems, including lakes used as water supplies. Examining water quality in lakes located in areas that receive, and are potentially sensitive to, acidic deposition may allow the extent to which acidic deposition potentially threatens human health to be evaluated.

APPROACH: The National Statistical Assessment of Rural Drinking Water was conducted previously for the Office of Drinking Water. This data base was used to examine noncommunity, precipitation-dominated water supplies to determine if they have generally lower water quality than federally regulated systems, and to determine if the water quality of these systems is related to patterns of acidic deposition. If a relationship was apparent, further analyses, e.g., examining water quality with respect to geological patterns, were conducted. A second approach was to calculate regional estimates of the lakes in the National Lake Survey regions that have metals concentrations exceeding federal standards, and to identify their locations. Information on whether the lakes are used as drinking water supplies, the type of system construction, etc., was collected from state contacts.

KEY WORDS:
Medium: Chemistry, Lakes
Chemicals: Acid Neutralizing Capacity, Metals, pH
Approach: Existing Data Analyses, Literature
Processes: Metals Mobilization

PPA: E-04 **EPA Code:** E-04.1B **NAPAP Code:** 6E-1.02

Element: Project

Contributing to: E-01, E-09

Cross Reference: Program: Indirect Human Health Effects (E-04)
Program Element: Effects of Acidic Deposition on Drinking Water (E-04.1)

Status: Completed **Period of Performance:** 1987 to 1988

Contact: Daniel McKenzie

TITLE: Effects of Acidification on Metals Bioavailability and Bioaccumulation

SHORT TITLE: Bioaccumulation of Metals

REGION(S)/STATE(S): Canada, Northeast (CT, MA, ME, NH, NJ, NY, PA, RI, VT), Scandinavia, Southeast (FL, GA, NC, SC, TN, VA), United States, Upper Midwest (MI, MN, WI), West (CA, CO, ID, MT, NM, NV, OR, UT, WA, WY)

GOAL(S)/OBJECTIVE(S): To determine the extent of effects of acidic deposition on bioaccumulation of toxic metals by biota used as food sources by humans.

RATIONALE: Acidic water is known to mobilize certain metals that have a demonstrated human toxicity. These may be accumulated in the tissues of fish and other biota used as sources of food.

APPROACH: Existing survey data and sampling of biota in areas receiving high acidic deposition is used to determine the extent of effects. The population potentially affected may also be determined through existing survey data of consumption habits and additional surveys as needed. Models may be developed to help identify potentially affected resources and/or species.

KEY WORDS:

Medium:	Biology, Chemistry, Lakes, Sediments, Watersheds
Chemicals:	Mercury, Metals, Nitrate, Organics, pH, Sulfate
Approach:	Existing Data Analyses, Field Sampling, Laboratory, Literature
Processes:	Aluminum Mobilization, Mercury Bioaccumulation, Mercury Cycling, Mercury Mobilization, Metals Bioaccumulation, Metals Mobilization, Organic Chelation

PPA: E-04 **EPA Code:** E-04.2 **NAPAP Code:** 6E-2

Element: Program Element

Contributing to: E-01, E-03, E-05, E-09

Cross Reference: Program: Indirect Human Health Effects (E-04)

Status: Ongoing **Period of Performance:** 1986 to 1991

Contact: Dixon Landers

TITLE: Effects of Acidic Conditions on Bioaccumulation of Toxic Metals in Aquatic Organisms

SHORT TITLE: Metals in Biota

REGION(S)/STATE(S): Canada, Scandinavia, United States, Upper Midwest (MI, WI)

GOAL(S)/OBJECTIVE(S): To determine the extent of effects of acidic deposition on bioaccumulation of toxic metals by biota used as food sources by humans.

RATIONALE: Acidic water is known to mobilize certain metals that have a demonstrated human toxicity. These may be accumulated in the tissues of fish and other biota used as sources of food. Bioaccumulation of metals, especially mercury, by sport fish has been documented in areas of the United States and Canada receiving acidic deposition.

