Annual Report

on the

EPA Program for Long-Term Monitoring of

Surface Waters in the United States

NAPAP Project No. E1-15

by

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Overview and Objectives

An EPA program for long-term monitoring of lakes and streams was initiated in 1982 within the NAPAP organizational framework. The Aquatic Effects Task Group (Task Group E) recognized that a national monitoring program would involve all the agencies comprising the Task Group. An *ad hoc* committee was organized in July 1982 to develop a national program and a standardized sampling/analysis protocol for chemical monitoring. The committee, with representation from EPA, USGS, TVA, USDA-FS, USFWS, USNPS, and Brookhaven National Laboratory, produced a draft protocol in January 1983 as the basis for a national surface water chemistry monitoring effort. This document received extensive peer review. The revised draft is included as Appendix I. At present EPA supports lake or stream monitoring at 126 sites comprising eleven sets of lakes or streams in twelve states. These are summarized in Table 1.

The existing long-term monitoring studies are expected to be subsumed by Phase III of the NSWS, in which geographically representative lakes will be selected for long-term study. Those lakes will be chosen on the basis of data acquired during Phase I (survey) and Phase II (chemical and biological variability) and will be representative of the various geographical regions defined in Phase I. The transition to Phase II will probably begin in FY86 after results of Phase I are available. Most of the existing monitoring sites are probably compatible with Phase III owing to their location in low alkalinity regions and their positioning with respect to minimization of extraneous effects which could compromise interpretations of observed changes or trends. Such effects include land use and recent land-use changes (timber harvest, agriculture, residential, or recreational development, road building, mining), local atmospheric or water pollution sources, and forest fires.

The objectives of the EPA long-term monitoring program are to:

Table 1
FY84 EPA-Funded Long-Term Surface Water Monitoring Projects

Location	Principal Investigator	Agency	Sites	Type	Start	$(K)
Montana-Wyoming	Gordon Pagenkopf	Montana State U.	11	lakes	Fall 1983	20
Upper Great Lakes Region(MN, WI, MI)	Patrick Brezonik	U. of Minnesota	38	lakes	Fall 1982	56
Maine	Terry Haines	USFWS, U. of ME	6	lakes	Fall 1982	25*
Vermont	Wallace McLean	State of Vermont	36	lakes	Winter 1981	15**
New York	Peter Murdoch	USGS, Albany, NY	7	streams	Summer 1983	25
Pennsylvania	James Barker	USGS, Harrisburg, PA	6	streams	Summer 1983	25
North Carolina	Kent Crawford	USGS, Raleigh, NC	5	streams	Summer 1983	25
Southern Blue Ridge Province (NC, TN, GA)	Harvey Olem	TVA, Chatanooga, TN	5 12	streams reservoirs	Fall 1983 Fall 1982	100*** 20
Totals: 11 (3 in Upper Great Lakes, 2 in Southern Blue Ridge)			127 sites		FY84 Funding	$211K

* Includes work on development of methodology for monitoring fish populations.

** Partial support for FY83 and FY84. Additional support being requested for FY85.

*** Combined research/monitoring project; FY83 funding.

(1) detect and measure long-term trends in the chemistry of low-alkalinity surface waters that are related to atmospheric deposition; and

(2) compare the response of low alkalinity waters (a) over a geographic gradient of H^+ and sulfate deposition (b) in different major sensitive geographic areas that receive comparable deposition.

Sites would be in locations where annual sulfate deposition averaged 0-10, 10-20, 20-30, and 30-40 kg/ha, with average volume-weighted precipitation pH ranging from about 5.3 to 4.2. Sites would at the same time be chosen to provide observations in geographically separate regions (e.g., New England and the southern Appalachians) receiving comparable sulfate and hydrogen ion deposition. Questions to be answered relative to Objective 2 are:

(1) At what level(s) of sulfate and hydrogen-ion deposition do measurable changes in lake or stream chemistry occur?

(2) Do lakes or streams of comparable alkalinity located in different geographical regions respond the same to similar levels of sulfate and hydrogen ion deposition?

In planning a program with these objectives, it was necessary to take into consideration the distribution and regionality of acidic deposition, which occurs in all states east of the Mississippi River and to some degree in certain areas of the West. Some areas receiving acidic deposition contain lakes and/or streams of low alkalinity (hence, presumably sensitive to acidification); in others, surface water alkalinities are uniformly high, and acidification from atmospheric deposition is not expected. Sensitive waters also occur in areas where deposition is not now acidic, or where acidic deposition is minimal. However, it cannot be assumed that such precipitation chemistries will remain unchanged in the future.

Although precipitation chemistry may be essentially uniform within a given geographical area, not all lakes or streams can be expected to respond identically. There are probably even greater uncertainties with respect to comparability of response of surface waters between geographical areas. For example, although average precipitation acidity and sulfate deposition in the southern Appalachians and in New England fall within the same range, significant differences exist between those regions. New England was glaciated, but the southern Appalachians were not; New England contains many hundreds of small natural lakes, but southern Appalachian surface waters are characterized by streams and artificial reservoirs; soils in New England are quite young, while those in the South are much older. Low alkalinity waters occur in both regions, but there is evidence that the rate of response to acidifying forces may not be the same. Present indications are that results regarding the influence of acid deposition on low alkalinity waters cannot be extrapolated from one such region to another.

Monitoring sites were selected so as to best satisfy the objectives of the program, that is, to detect trends relatable to effects of deposition, and to compare responses of surface waters over deposition chemistry gradients and between sensitive areas receiving comparable deposition. The first of these two objectives requires sites in sensitive areas receiving acidic deposition, as removed from disruptive anthropogenic influences (land use, local pollution, fire) as possible. The second objective requires, in addition, the selection of sites from a variety of locations exposed to various degrees of precipitation acidity. Accordingly, monitoring sites are situated where surface waters are commonly less than 200 μeq/l total alkalinity (ANC). The national and regional alkalinity maps generated by EPA have assisted in the identification of these locations. Areas selected for monitoring to date include the Northern Rocky Mountains; the Upper Midwest lake district (Minnesota, Wisconsin,

Michigan); Maine; Vermont; the Catskill Mountains in southeastern New York; the Allegheny Mountains of southwestern Pennsylvania; the southern Appalachians (Southern Blue Ridge Province of North Carolina, Tennessee, and Georgia); and the Sandhills of south-central North Carolina (Figure 1). These locations not only provide a broad sampling of sensitive (low alkalinity) waters, but lie across a gradient of precipitation chemistry from essentially background chemical concentrations in the northern Rockies to the acidic precipitation of the East (see Table 2). Individual sites were selected to minimize disruptive effects of past or future land use, local atmospheric pollution, forest fires, logging, and fish management (see Appendix I). When possible, sites where concurrent research will provide related data are chosen, and sites with good historical data are preferred over those without, other factors being equal. Accessibility is also carefully considered.

The rationale for the selection of the particular monitoring sites presently comprising the program was as follows. First, it was evident from the geographic distribution of lakes, reservoirs, and streams in the United States that natural lakes are the dominant resource of concern in the northern tier of states (south to the limit of Pleistocene glaciation) and in the mountainous West, but are replaced by streams and reservoirs in the South. In comparing this distribution with known distributions of low alkalinity waters and deposition chemistry, it became further evident that monitoring sites should be identified in the mountainous West, the upper Great Lakes region, the Adirondacks, New England, and the Appalachians. Emphasis would be on lakes in all areas except the Appalachians where the focus would be on streams and reservoirs.

Proceeding on these premises, opportunities for initiation of monitoring were sought which (1) would provide lake, stream, or reservoir monitoring sites

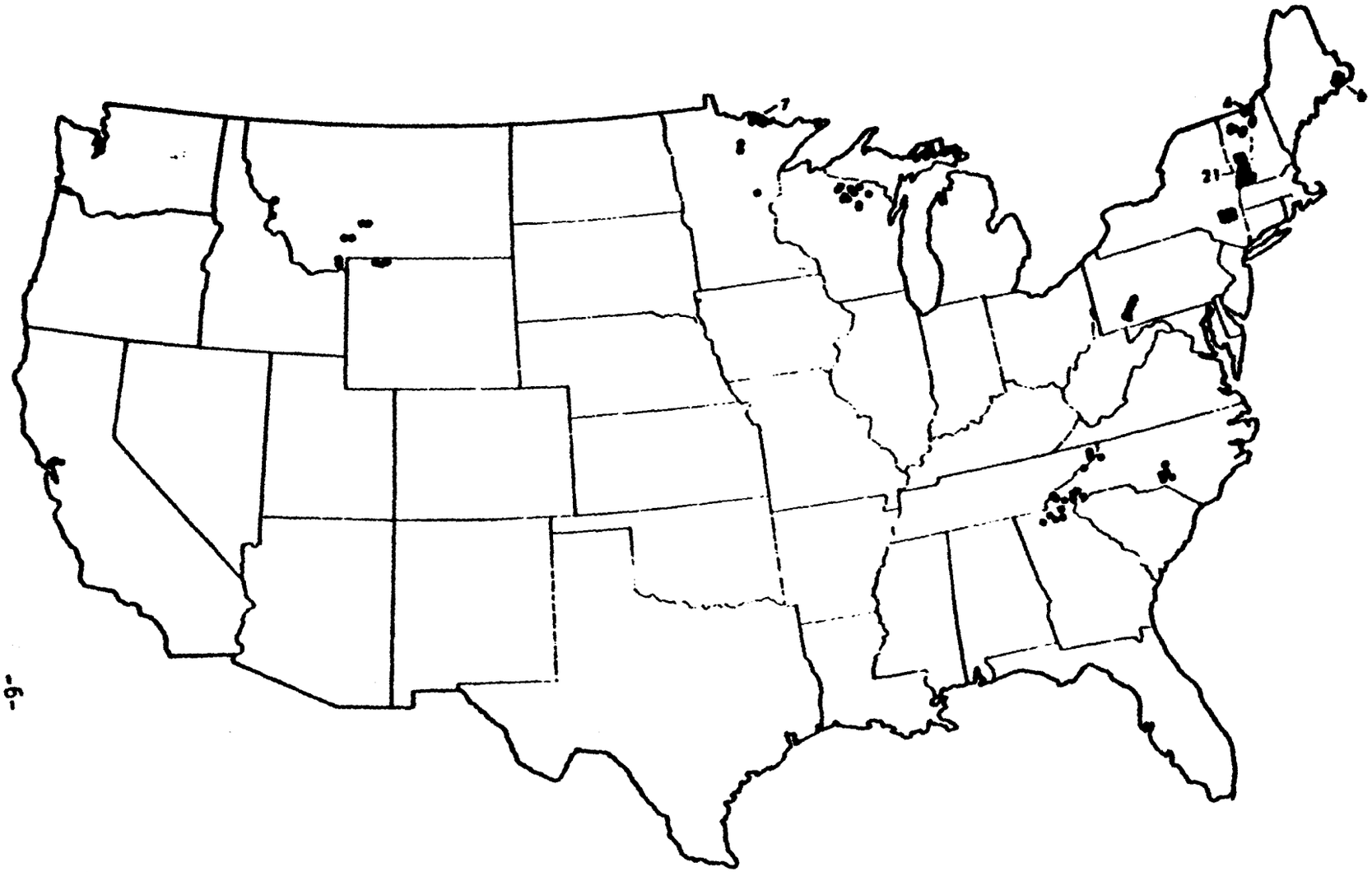

Figure 1. Locations of long-term lake and stream monitoring sites.

TABLE 2
MEAN 1982 PRECIPITATION PH AND SULFATE DEPOSITION MEASURED
NEAR THE LONG-TERM SURFACE WATER MONITORING SITES

Monitoring Project	Precipitation Site	Lat. °N	Long. °W	Precipitation Mon. Network	Vol.-Wt. pH	SO_4 dep., kg/ha
Northern Rocky Mts. (MT, WY)	Headwaters, ID	46°38'	115°49'	NADP	5.40	1.2
	Yellowstone Nat. Park, WY	44°55'	110"25'	NADP	5.22	3.5
Upper Midwest (MN, WI, MI)	Fernberg, MN	47°57'	91°29'	NADP	4.96	10.3
	Trout Lake, WI	46°03'	89°39'	NADP	4.68	19.4
	Spooner, WI	45°49'	91°52'	NADP	4.92	12.0
	Douglas Lake, MI	45°34'	86°41'	NADP	4.42	20.3
Maine	Acadia Park	44°22'	68°16'	NADP	4.46	25.0
Vermont	Bennington	42°52'	73°10'	NADP	4.36	20.1
	West Dover[1]			State of	4.36	--
	Concord[1]			Vermont	4.39	--
	Mt. Mansfield[1]			"	4.42	--
	Swanton[1]			"	4.52	--
Catskill Mts. (NY)[2]	Stillwell Lake	41°21'	74°02'	NADP	4.31	26.4
	Knobit	42°23'	73°30'	NADP	4.40	16.2
Laurel Ridge (PA)[3]	Parsons, WV	39°05'	79°40'	NADP	4.31	40.1
	Leading Ridge, PA	40°40'	77°56'	NADP	4.16	36.6
Southern Appalachians[4] (TN, GA, NC)	Elkmont, TN	35°40'	83°35'	NADP	4.66	21.7
	Walker Branch, TN	35°58'	84°17'	NADP	4.33	36.9
	Coweeta, NC	35°04'	83°26'	NADP	4.66	23.6
Sandhills (NC)[3]	Piedmont Station	35°42'	80°37	NADP	4.35	29.1
	Clinton Station	35°01'	78°17'	NADP	4.53	21.2

[1] Bulk event samples.
[2] Weekly and event sites also operated by project.
[3] Weekly site also operated by project.
[4] Four weekly sites also operated by project.

in locations corresponding to the criteria for geographical location, low alkalinity, and deposition chemistry and (2) were sites where ongoing work could be modified or adapted to EPA's monitoring needs (thereby precluding the necessity of "starting from scratch"). Refer to Table 1 for a summary of present monitoring projects.

In the Upper Great Lakes region, the EPA-Duluth laboratory, together with universities and state agencies, had begun a broad scale survey of lakes in 1978. Three subsets of these lakes plus six streams in upper Minnesota (in the vicinity of the Boundary Waters Canoe Area and Voyageurs National Park); northeast Wisconsin; and the eastern half of the Upper Peninsula of Michigan were chosen for monitoring, with the work to be carried out by the University of Minnesota-Duluth cooperatively with EPA-Duluth. Sampling for this program was conducted in the fall of 1982 and the spring and summer of 1983. Reorientation of the Duluth program necessitated continuation of work beyond the summer of 1983 by a new contractor. Monitoring of 38 lakes was assumed in fall 1983 by the University of Minnesota at Minneapolis, with contractual assistance from the Wisconsin Department of Natural Resources. The stream sites were eliminated. The list of lakes was further modified to eliminate some redundancy in lake characteristics, to reflect recent information on water quality changes in some Wisconsin lakes, to eliminate some insensitive lakes and lakes subject to watershed disturbance, and to provide a broader range of lake coverage in Minnesota.

In Maine, the U.S. Fish and Wildlife Service at the University of Maine had just recently completed an excellent survey of lakes of New England, and had undertaken fisheries-related research on effects of acidic deposition. It was logical to draw on their extensive expertise for the Northeast and to expand the existing program to include long-term montoring. Accordingly,

monitoring of six lakes in the Tunk Lakes area of southeast Maine was begun in fall 1982. Included in this project is exploratory work on non-destructive fish sampling as well as chemical monitoring.

The State of Vermont had initiated lake monitoring on twenty lakes in 1981. Coverage was later expanded to 36 lakes with 24 sampled in alternate years. EPA initiated partial funding of the Vermont effort in 1982.

The need for monitoring low alkalinity reservoirs in the Southeast had been established. The Tennessee Valley Authority (TVA) possessed a large body of chemical and other data on reservoirs of the region, and arrangements were made for a survey by TVA of 54 reservoirs selected on the basis of the existing data. Based on the results of that survey, 12 reservoirs were chosen for long-term monitoring.

In the West, ongoing or planned long-term studies by the U.S. National Park Service and the U.S. Geological Survey provided monitoring coverage in Sequoia National Park, California, and Rocky Mountain National Park, Colorado. Proposed studies by the Geological Survey in the northern Cascade Mountains in Washington have been delayed, but work has been initiated by the National Park Service in the Olympic Mountains in that state. The most obvious omission in the West appeared to be the northern Rocky Mountains, and a cooperative agreement was implemented with Montana State University for a survey and subsequent monitoring of lakes in southwest Montana and northwestern Wyoming near Yellowstone National Park. From results of the survey, eleven lakes were chosen for monitoring. These are all high-elevation, low-alkalinity lakes.

As stated in the Task Group E protocol (Appendix I), monitoring is more complex for streams than for lakes because of the influence of discharge coupled with season. Base flow tends to display uniform representative composition, but storm flow and snowmelt runoff may significantly alter stream

chemistry. Proper stream monitoring, therefore, requires continuous recording of flow and sampling over a complete range of discharge, including during and following storm events and snowmelt.

Obviously, the high frequency of sampling required for streams presents a serious budgetary problem in a monitoring program. A reasonable solution was achieved through a cooperative approach with the U.S. Geological Survey. The Survey had initiated or was planning watershed studies on a number of low alkalinity streams in the East. A single stream in each watershed was gauged and instrumented for automatic sampling during storm or snowmelt events. Wet-dry deposition sampling was carried out at each site. EPA arranged to provide additional funding at three sites (the Catskills of southeastern New York, the Alleghenies of southwestern Pennsylvania, and the Sandhills of North Carolina) for sampling five or six additional streams on an approximately monthly basis to provide more broadly based monitoring data. Event samples from the primary stream would provide indications of the effect of storms and snowmelt on stream chemistry, and monthly sampling would provide information on seasonal variation and long-term change.

Stream studies were also undertaken with TVA, in which five streams in the southern Appalachians have been instrumented for automatic storm event sampling. The project is funded jointly by Task Group E Objectives E-01 and E-02. Weather-related delays in this project have precluded its inclusion in this report.

In practically all cases, lakes or streams are clustered to facilitate sampling and to minimize within-cluster variations in climate and deposition patterns.

Each group of monitored lakes or streams must be sufficiently represented by deposition chemistry monitoring sites to permit characterization of chemical

loading. In most cases, one or more NADP sites are located in the monitoring area (Table 2). An initial exception was the eastern end of the Upper Peninsula of Michigan, where the nearest deposition site was at Douglas Lake, about 65 km south and across Lake Michigan. EPA has now established an NADP site in Chippewa County at Raco to provide representative deposition data for monitored lakes in that region.

Sampling and analytical methodology have generally followed Task Group protocols. Methodology is summarized, by project, in Table 3. Methodologies were not always identical, and such cases are specifically noted. The use of Technicon automated procedures for anions by the University of Minnesota and the State of Vermont, and the Eriochrome-cyanine reduction procedure for aluminum by Montana State University, are the most notable departures.

The authors thank Dan Michaels of Radian Corporation for his thoughtful review of this report and his many helpful suggestions.

Quality Assurance

As used here, "quality assurance" (QA) refers to the total program for assuring sample integrity and the reliability and utility of the data collected during the long-term monitoring project (NAPAP Task E1-15), including "quality control" (QC); i.e., the control of collection, handling, storage, and analyses of samples and data processing and storage.

The basic quality control document for the monitoring program has been the Task Group E sampling and analysis protocol (Appendix I). That document describes field sampling procedures and recommended analytical methodology, but in a more general fashion than does the National Surface Water Survey protocol. Each cooperator was required to submit a quality assurance plan in accordance with EPA requirements. Further, site visits to evaluate and audit procedures

TABLE 3. METHODS OF ANALYSIS

Cooperator	Parameter*				
	Color	ANC	Ca, Mg, Na, K	SO_4, Cl, NO_3	Al
Maine (FWS)	apparent, Pt-Co standards	Gran titration	atomic absorption (AA)	ion chromatography (IC)	0.45 μ filtration, atomic absorption (AA)
Minnesota (U.)	true, centrifuge; Pt-Co standards	Gran	AA	autoanalyzer (A)**	0.1 μ filter, AA
Montana (St.U.)	true, centrifuge; Pt-Co standards	Gran	AA	IC	0.45 μ filter, spectrophotometer (Eriochrome-cyanine R)
TVA	true, centrifuge; Pt-Co standards	Gran	AA	IC	0.45 μ filter, atomic emission
USGS	none	Gran	AA	IC	0.1 μ filter, AA (chelation-extraction)
Vermont (State)	true, 0.45 μ filter; Pt-Co standards	Gran	AA	A**	0.45 μ filter, AA

* Specific conductivity and pH are determined electrometrically by all cooperators.