APPROACH: Existing survey data and sampling of biota in areas receiving high acidic deposition is used to determine the extent of effects. The population potentially affected may also be determined through existing survey data of consumption habits and additional surveys as needed. Models may be developed to help identify potentially affected resources and/or species.

KEY WORDS:
Medium: Biology, Chemistry, Lakes, Sediments, Watersheds
Chemicals: Mercury, Metals, Nitrate, Sulfate
Approach: Existing Data Analyses, Field Sampling, Literature
Processes: Mercury Bioaccumulation, Mercury Cycling, Mercury Mobilization, Metals Bioaccumulation, Metals Mobilization

PPA: E-04 **EPA Code:** E-04.2A **NAPAP Code:** 6E-2.01

Element: Project

Contributing to: E-01, E-03, E-05, E-09

Cross Reference: Program: Indirect Human Health Effects (E-04)
Program Element: Bioaccumulation of Metals (E-04.2)

Status: Ongoing **Period of Performance:** 1986 to 1990

Contact: Dixon Landers

TITLE: Accumulation of Toxic Metals in Surface Waters and Sediments

SHORT TITLE: Metals in Surface Water/Sediments

REGION(S)/STATE(S): Northeast (CT, MA, ME, NH, NJ, NY, PA, RI, VT), Southeast (FL, GA, NC, SC, TN, VA), Upper Midwest (MI, MN, WI), West (CA, CO, ID, MT, NM, NV, OR, UT, WA, WY)

GOAL(S)/OBJECTIVE(S): To collect and compare dissolved mercury data for lakes in the Upper Midwest, examine which mercury pool best explains variance in fish tissue mercury content, develop sediment-water mercury distribution coefficients, and develop a model to forecast dissolved mercury concentrations based on suspended/surficial bed sediment content, pH, and dissolved organic carbon. To determine the regional distribution and the relationships to other water quality parameters for trace metals in lakes that are potentially sensitive to acidic deposition. To identify an element or group of elements to be used as an index to lake acid status.

RATIONALE: Acidic deposition potentially may affect metals mobility in lakes through direct metals loading to surface waters or watersheds, accelerating release rates from watersheds or sediments, or altering aqueous speciation of metals into biologically available forms. Two metals that are particularly important with respect to biota are aluminum and mercury, both of which can be affected by changes in acidic status. Other metals have also been documented to be toxic either to humans or to aquatic biota. Little is known, however, about the distributions of these metals on a regional basis, or the degree to which increases in their concentrations or changes in their aqueous forms present a risk to human health.

APPROACH: Sediment and water samples will be collected from a subset of lakes in the Upper Midwest that is part of the National Lake Survey (E-01.1) regional frame. Samples will be analyzed for mercury content and a variety of other chemical parameters. The data will be used to examine regional patterns of mercury in lakes located in the Upper Peninsula of Michigan. Metals data collected in the Eastern Lake Survey-Phase I, the Northeastern Seasonal Variability Study (E-01.1B), and the Upper Midwestern Fish Survey (E-03.1B), are being or will be used to estimate their regional distribution. Regional estimates with known confidence bounds can be made, because the sampled lakes were selected from the National Lake Survey statistical frame.

KEY WORDS:
Medium: Chemistry, Lakes, Sediments
Chemicals: Mercury, Metals, Organics, pH
Approach: Existing Data Analyses, Field Sampling, Laboratory
Processes: Aluminum Mobilization, Mercury Bioaccumulation, Mercury Cycling, Mercury Mobilization, Metals Mobilization, Organic Chelation

PPA: E-04 **EPA Code:** E-04.2B **NAPAP Code:** 6E-2.02

Element: Project

Contributing to: E-01, E-03, E-09

Cross Reference: Program: Indirect Human Health Effects (E-04)
Program Element: Bioaccumulation in Metals (E.04.2)

Status: Ongoing **Period of Performance:** 1987 to 1991

Contact: Dixon Landers

SECTION 3

INDICES

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