** SO_4-methylthymol blue; Cl-ferricyanide; NO_3-cadmium reduction (Minnesota cross-checked with ion chromatography).

were made to the three USGS projects and the TVA project in 1984. Visits to the remaining projects are planned for 1985. Further visits will be made on an "as needed" basis.

QA has proven to be more of a problem during this first full year of multi-agency sampling than any other aspect of the long-term monitoring program. This can be attributed in part to communication with one cooperator (Montana State University) and in larger part to a lack of flexibility in one cooperating agency's QA reporting procedures (USGS-New York, North Carolina, and Pennsylvania).

The first aspect of the QA problem, communication, became evident when we reviewed the field data contained in the Montana State University annual report. Our routine check of ion balances indicated a probable error in cation and/or anion analyses. When we called this to the attention of the cooperator, we found that he was not aware of the potential problem because ion balances were not being routinely calculated. Subsequently, he found some procedural errors in the analyses of two cations and one anion, and some of the data were corrected by re-analysis of existing samples (unfortunately, some earlier samples had by then been discarded, and those data could not be corrected). We have since reviewed with the cooperator the routine QA procedures we expect (duplicate field samples, field banks, replicate analyses, spikes, and the like, including ion balances). The initiation of an audit sample program (see page 16) will result in improved communication relative to data quality. Results of analyses of audit samples will be submitted to ERL-Corvallis three times yearly, corresponding with the spring, summer, and fall sampling periods.

The larger part of the QA problem appears to be a result of the multi-level procedures of the Geological Survey. Operationally, all of the parts of an adequate QA plan are in place, but they are in different places; i.e., each

Central Laboratory has internal analytical quality assurance; each District has QA for field determinations, sample collection and storage, etc.; and the Quality of Water Branch, which is independent of the laboratories and the Districts, provides audit samples to both labs and Districts and analyzes the results. This segmentation, together with the routine reporting safeguards of USGS (data evaluation, verification, multi-level review, and final approval), while laudable, can result in considerable delay in the delivery of all pertinent QA information even to an investigation within USGS, let alone to an outside agency such as EPA. Note, for example, that all of the USGS analytical data shown in this report are "provisional," because they have not yet been verified, reviewed, and approved for publication by the Geological survey.

A lesser problem relating to USGS data, but one requiring resolution, is the routine rounding of reported values to conform to USGS policy on analytical data. Alkalinities less than 1000 mg/l, for example, are reported to the nearest mg/l (essentially $\pm$ 20 μeq/l), and aluminum concentrations less than 100 μg/l are reported to the nearest 10 μg/l. Such rounding may be acceptable in reporting data for, say, the Ohio River, but it is not acceptable for the poorly-buffered, dilute waters being sampled in the long-term monitoring program, for which data need to be reported to the nearest micro-equivalent per liter.

Arrangements have been made with the USGS Central Laboratory at Denver for analyses of National Surface Water Survey (NSWS) samples with provisions for all of the quality assurance requirements of the NSWS, <u>including</u> timely reporting of QA results. Beginning in October 1984, ion/metals samples from our cooperative stream monitoring projects with USGS are being sent to the Denver lab for analysis along with the NSWS samples. This arrangement is particularly advantageous from the standpoint of linkage with the NSWS and will provide

continuity of analytical effort since it is probable that a majority of the Project E1-15 waters will be included in the NSWS Phase III monitoring along with the other waters selected on the bases of Phase I and II sampling.

A review of the quality assurance effort for the monitoring program was conducted by Dr. Eugene Meier, director of quality assurance and quality control for the National Survey. His specific recommendations and the present status of their implementation follow:

Recommendation: Work with the data users to define the data quality objectives necessary to observe the trends necessary to establish problems related to acidic deposition.

Status: A set of data quality objectives has been developed. The document is included here as Appendix III.

Recommendation: Document specific requirements for duplicates, blanks, and data reporting requirements for this program. A statistician should review the objectives and requirements of the program to provide a reasonable estimate of the number of blanks, duplicates, audit samples, etc. that should be required to define the numbers of each sample that are required to adequately define the quality of the data. This document should be provided to all program participants to assure that they understand what is required.

Status: A draft sampling, analysis, and QA/QC protocol document has been developed. This document has drawn extensively upon the "Methods Manual for the National Surface Water Survey Project -- Phase I." It is included here as Appendix IV, but is still undergoing review.

Recommendation: Document procedures for performing onsite evaluation. These evaluations should include both field and analytical laboratory sites. The document should include an outline or form to be followed to assure

that the basic information is obtained in a consistent manner for all sites. The document should be provided to all participants to assure that they are aware of what is expected and to expedite the evaluations.

Status: These procedures are being developed with the assistance of Jeffrey Sprenger, ERL-Corvallis quality assurance specialist. Mr. Sprenger will conduct onsite evaluations at Montana State University and the University of Minnesota this spring.

Recommendation: Document and provide a formal data review process, along with requirements for standard data reporting formats, to the program participants. This assures that everyone knows what data are required and how they are to be reported and evaluated. Criteria specified in the methods manual for the National Surface Water Survey will be utilized.

Status: We are working with Oak Ridge National Laboratory to implement a data management procedure similar to, and closely modeled after, that developed for NSWS. Standard data reorting forms have been developed and are being provided to program participants.

All products are being reviewed by Dr. Meier.

The first set of audit ("round-robin") samples was sent to all cooperators in October 1984. Audit samples suitable for the evaluation of analyses of poorly-buffered waters have only recently become available from the Radian Corporation, Austin, Texas through arrangements made by the NSWS. They will be sent to all participants three times each year, coinciding with the spring, summer, and fall sampling periods. This phase of our QA was delayed because dilute audit samples that have been available from the RTP and the Denver USGS laboratories either lack constituents of particular interest (e.g., alkalinity) or the auditing labs do not perform analyses for those constituents. Similarly, the audit samples available from MERL-Cincinnati have solute concentra-

tions that are usually much greater than those in the dilute project waters, and evaluations of accuracy of analyses based on such audit samples would not be very meaningful.

The QA/QC procedures as reported by the various cooperators are presented as Appendix II of this report. Results of the October audit sample analyses, which are still being evaluated, are not included; they will be documented in the next report. Preliminary analysis of the results is quite encouraging. Except for an obvious problem with the ion chromatograph work at Montana State, and what appears to be a calibration problem at a number of laboratories with the atomic absorption procedure for total aluminum, results are for the most part consistent and near the theoretical concentrations reported by Radian.

The Lake and Stream Monitoring Program

Northern Rocky Mountains

Montana-Wyoming

Principal Investigator: Gordon Pagenkopf, Department of Chemistry, Montana State University, Bozeman, Montana 57917.

Twenty-six lakes were surveyed in southwestern Montana and northwestern Wyoming in 1983. Eleven were selected for long-term monitoring beginning in fall 1983. The criteria for selection were alkalinity and access; all were pristine and essentially unimpacted. Those lakes are variously located in the Beartooth Plateau, Crazy Mountains, Gallatin Range, Madison Range, and the Bitterroot Range. Elevations range from 2682 to 2975 m. All lakes are in alpine situations, with a number at or above timber line.

Precipitation quantity and chemistry are monitored by NADP stations at Headwaters, Idaho, and at Yellowstone National Park (Table 2). The Headwaters site, while relatively near the two westernmost lakes, is about 400 km west and

north of the remaining nine. A planned NADP site at Bozeman (Montana State University) would greatly improve coverage. Deposition chemistry from the two existing sites indicates essentially background conditions: mean 1982 pH 5.40, sulfate deposition 1.2 kg/ha at Headwaters and 5.22 and 3.5 kg/ha, respectively, at Yellowstone. Natural sulfur emissions in Yellowstone National Park may partially account for the greater sulfate deposition there. The Northern Rocky Mountain project appears to provide an excellent reference area where sensitive waters are exposed to essentially background deposition chemistry.

Tables 4 and 5 present locational and water chemistry data for the eleven Rocky Mountain lakes for 1984. [In all chemistry data tables, the final column, headed +/-, is the ratio of the sum of cations (Ca, Mg, Na, K) to the sum of anions (SO_4, NO_3, Cl)].

Upper Midwest

Minnesota-Wisconsin-Michigan

Principal Investigator: Patrick Brezonik, Department of Civil and Mineral Engineering, University of Minnesota, Minneapolis, Minnesota 55455.

Extensive surveys of lakes and some streams in northern Minnesota, Wisconsin, and Michigan were made by ERL-Duluth (EPA) and cooperating state agencies beginning in 1978-79; subsets were monitored seasonally until summer 1983. The locational data and mean chemical characteristics of 37 lakes and six streams monitored by ERL-Duluth through summer 1983 are given in Tables 6 through 10. Data for individual years could not be presented in this report, but should be available for subsequent analytical treatment. The present University of Minnesota at Minneapolis-based project, comprising 38 lakes and no streams, began with the fall 1983 sampling period. As pointed out earlier,

TABLE 4

LAKES MONITORED IN THE NORTHERN ROCKY MOUNTAINS (MONTANA, WYOMING)

State	Lake	Latitude (°N)	Longitude (°W)	Surface Area (ha)	Elevation (m)
Montana	Emerald	44°24'48"	110°55'33"	2.0	2682
	Heather	45°24'35"	110°56'33"	2.0	2718
	Blue	46°02'01"	110°17'19"	1.6	(at tree line)
	Granite	46°02'06"	110°15'56"	1.2	(at tree line)
	Triple	44°52'50"	111°25'57"	0.4	2755
	Blue Danube	44°52'37"	111°26'17"	2.4	2761
	Upper Twin	46°09'26"	114°29'45"	8.1	(tree line)
	Carlton	46°41'01"	114°13'12"	---	---
Wyoming	Island	44°57'01"	109°32'30"	~30.0	2901
	Little Bear	44°56'30"	109°31'02"	2.0	2911
	Long	44°56'45"	109°30'31"	4.0	2975

TABLE 5

CHEMICAL CHARACTERISTICS OF MONTANA-WYOMING LAKES

Lake	Date	Temp. (°C)	Color (true) (PCU)	Sp. Cond. (µS/cm @ 25°C)	pH (field)	µeq/l ANC	Ca	Mg	Na	K	Al µg/l	µeq/l SO_4	Cl	NO_3	+/-
Emerald	7/84	11.8	6	26	7.23	201	85	40	27	15	4	6	<6	<4	0.81
Heather	7/84	13.0	3	20	6.94	154	67	30	24	11	1	4	<6	<4	0.85
Blue	7/84	10.0	6	15	6.94	101	80	11	9	<1	13	10	12	<4	0.81
Granite Outlet	7/84	7.0	5	15	6.89	83	82	11	3	<1	2	10	9	<4	0.94
Granite	7/84	12.0	3	14	6.97	93	85	11	17	<1	4	10	<6	<4	1.00
Island	7/84	16.0	4	13	6.98	96	60	21	12	<1	4	<4	7	<4	0.90
Little Bear	7/84	17.0	9	14	7.12	123	62	25	12	<1	5	6	<6	<4	0.77
Long	7/84	17.0	7	16	7.12	113	69	22	12	--	33	6	<6	<4	--
Blue Danube	7/84	11.0	1	10	6.92	64	45	11	5	<1	<1	<4	<6	<4	0.97
Triple	7/84	12.0	4	15	6.93	108	78	16	10	1	11	4	9	<4	0.87
Upper Levin	7/84	18.0	2	7	6.47	48	28	5	7	<1	53	<4	<6	<4	0.83
Carlton	7/84	12.0	5	7	6.59	33	20	7	12	<1	13	10	<6	<4	0.91
Emerald	8/84	8.0	7	25	7.54	234	95	61	37	37	2	4	<6	<4	0.97
Heather	8/84	8.5	4	18	7.44	163	62	39	31	27	0	<4	<6	<4	0.97
Blue	8/84	11.0	5	14	7.09	107	95	11	8	<1	3	10	<6	<4	0.97
Granite Outlet	8/84	10.0	3	14	7.16	106	97	11	8	<1	2	10	<6	<4	0.99
Granite	8/84	11.0	1	14	7.20	108	97	11	6	<1	5	12	<6	<4	0.94
Island	8/84	10.0	4	12	7.33	87	59	25	11	<1	6	6	<6	<4	1.00
Little Bear	8/84	10.0	8	12	7.37	128	70	35	17	<1	8	4	<6	<4	0.92
Long	8/84	11.0	8	12	7.31	117	80	32	17	<1	9	6	<6	<4	1.05
Blue Danube	8/84	15.5	2	12	6.93	73	47	12	34	8	3	<4	20	<4	1.09
Triple	8/84	16.0	8	13	7.04	117	80	16	14	2	26	<4	<6	<4	0.97
Upper Levin	8/84	12.0	3	7	6.70	47	39	2	10	<1	25	<4	<6	<4	1.11
Carlton	8/84	11.0	4	7	6.55	33	22	5	16	<1	12	10	<6	<4	1.00

the lakes are not all identical with those monitored by ERL-Duluth. Locational and chemical data for these lakes appear in Tables 11 and 12.

Minnesota monitoring lakes are located in the northeastern area of the state, primarily in or near Voyageur National Park and the Boundary Waters Canoe Wilderness Area. This region contains numerous lakes, many of which have soft, low alkalinity water. Soils are thin, and granitic rock outcroppings are common, suggesting the watersheds have low capacity to neutralize acid deposition. Wisconsin lakes are located in the north-central area of the state, primarily in Vilas, Oneida, and Lincoln counties. This region, which is one of the richest lake districts in the world, has a great diversity of lake types, but the majority have soft, low alkalinity waters. Soils in the region are a thick glacial till high in sand and low in organic and clay content. Michigan lakes are located in the eastern part of the Upper Peninsula, near the southeastern corner of Lake Superior. This region has a rather diverse geology, but the monitored lakes generally are located in areas with resistant bedrock and sandy soils.

Criteria for selection of the lakes were based on water chemistry, watershed characteristics, and geographic considerations. Selected lakes are low in alkalinity but generally reflect chemical characteristics for the numerous softwater lakes in the regions. Watersheds of the lakes are forested or mostly forested and have little or no human habitation. Consequently, watershed influences on pH/alkalinity trends should be minimal.

Five NADP stations provide deposition data for the Upper Midwest project (Table 2). The 1982 data show a generally west to east gradient in both pH and sulfate deposition. Highest average pH and lowest sulfate occurred at Fernberg (pH 4.96, sulfate 10.3 kg/ha) and Spooner (pH 4.92, sulfate 12.0 kg/ha), the westernmost sites. Acidity and sulfate were greater at Trout Lake, in east-

TABLE 6

LAKES MONITORED IN THE UPPER MIDWEST (MINNESOTA, WISCONSIN, MICHIGAN) THROUGH SUMMER 1983

State	Lake	Latitude (°N)	Longitude (°W)	Surface Area (ha)
Minnesota	Cruiser	48°29'54"	92°48'19"	48.0
	Spring	48°22'22"	92°37'48"	90.1
	Weir	48°29'47"	92°44'33"	26.2
	Shoepack	48°30'13"	92°53'00"	126.2
	Loiten	48°31'33"	92°55'24"	38.8
	Locator	48°32'26"	93°00'13"	54.1
	Franklin	48°18'00"	92°36'50"	60.9
	Long	48°18'00"	92°42'32"	191.5
	Columbus	45°50'15"	89°14'30"	269.0
	Duck	45°22'50"	89°14'45"	49.0
	Summit	45°22'30"	89°12'25"	112.0
	Sunset	45°55'35"	89°20'15"	83.0
Wisconsin	Vandercook	45°58'55"	89°41'13"	40.0
	Finley	45°54'40"	89°24'00"	43.0
	Greater Bass	45°21'17"	89°12'00"	99.7
	Camp Ten	45°59'50"	89°23'05"	13.0
	Elna	45°40'55"	89°34'05"	9.0
	Sand	45°43'28"	89°39'05"	25.0
	Nichols	46°06'14"	89°41'20"	16.2
	Luna	45°54'19"	88°57'35"	27.1
	Smokey	46°05'47"	89°56'32"	250.0
	McGrath	45°47'28"	89°38'37"	21.4
	Sugar Camp	45°48'05"	89°18'25"	220.6
Michigan	Monocle	46°28'30"	84°38'45"	70.7
	Johnson	46°25'30"	85°02'40"	16.1
	Andrus	46°42'00"	85°02'25"	12.6
	Kelly	46°26'24"	85°23'43"	12.2
	Murray	46°28'15"	85°42'05"	38.3
	Bass	46°27'49"	85°42'58"	58.3
	Buckeye	46°27'57"	85°44'19"	48.1
	Stuart	46°35'24"	85°30'35"	30.1
	Chris Brown	46°37'34"	85°30'27"	24.2
	Pretty	46°36'03"	85°39'35"	18.9
	Camp 8 Mile	46°35'57"	85°40'12"	25.6
	Cusino	46°27'16"	86°15'30"	53.2
	Nevins	46°31'00"	86°14'35"	113.5
	McNearny	46°25'38"	84°57'30"	50.4

TABLE 7

MEAN CHEMICAL CHARACTERISTICS OF UPPER MIDWEST LAKES
(Minnesota, 1978-1983)

Lake	Color (apparent) (PCU)	Sp. Cond. (µS/cm @ 25°C)	pH (field)	µeq/l ANC	Ca	Mg	Na	K	Al µg/l	µeq/l SO_4	Cl	NO_3	+/-
Cruiser	6	23	6.83	122	100	56	28	14	43	64	6	2	1.00
Spring	13	38	6.92	242	175	128	43	19	39	74	9	5	1.08
Weir	87	24	6.51	128	99	63	36	16	125	27	8	14	1.24
Shoepack	88	24	6.11	82	110	71	38	3	177	61	7	12	1.52
Loiten	23	30	6.69	129	131	93	34	17	77	98	9	4	1.16
Locator	37	29	6.61	118	128	87	43	15	93	91	11	7	1.24
Franklin	15	52	7.51	441	254	190	46	27	48	46	8	13	1.02
Long	72	22	7.63	859	582	359	55	24	55	84	10	19	1.13

TABLE 8

MEAN CHEMICAL CHARACTERISTICS OF UPPER MIDWEST LAKES
(Wisconsin, 1979-1983)

Lake	Color (apparent) (PCU)	Sp. Cond. (µS/cm @ 25°C)	pH (field)	µeq/l ANC	Ca	Mg	Na	K	Al µg/l	µeq/l SO_4	Cl	NO_3	+/-
Columbus	422	41	7.05	269	241	147	48	21	52	46	22	8	1.34
Duck	81	23	5.39	7	71	40	27	13	129	100	22	5	1.22
Summit	192	24	4.85	-8	61	35	26	26	285	96	23	4	1.35
Sunset	4	16	6.25	26	64	22	18	7	47	84	10	3	0.98
Vandercook	12	16	6.09	17	67	26	17	9	38	87	7	8	1.06
Finley	9	20	6.77	81	78	47	26	9	49	72	10	6	1.02
Greater Bass	40	20	5.53	11	71	43	26	17	109	92	23	2	1.22
Camp Ten	5	20	6.19	53	79	41	21	8	78	91	6	2	1.08
Elna	19	16	6.40	52	59	29	18	12	42	54	6	4	1.09
Sand	5	27	5.01	-9	87	27	23	12	70	168	20	4	0.85
Nichols	14	14	5.76	16	57	22	11	10	68	73	6	6	1.18
Luna	5	20	5.54	5	72	29	14	10	51	116	10	3	1.00
Smoky	6	31	7.15	195	148	89	34	10	33	69	8	4	1.03
McGrath	7	17	5.22	-5	49	22	13	14	41	100	8	2	1.06
Sugar Camp	4	23	5.40	0	77	22	26	13	48	134	26	1	0.92

TABLE 9

MEAN CHEMICAL CHARACTERISTICS OF UPPER MIDWEST LAKES
(Michigan, 1982-1983)

Lake	Color (apparent) (PCU)	Sp. Cond. (µS/cm @ 25°C)	pH (field)	µeq/l ANC	Ca	Mg	Na	K	Al µg/l	µeq/l SO_4	Cl	NO_3	+/-
Monocle	13	40	6.98	237	229	92	41	12	39	108	9	2	1.08
Johnson	6	23	4.82	-14	60	25	8	11	39	125	8	2	0.89
Andrus	18	21	5.52	6	74	27	23	12	55	127	9	2	0.91
Kelly	8	15	5.22	-5	77	30	9	9	25	82	7	1	1.62
Murray	20	14	5.77	32	46	22	10	9	64	50	7	2	1.13
Bass	14	23	6.57	114	109	46	16	12	35	68	7	11	0.95
Buckeye	14	28	6.68	129	150	63	19	15	45	92	9	6	1.04
Stuart	6	18	4.82	-17	28	21	7	10	48	82	6	3	0.89
Chris Brown	24	33	6.85	201	216	77	23	20	43	73	6	2	1.12
Pretty	13	18	6.40	60	86	26	17	10	44	71	8	3	0.95
Camp Eight	14	21	6.60	95	108	40	18	10	41	67	8	2	1.02
Cusino	22	15	5.32	0	58	22	9	7	68	82	7	3	1.11
Nevins	10	36	6.72	161	232	66	20	8	59	132	8	6	1.05
McNearney	3	33	4.44	-38	60	21	7	6	254	150	7	10	0.80

TABLE 10

MEAN CHEMICAL CHARACTERISTICS OF UPPER MIDWEST STREAMS

Stream	Color (apparent) (PCU)	Sp. Cond. (µS/cm @ 25°C)	pH (field)	µeq/l ANC	Ca	Mg	Na	K	Al µg/l	µeq/l SO_4	Cl	NO_3	+/-
						Michigan (1982-1983)							
Pine R.	127	126	7.50	1183	980	460	65	35	1182	152	21	15	1.18
Tahquamenon R.	100	114	6.95	878	848	352	61	21	149	195	31	10	1.12
						Minnesota (1979-1983)							
Filson Cr.	154	39	6.21	238	161	190	47	13	225	64	11	31	1.37
Lester R.	75	105	7.55	791	589	391	132	33	963	85	54	11	1.05
Amity Cr.	63	157	7.68	937	789	492	332	37	995	130	195	12	1.25
						Wisconsin (1982-1983)							
Popple R.	87	126	7.54	1179	805	673	52	13	38	92	45	1	1.24

TABLE 11

LAKES MONITORED IN THE UPPER MIDWEST (MINNESOTA, WISCONSIN, MICHIGAN) BEGINNING FALL 1983

State	Lake	Latitude (°N)	Longitude (°W)	Surface Area (ha)
Minnesota	Cruiser	48°29'54"	92°48'19"	48.0
	Spring	48°22'22"	92°37'48"	90.1
	Shoepack	48°30'13"	92°53'00"	126.2
	Loiten	48°31'33"	92°55'24"	38.8
	Locator	48°32'26"	93°00'13"	54.1
	Franklin	48°18'00"	92°36'50"	60.9
	Long	48°18'00"	92°42'32"	191.5
	Chester	47°58'00"	90°03'00"	--
	Crum	47°50'00"	93°25'00"	--
	Moon	47°30'00"	93°30'00"	--
	Five	46°07'00"	93°12'00"	--
Wisconsin	Long	45°43'06"	89°36'17"	40.0
	Sunset	45°55'35"	89°20'15"	83.0
	Clara	45°30'46"	89°34'17"	34.0
	Vandercook	45°58'55"	89°41'13"	40.0
	Greater Bass	45°21'17"	89°12'00"	99.7
	Sand	45°43'28"	89°39'05"	25.0
	Clear	45°21'15"	89°13'14"	35.0
	Little Rock	45°59'50"	89°42'15"	--
	Nichols	46°06'14"	89°41'20"	16.2
	Luna	45°54'19"	88°57'35"	27.1
	Camp Twelve	45°59'10"	89°22'20"	29.9
	McGrath	45°47'28"	89°38'37"	21.4
	Sugar Camp	45°48'05"	89°18'25"	220.6
	Morgan	45°46'00"	88°33'00"	17.2
Michigan	Garlinghouse	46°17'45"	84°33'30"	--
	Monocle	46°28'30"	84°38'45"	70.7
	Johnson	46°25'30"	85°02'40"	16.1
	Kelly	46°26'24"	85°23'40"	12.2
	Murray	46°28'15"	85°42'05"	38.3
	Bass	46°27'49"	85°42'58"	58.3
	Buckeye	46°27'57"	85°44'19"	48.1
	Stuart	46°35'24"	85°30'35"	30.1
	Chris Brown	46°37'34"	85°30'27"	24.2
	Cusino	46°27'16"	86°15'30"	53.2
	Nevins	46°31'00"	86°14'35"	113.5
	McNearney	46°25'38"	84°57'30"	50.4

TABLE 12

CHEMICAL CHARACTERISTICS OF UPPER MIDWEST REGION LAKES, November 1983

Lake	Temp. (°C)	Color (apparent) (PCU)	Sp. Cond. (µS/cm @ 25°C)	pH (field)	ANC	Ca	Mg	Na	K	Al µg/l	SO_4	Cl	NO_3	+/-
					µeq/l						µeq/l			
Michigan														
Andrus	10.7	32	14	5.72	25	72	46	87	7	31	129	13	<1	1.27
Bass	12.2	13	22	6.80	125	109	56	67	9	8	73	10	<1	1.16
Buckeye	8.4	16	22	7.03	164	166	73	73	13	5	96	9	<1	1.21
Chris Brown	9.7	47	30	7.19	209	205	77	63	9	10	87	17	<1	1.13
Cusino	9.3	19	15	5.46	13	72	29	80	4	8	127	8	<1	1.25
Garling	8.9	30	23	4.54	-12	73	38	77	8	21	100	11	2	1.99
Johnson	9.8	5	22	4.74	2	67	41	38	9	5	131	8	<1	1.19
Kelly	12.6	8	20	5.23	14	63	27	90	5	5	90	10	<1	1.62
McNearney	12.1	4	28	4.50	-24	80	31	53	6	139	148	7	1	1.30
Monocle	11.8	16	38	7.31	252	228	94	71	9	12	118	13	<1	1.05
Murray	7.6	29	13	6.03	38	57	29	75	5	10	61	9	<1	1.54
Nevins	10.3	14	31	7.02	162	209	67	66	4	9	129	10	1	1.15
Stuart	9.9	21	14	4.95	2	50	30	72	7	10	81	8	1	1.85
Minnesota														
Cruiser, 0.5 m	13.9	13	22	6.72	119	96	66	44	12	8	71	16	<1	1.06
26.0 m	14.1	12	24	6.31	122	101	70	71	14	10	71	8	<1	1.27
Franklin	14.8	30	51	7.52	540	297	228	82	24	10	55	12	<1	1.04
Locator	14.2	73	29	6.50	172	127	94	120	13	41	98	18	<1	1.27
Loiten	14.5	49	29	6.61	169	126	95	120	15	29	100	65	<1	1.07
Long	14.7	91	94	7.43	950	554	425	111	24	28	86	21	<1	1.05
Shoepack	14.6	215	24	6.30	173	107	84	152	16	85	107	28	1	1.16
Spring	14.1	19	37	6.92	306	173	136	74	17	10	77	11	<1	1.02
Wisconsin														
Camp Twelve	9.7	7	13	5.32	31	53	26	33	4	7	74	5	<1	1.05
Clara	11.6	14	32	6.37	43	94	53	162	16	8	100	127	<1	1.20
Clear	11.2	40	16	5.06	NA*	62	39	72	9	28	96	16	<1	--
Greater Bass	12.0	38	19	5.85	30	80	45	89	10	27	105	27	<1	1.38
Long	NA	7	14	5.27**	10	56	28	56	7	8	81	14	<1	1.40
Luna	12.4	13	18	6.07	17	73	39	91	9	10	106	11	<1	1.58
McGrath	12.4	9	18	5.39	10	59	34	42	10	7	101	12	<1	1.18
Morgan	10.3	7	21	4.73	-3	72	51	55	9	25	147	6	<1	1.35
Nichols	12.8	28	15	5.94	34	74	37	121	4	9	87	9	<1	1.82
Sand	12.2	3	23	5.23	18	84	45	47	11	9	144	17	1	1.04
Sugar Camp	12.7	3	21	5.62	23	81	35	53	10	5	125	26	<1	1.03
Sunset	12.5	6	17	6.57	32	66	33	44	4	7	86	17	<1	1.09
Vandercook	12.4	3	23	5.23	18	84	45	47	11	4	88	8	<1	1.64

* Not available.
** Field value NA; lab value shown.

central Wisconsin (pH 4.68, sulfate 19.4 kg/ha), and greatest at Douglas Lake near the Straits of Mackinac in Michigan (pH 4.42, sulfate 20.3 kg/ha). This latter site, as previously noted, is not ideally situated for purposes of this project; the recently activated Raco, Michigan, site is now providing data more representative of the monitored lakes in Michigan.

New England

Maine

Principal Investigator: Terry A. Haines, U.S. Fish and Wildlife Service, Department of Zoology, University of Maine, Orono, Maine 04469.

The six lakes selected for the monitoring program are located southeast of Orono in Hancock County. Sampling was initiated in October 1982. All lakes are underlain by the Tunk Lake Pluton, a medium grained horneblende-aegerine-augite-perthite granite. The surficial material is almost exclusively granitic and was probably locally derived. The soils are generally well drained spodosols of the Hermon and Lyman series, formed in till. Soil thickness ranges from 0 to >30 cm with a 3-10 cm organic mat.

The watersheds are entirely forested with mixed hard and softwood species. Hardwood species include paper birch, oak, beech, and red maple; softwood species are red spruce, fir, and white pine. There are a few seasonal dwellings on Spring River Lake, and one seldom-used seasonal dwelling on Anderson Pond. There is no other human habitation or disturbance in the watersheds. The northern half of the Anderson Pond watershed burned about 1960, otherwise the vegetation in all watersheds has been undisturbed for at least 50 years.

The NADP site at Acadia National Park appears to provide precipitation data most representative of the Maine study lakes. Average sulfate deposition in 1982 was relatively high, 25 kg/ha, although lower than for a number of

sites in the Catskill and Appalachian regions farther south (Table 2). Average pH was 4.46. Locational and chemical data are given in Tables 13 and 14.

Vermont

Principal Investigator: Wallace McLean, Chief, Monitoring and Surveillance, Water Quality Division, Department of Water Resources and Environmental Engineering, State Office Building, Montpelier, Vermont 05602.

Thirty-six lakes presently comprise the Vermont long-term monitoring program. Sampling began in 1981 with twenty lakes. At the present time, twelve lakes are sampled every year, and the remaining 24 in alternate years. Twenty-four lakes are thus sampled annually. Lakes primarily are small, with a median surface area of 14 hectares and a median drainage area of 120 hectares. Major geologic formations in Vermont have been mapped following the classification of Norton. The drainages for twenty-nine of the study lakes lie primarily over Type I bedrock which is highly sensitive to acidification. Four drainages lie primarily over Type II bedrock which is moderately sensitive to acidification. The drainages of the three remaining lakes are in well buffered areas.

All drainage basins are primarily forested, with vegetation characteristics ranging from predominantly softwood to predominantly hardwood. Only in the Hardwood Pond drainage basin was there historical evidence of agricultural activity.

Thirty of the lakes have no permanent inlet. Thirty-three are headwater lakes. Wheeler Pond, Holland Pond, and Somerset Reservoir have one or more bodies of water within their drainage basin. All of the lakes appear to have permanent outlets.

Cultural impact is generally light or non-existent in the drainage basins of almost all thirty-six lakes. Given the logging history of Vermont, it can

TABLE 13

LAKES MONITORED IN MAINE

Lake	Latitude (°N)	Longitude (°W)	Surface Area (ha)	Elevation (m)
Anderson Pond	44°38'51"	68°03'33"	5	68
Little Long Lake	44°38'16"	68°04'42"	22	75
Mud Lake	44°38'00"	68°05'24"	1	104
Salmon Pond	44°37'53"	68°04'12"	4	94
Spring River Lake	44°37'10"	68°03'06"	285	60
Tilden Pond	44°37'04"	68°04'23"	15	72

TABLE 14

CHEMICAL CHARACTERISTICS OF MAINE LAKES

Lake	Date	Depth (meters)	Temp. (°C)	Color (apparent) (PCU)	Sp. Cond. (µS/cm @ 25°C)	pH (field)	ANC	Ca	Mg	Na	K	Al µg/l	SO_4	Cl	NO_3	+/-
							µeq/l						µeq/l			
Anderson	11/21/82	0.5	10	15	17	5.51	14	36	30	74	6	3	59	61	0	1.09
		5.0	9	10	--	5.78	17	37	28	74	5	3	59	61	0	1.05
	02/21/83	0.5	0	10	18	5.86	15	45	29	78	9	5	59	63	0	1.18
		5.0	--	10	17	5.68	14	41	28	83	7	4	59	65	0	1.18
	04/21/83	0.5	7	10	18	5.90	10	33	25	72	5	5	55	69	0	1.01
		5.0	--	15	18	5.88	11	33	25	73	5	5	56	71	0	0.99
	07/07/83	0.5	23	10	20	5.95	9	33	25	75	5	3	59	60	4	1.05
		5.0	19	15	22	5.86	8	34	25	76	5	10	59	67	4	1.01
	01/16/84	1.0	--	10	20	5.64	8	42	28	84	7	5	56	80	0	1.12
		4.5	--	10	20	5.36	4	40	27	85	8	4	58	85	0	1.09
Little Long	05/01/82	0.5	6.5	5	19	5.15	3	44	30	89	7	11	79	81	0	1.04
		22.0	7	10	20	5.03	-11	44	30	77	7	11	79	83	0	1.03
	08/08/82	0.5	21	10	20	5.70	4	44	27	90	6	3	78	85	0	1.00
		22.0	8	10	17	5.17	11	47	28	90	6	12	81	81	0	0.99
	11/21/82	0.5	7.5	10	14	5.60	9	44	29	87	6	6	80	76	0	1.01
		22.0	8	15	13	5.82	8	44	29	91	6	6	78	84	0	1.00
	02/21/83	0.5	1	15	20	5.51	4	48	27	102	7	11	85	88	0	1.04
		22.0	5	15	13	5.65	12	51	27	100	7	6	83	84	0	1.03
	04/21/83	0.5	7	10	22	5.32	-2	43	30	91	6	10	80	84	0	1.07
		22.0	5	10	21	5.72	6	46	30	94	6	11	80	77	0	1.08
	07/07/83	0.5	23	10	23	5.56	0	42	28	89	6	9	78	86	0	1.02
		22.0	6.5	10	29	5.42	9	47	30	94	7	8	79	88	0	1.01
	01/16/84	1.0	--	10	24	5.12	-4	46	31	114	8	4	87	93	1	1.14
		20.0	--	15	24	5.51	3	49	30	100	8	9	81	94	1	1.04
Mud	05/01/82	0.5	7	30	22	4.39	-24	24	24	67	5	37	96	57	0	1.04
		14.0	6	40	24	4.41	-23	30	26	82	6	41	105	74	0	1.02
	08/08/82	0.5	20	15	25	4.52	-28	27	22	82	5	34	98	68	0	1.00
		14.0	--	35	26	4.48	-32	28	25	91	6	48	108	79	0	0.98
	11/21/82	0.5	8	25	19	4.60	-27	31	28	102	12	53	107	91	0	1.00
		14.0	5	35	20	4.61	-27	30	29	97	6	54	107	86	0	0.97
	02/21/83	0.5	6	25	20	4.52	-27	35	35	110	6	46	108	117	0	0.96
		14.0	--	30	--	4.65	-22	37	34	105	7	46	110	103	0	0.96
	04/21/83	0.5	6	30	31	4.52	-30	29	27	87	6	42	94	85	0	1.00
		14.0	5	30	31	4.57	-29	30	30	92	6	45	100	90	0	0.97
	07/07/83	0.5	22	15	27	4.64	-22	27	24	87	4	30	104	77	0	0.91
		14.0	4	25	33	4.57	-31	28	28	89	6	40	105	94	2	0.89
	01/16/84	1.0	--	30	34	4.45	-32	33	30	101	10	46	97	116	0	0.99
		14.0	--	35	32	4.48	-31	33	29	94	10	46	92	102	1	1.02
Salmon	05/01/82	0.5	8	20	18	6.11	38	62	30	79	7	3	50	75	3	1.09
		9.0	7	20	--	5.82	37	66	31	79	7	3	51	70	3	1.14
	08/08/82	0.5	21	20	20	6.42	30	67	29	85	8	2	52	76	0	1.20
		9.0	--	25	--	5.52	67	71	31	80	7	4	49	75	0	0.99
	11/21/82	0.5	55	15	12	6.57	54	71	32	88	9	3	55	73	0	1.10
		9.0	55	20	12	6.52	74	74	32	85	7	3	57	71	2	0.97
	02/21/83	0.5	0	25	19	6.25	57	78	30	91	9	7	55	71	0	1.14
		9.0	4	25	20	5.91	60	80	30	94	7	2	55	73	0	1.12
	04/21/83	0.5	6	20	21	6.54	47	65	31	87	6	3	54	69	0	1.11
		9.0	5	20	--	6.48	53	71	32	83	6	3	50	72	0	1.10
	07/07/83	0.5	22	20	22	6.55	59	60	30	84	6	3	53	72	0	0.99
		9.0	7.5	25	--	5.86	73	88	34	168	7	3	51	81	0	1.45
	01/16/84	1.0	--	25	24	6.10	38	73	33	93	8	1	57	84	2	1.14
		9.5	--	20	24	6.01	51	78	35	91	8	2	54	76	2	1.16
Spring River	07/07/83	0.5	22.5	15	21	6.22	15	52	31	117	7	4	71	102	3	1.10
		5.0	18.5	15	27	6.19	14	53	31	119	8	4	72	109	3	1.07
	01/16/84	1.0	--	15	30	5.82	11	64	37	145	8	5	79	147	1	1.07
		7.3	--	20	30	6.01	20	68	36	142	8	2	78	156	1	1.00

(continued)

CHEMICAL CHARACTERISTICS OF MAINE LAKES (continued)

Lake	Date	Depth (meters)	Temp. (°C)	Color (apparent) (PCU)	Sp. Cond. (µS/cm @ 25°C)	pH (field)	µeq/l ANC	Ca	Mg	Na	K	Al µg/l	µeq/l SO_4	Cl	NO_3	+/-
Tilden	05/01/82	0.5	7	20	17	5.79	32	57	29	85	6	6	54	69	0	1.14
		9.0	7	25	19	5.84	26	57	29	84	6	6	54	76	0	1.13
	08/08/82	0.5	21	10	13	6.50	41	57	28	88	6	2	58	73	0	1.04
		9.0	--	25	--	5.74	77	68	31	88	7	6	50	70	0	0.98
	11/21/82	0.5	6	15	15	6.47	39	63	31	92	6	2	62	69	0	1.13
		9.0	6	15	15	6.47	35	61	31	94	6	3	62	70	0	1.15
	02/21/83	0.5	1	15	--	6.28	45	69	34	102	7	3	62	86	0	1.10
		9.0	4	20	--	6.18	51	70	34	103	7	5	62	83	0	1.09
	04/21/83	0.5	7	25	18	6.49	39	60	30	90	5	5	56	76	0	1.08
		9.0	6	20	18	6.39	42	62	30	91	5	10	57	78	0	1.06
	07/07/83	0.5	23.5	15	22	6.82	37	55	28	93	6	5	58	76	0	1.06
		9.0	8	20	27	6.00	56	67	33	100	8	3	60	82	0	1.05
	01/16/84	1.0	--	30	22	6.06	32	67	34	102	7	5	66	107	2	1.01
		7.3	--	20	24	6.18	37	70	34	107	9	4	61	81	0	1.23

be assumed that virtually all of the basins have been subject to silvicultural perturbations to some degree within the last 150 years. Several of the ponds are on the Long Trail and thus are subject to relatively light recreational use by hikers. Five of the lakes, Sunset Lake, Somerset Reservoir, Lake Ninevah, Little Averill Pond, and Lake Mansfield, have dams and are subject to potential water level regulation. Somerset Reservoir serves a hydroelectric facility and is subject to seasonal water level fluctuations. Ten of the ponds have light seasonal camp development in the immediate basin. Permanent residences along the shoreline are found at Cole Pond.

Precipitation quantity and pH were measured at four locations for the full twelve months of 1983. Data from nine other sites were incomplete for the calendar year. Precipitation was collected in bulk deposition collectors and the pH measured on an event basis. Annual weighted averages of rainfall pH were calculated for the four locations.

Station	Precipitation Amount (cm)	pH (Weighted Average)
West Dover	159	4.36
Concord	121	4.39
Mt. Mansfield	141	4.42
Swanton	104	4.52

The weighted-average pH of the precipitation for these four sites was 4.41 with an average rainfall of 131 cm/year. Average pH for 1982 from the Bennington NADP site was 4.36 (Table 2), in good agreement with the above 1983 data. Average sulfate deposition as measured at Bennington in 1982 was 20.1 kg/ha, about 5 kg less than at Acadia Park in Maine.

Locational and chemical data for Vermont lakes are presented in Tables 15 and 16.

TABLE 15

LAKES MONITORED IN VERMONT

Lake	Latitude (°N)	Longitude (°W)	Surface Area (ha)	Elevation (m)
Beaver Pond	45°00'30"	71°56'30"	16	468
Beebe Pond	43°03'	73°03'	4	710
Big Mud Pond	43°18'	72°53'	6	790
Big Muddy Pond	44°45'	72°36'	8	427
Bourn Pond	43°06'	73°00'	20	778
Branch Pond	43°05'	73°01'	14	802
Cole Pond	43°09'	72°48'	17	363
Cow Mountain Pond	44°37'	71°40'	4	630
Forester Pond	43°05'	72°52'	4	641
Griffith Lake	43°21'	72°53'	7	793
Grout Pond	43°03'	72°57'	35	679
Hardwood Pond	44°28'	72°30'	18	479
Haystack Pond	42°55'	72°53'	11	910
Holland Pond	44°59'	71°56'	135	436
Howe Pond	42°47'	72°59'	20	587
Kettle Pond	44°18'	72°19'	42	440
Levi Pond	44°16'	72°14'	9	498
Lily Pond	43°14'	72°49'	8	454
Little Pond (Winhall)	43°08'	72°58'	4	753
Little Pond (Woodford)	42°46'	73°05'	6	793
Little Averill Pond	44°57'	71°43'	196	531
Little Rock Pond	43°22'	72°54'	8	565
Lake Mansfield	44°28'	72°49'	14	348
Moses Pond	43°20'	72°48'	5	686
Lake Ninevah	43°28'	72°45'	96	535
Osmore Pond	44°18'	72°16'	20	448
Pidgeon Pond	44°15'	72°20'	29	596
Somerset Reservoir	43°00'	72°56'	647	651
South Pond	42°51'	72°43'	28	503
Stamford Pond	42°49'	73°03'	5	726
Sterling Pond	44°35'	72°45'	5	917
Stratton Pond	43°06'	72°58'	18	779
Sucker Pond	42°48'	73°07'	20	691
Sunset Lake	42°55'	72°41'	38	418
Unknown Pond	44°55'	71°50'	8	720
Wheeler Pond	44°43'	71°39'	28	314

TABLE 16

CHEMICAL CHARACTERISTICS OF VERMONT LAKES

Lake	Date	Temp. (°C)	Color (true) (PCU)	Sp. Cond. (µS/cm @ 25°C)	pH (field)	ANC (µeq/l)	Ca (µeq/l)	Mg (µeq/l)	Na (µeq/l)	K (µeq/l)	Al µg/l	SO_4 (µeq/l)	Cl (µeq/l)	NO_3 (µeq/l)	+/-
Beaver Pond	02/23/81	--	--	50	5.62	38	160	35	--	--	--	146	14	--	--
	04/23/81	--	--	32	6.03	64	190	51	--	--	--	133	--	6	--
	06/24/81	--	--	26	6.34	42	170	35	--	--	--	135	--	5	--
	07/22/81	--	--	28	6.38	70	175	35	--	--	--	114	--	3	--
	08/19/81	--	--	28	6.09	98	190	39	--	--	--	142	--	4	--
	10/15/81	--	--	28	6.11	54	155	34	--	--	--	129	--	1	--
	02/03/82	1	--	24	5.90	72	180	35	--	--	--	125	--	2	--
	06/22/82	18	46	29	6.07	56	144	30	--	--	--	118	--	2	--
	08/04/82	22	68	26	6.11	58	149	30	10	14	--	110	14	1	1.11
	10/14/82	12	43	22	6.53	69	169	33	26	7	--	110	12	<1	1.23
Beebe Pond	05/13/82	16	75	23	4.97	-6	54	29	--	--	--	106	--	3	--
	07/14/82	24	102	29	4.86	-5	49	28	29	7	--	117	--	<1	--
	08/18/82	20	101	20	5.22	20	56	30	29	7	--	118	17	1	0.78
	11/05/82	13	89	22	5.40	8	59	33	34	9	--	113	17	1	0.97
	02/16/83	1	--	28	4.82	-9	70	37	41	13	350	142	15	8	1.07
	05/13/83	11	85	20	4.79	-18	50	30	25	8	380	110	16	4	0.99
	06/23/83	25	77	28	4.86	-8	50	30	27	8	440	119	17	2	0.93
	08/30/83	23	59	20	4.91	-7	50	31	30	9	190	115	14	<1	1.02
	01/11/83	7	65	22	5.10	0	50	31	33	10	300	116	6	1	1.01
Big Muddy Pond	02/18/81	--	--	45	5.49	70	165	37	--	--	--	137	17	--	--
	04/28/81	--	--	27	6.11	38	145	42	--	--	--	112	--	1	--
	06/02/81	--	--	21	6.89	38	140	34	--	--	--	137	--	2	--
	07/03/81	--	--	22	6.52	48	155	105	--	--	--	135	--	<1	--
	08/24/81	--	--	20	6.48	52	165	35	--	--	--	135	--	<1	--
	10/02/81	--	--	25	6.54	58	170	35	--	--	--	139	--	<1	--
	02/18/82	1	--	39	6.10	138	210	39	--	--	--	87	--	1	--
	05/21/82	18	26	23	6.46	58	144	29	--	--	--	111	--	2	--
	06/14/82	18	28	25	6.09	46	141	30	--	--	--	116	--	<1	--
	07/29/82	21	32	24	6.45	63	156	33	10	5	--	119	21	<1	1.00
	10/19/82	9	42	26	6.71	73	171	34	11	16	--	118	12	<1	1.14
Big Mud Pond	02/10/82	1	--	35	4.48	20	90	35	--	--	--	144	--	8	--
	06/30/82	19	107	19	4.90	5	62	27	--	--	--	111	--	<1	--
	01/26/83	1	59	25	5.36	38	120	41	28	11	410	162	25	2	0.88
	05/25/83	16	65	16	4.97	-5	70	25	18	9	300	108	14	<1	1.09
	08/07/83	19	131	20	5.03	1	70	30	22	7	380	148	13	<1	0.80
	09/01/83	20	71	30	4.79	-14	105	40	18	7	220	185	10	2	0.94
	11/03/83	6	58	30	5.03	-1	125	44	25	9	370	189	7	<1	1.08
Bourne Pond	08/17/82	21	58	16	5.23	4	38	27	22	7	--	90	11	1	0.89
	11/09/82	6	60	10	5.52	5	52	32	13	11	--	105	10	1	0.89
	02/16/83	1	40	27	4.85	-1	70	39	35	14	280	152	16	3	1.01
	05/26/83	16	37	15	5.17	-5	45	27	23	9	260	83	13	1	1.14
	07/07/83	21	40	16	4.96	-6	35	27	27	10	160	98	13	<1	0.99
	08/31/83	21	30	16	4.92	-6	35	29	25	10	110	100	11	<1	1.00
	11/02/83	5	28	16	5.26	2	40	27	26	11	110	98	6	<1	0.98
Branch Pond	04/30/81	--	--	22	4.22	--	100	36	--	--	--	142	20	5	--
	06/10/81	--	--	18	4.62	-20	50	27	--	--	--	125	--	4	--
	07/08/81	--	--	20	4.73	-16	40	27	--	--	--	127	--	3	--
	08/05/81	--	--	24	4.41	-18	45	26	--	--	--	127	--	2	--
	09/02/81	--	--	17	4.59	-16	45	26	--	--	--	117	--	1	--
	10/22/81	--	--	24	4.64	-15	45	28	--	--	--	127	--	1	--
	01/30/82	1	--	27	4.50	-13	50	31	--	--	--	162	--	13	--
	05/13/82	15	84	23	4.50	-12	48	38	--	--	--	98	--	3	--
	07/14/82	23	96	27	4.66	-18	34	21	20	11	--	105	--	1	--
	08/19/82	20	88	19	4.80	-11	36	24	21	8	--	103	12	2	0.90
	11/05/82	10	90	18	4.95	-5	45	24	23	12	--	100	14	1	1.00

(continued)

CHEMICAL CHARACTERISTICS OF VERMONT LAKES (continued)

Lake	Date	Temp. (°C)	Color (true) (PCU)	Sp. Cond. (µS/cm @ 25°C)	pH (field)	ANC (µeq/l)	Ca (µeq/l)	Mg (µeq/l)	Na (µeq/l)	K (µeq/l)	Al µg/l	SO_4 (µeq/l)	Cl (µeq/l)	NO_3 (µeq/l)	+/-
Branch Pond (cont.)	02/16/83	1	65	28	4.56	-25	60	28	30	11	360	158	17	4	0.88
	05/26/83	15	67	17	4.88	-10	40	23	23	13	320	98	14	3	0.97
	07/07/83	21	71	21	4.64	-20	45	26	22	11	260	112	14	1	1.00
	08/31/83	21	70	19	4.66	-17	35	22	23	10	140	104	9	<1	0.99
	11/02/83	5	48	18	4.81	-6	40	21	24	11	190	115	6	<1	0.93
Cole Pond	02/02/83	1	7	30	5.77	50	120	59	70	20	40	152	57	1	1.03
	04/28/83	15	12	25	6.22	44	95	47	69	16	70	119	54	<1	1.05
	07/06/83	22	33	27	6.33	35	95	47	65	17	80	125	49	<1	1.07
	08/30/83	24	15	27	6.31	42	90	52	67	18	30	125	51	<1	1.04
	11/01/83	7	9	29	6.38	43	100	48	73	18	20	135	41	<1	1.09
Cow Mountain Pond	02/23/81	--	--	46	5.70	134	100	76	--	--	--	137	10	--	--
	05/01/81	--	--	26	6.31	110	150	69	--	--	--	117	--	2	--
	06/23/81	--	--	24	6.76	110	145	67	--	--	--	171	--	<1	--
	07/21/81	--	--	25	6.38	84	145	67	--	--	--	110	--	<1	--
	08/18/81	--	--	29	6.42	100	150	66	--	--	--	127	--	<1	--
	10/14/81	--	--	32	6.32	122	145	66	--	--	--	119	--	<1	--
	02/16/82	1	--	36	6.02	130	150	86	--	--	--	77	--	3	--
	05/14/82	15	66	31	6.13	104	139	63	--	--	--	108	--	2	--
	06/09/82	19	70	32	6.34	106	131	58	--	--	--	107	--	<1	--
	08/03/82	20	86	31	6.28	136	140	63	17	20	--	110	15	<1	0.92
Forester Pond	05/05/82	1	--	24	4.94	-9	41	20	--	--	--	85	--	2	--
	06/29/82	23	29	24	4.69	-13	52	19	--	--	--	114	--	1	--
	08/24/82	21	29	20	4.81	-10	54	18	37	4	--	99	31	<1	0.99
	10/06/82	15	32	18	4.30	-30	52	18	38	4	--	101	30	<1	1.24
Griffith Lake	01/21/82	1	--	33	5.16	44	130	46	--	--	--	150	--	3	--
	05/12/82	14	75	23	5.46	20	104	32	--	--	--	96	--	3	--
	07/01/82	18	84	18	5.69	29	140	31	--	--	--	107	--	<1	--
	08/26/82	18	56	18	6.03	25	80	34	17	8	--	97	15	1	1.01
	10/05/82	15	47	18	6.20	40	104	34	19	10	--	101	12	<1	1.09
Grout Pond	06/29/82	19	40	17	6.29	32	70	31	--	--	--	82	--	1	--
	08/17/82	22	32	18	6.42	32	66	30	23	12	--	82	12	<1	1.03
	11/03/82	11	31	20	6.40	41	79	34	27	14	--	72	14	<1	1.21
	02/15/83	1	7	21	6.08	45	90	38	28	14	40	106	14	<1	1.03
	05/25/83	16	15	16	5.97	19	75	31	25	12	90	90	14	10	1.08
	07/07/83	22	28	18	5.99	20	70	31	30	7	60	98	14	<1	1.05
	08/30/83	22	15	18	5.99	22	70	33	25	13	30	92	12	2	1.10
	11/01/83	6	10	19	6.30	35	75	30	26	13	20	87	6	<1	1.12
Hardwood Pond	01/28/82	1	--	22	5.64	42	105	47	--	--	--	121	--	1	--
	05/13/82	14	45	22	6.44	38	96	40	--	--	--	99	--	10	--
	06/15/82	18	42	27	6.22	27	86	37	--	--	--	101	--	<1	--
	08/05/82	23	55	20	6.09	26	86	54	15	6	--	102	14	<1	1.13
	10/01/82	16	50	18	--	19	90	41	21	4	--	100	14	<1	1.17
	01/26/83	1	27	28	5.66	34	110	48	24	5	80	127	19	1	1.03
	05/20/83	12	24	17	6.10	28	90	37	20	4	60	106	13	<1	1.03
	07/01/83	22	43	19	5.72	28	85	39	15	4	50	112	11	<1	0.95
	09/06/83	24	70	20	5.78	36	80	42	21	7	100	117	12	<1	0.91
	11/09/83	6	25	20	6.02	21	90	38	20	4	70	117	10	<1	1.03
Haystack Pond	03/05/81	--	--	31	4.17	--	55	19	--	--	--	100	21	--	--
	04/29/81	--	--	29	4.47	-30	40	21	--	--	--	92	--	5	--
	06/17/81	--	--	15	4.58	-29	45	21	--	--	--	90	--	4	--
	07/15/81	--	--	17	4.63	-15	50	21	--	--	--	87	--	4	--
	08/12/81	--	--	18	4.55	-18	45	21	--	--	--	90	--	4	--
	10/28/81	--	--	18	4.92	10	45	21	--	--	--	90	--	3	--

(continued)

CHEMICAL CHARACTERISTICS OF VERMONT LAKES (continued)

Lake	Date	Temp. (°C)	Color (true) (PCU)	Sp. Cond. (µS/cm @ 25°C)	pH (field)	ANC (µeq/l)	Ca (µeq/l)	Mg (µeq/l)	Na (µeq/l)	K (µeq/l)	Al µg/l	SO_4 (µeq/l)	Cl (µeq/l)	NO_3 (µeq/l)	+/-
Haystack Pond (cont.)	01/28/82	1	--	28	4.87	-7	48	24	--	--	--	83	--	7	--
	05/19/82	16	26	22	4.66	-14	45	21	--	--	--	81	--	6	--
	07/07/82	18	35	23	4.46	-14	41	21	--	--	--	98	--	6	--
	08/12/82	19	18	20	4.67	-16	39	21	15	1	--	81	12	5	0.99
	11/10/82	6	22	36	4.20	-20	46	21	16	5	--	111	9	3	1.23
Holland Pond	02/23/81	--	--	51	6.26	70	180	39	--	--	--	142	14	<1	--
	04/23/81	--	--	36	6.37	86	195	51	--	--	--	131	--	7	--
	06/24/81	--	--	29	6.73	110	195	43	--	--	--	142	--	3	--
	07/22/81	--	--	30	6.89	86	165	43	--	--	--	117	--	3	--
	08/19/81	--	--	31	6.86	108	215	44	--	--	--	137	--	2	--
	10/15/81	--	--	36	6.52	104	195	35	--	--	--	135	--	<1	--
	02/03/82	1	--	36	5.86	110	210	43	--	--	--	127	--	2	--
	06/22/82	18	45	32	6.74	105	169	37	--	--	--	--	--	2	--
	08/04/82	23	47	29	6.63	105	183	39	10	17	--	108	13	1	1.10
	10/14/82	13	47	27	6.84	122	195	40	30	7	--	114	11	<1	1.10
Howe Pond	03/05/81	--	--	25	4.80	6	170	35	--	--	--	125	17	--	--
	04/14/81	--	--	17	6.02	26	90	34	--	--	--	40	--	5	--
	06/17/81	--	--	15	6.12	24	95	35	--	--	--	119	--	<1	--
	07/14/81	--	--	22	5.93	40	100	36	--	--	--	119	--	<1	--
	08/11/81	--	--	26	5.33	8	105	38	--	--	--	104	--	<1	--
	10/27/81	--	--	22	5.92	40	95	36	--	--	--	117	--	6	--
	01/27/82	1	--	32	5.48	32	100	37	--	--	--	119	--	3	--
	05/06/82	13	44	21	4.50	-6	82	31	--	--	--	88	--	6	--
	07/06/82	21	79	19	5.61	38	81	29	--	--	--	107	--	<1	--
	08/10/82	23	127	21	6.51	87	111	34	28	6	--	110	13	<1	0.85
	11/10/82	6	115	22	6.30	64	113	40	38	13	--	125	22	1	0.96
Kettle Pond	02/17/81	--	--	39	5.99	116	210	49	--	--	--	171	20	--	--
	04/22/81	--	--	33	6.37	80	155	38	--	--	--	135	20	1	--
	06/03/81	--	--	26	6.68	76	155	38	--	--	--	144	--	<1	--
	07/01/81	--	--	29	6.92	74	150	25	--	--	--	142	--	<1	--
	08/25/81	--	--	27	6.97	88	170	39	--	--	--	142	--	<1	--
	10/07/81	--	--	28	6.61	90	160	38	--	--	--	144	--	1	--
	02/02/82	1	--	40	6.16	88	170	42	--	--	--	144	--	1	--
	05/13/82	14	--	30	6.35	93	118	31	--	--	--	109	--	--	--
	06/16/82	19	31	31	6.80	100	142	34	--	--	--	125	--	<1	--
	07/30/82	22	36	29	6.81	90	148	35	44	8	--	123	15	<1	1.03
	10/12/82	13	32	26	6.90	99	158	35	51	10	--	126	15	<1	1.06
	01/25/83	1	7	30	6.55	133	190	41	55	10	30	146	19	<1	0.99
	05/16/83	10	48	24	6.33	71	130	30	42	8	120	121	15	<1	1.01
	06/27/83	21	33	27	6.55	81	135	31	44	9	120	133	14	<1	0.96
	08/15/83	22	30	27	7.04	82	140	34	40	8	30	137	13	<1	0.96
	10/20/83	12	25	26	6.84	92	160	35	52	9	20	129	6	<1	1.13
Levi Pond	02/17/81	--	--	31	5.00	28	125	37	--	--	--	223	21	--	--
	04/22/81	--	--	--	5.17	--	100	32	--	--	--	112	--	1	--
	06/03/81	--	--	16	5.22	0	100	31	--	--	--	212	--	<1	--
	07/01/81	--	--	24	5.16	2	95	21	--	--	--	200	--	<1	--
	08/26/81	--	--	18	4.92	-4	95	30	--	--	--	206	--	<1	--
	10/07/81	--	--	22	5.00	2	100	30	--	--	--	209	--	<1	--
	02/18/82	1	--	31	5.43	38	105	31	--	--	--	108	--	2	--
	05/07/82	11	101	25	5.29	15	120	30	--	--	--	116	--	--	--
	06/16/82	19	61	24	5.19	9	80	26	--	--	--	127	--	<1	--
	07/30/82	22	58	22	5.18	3	84	26	32	9	--	127	16	<1	1.03
	10/12/82	13	56	20	5.61	9	94	24	34	9	--	128	16	<1	1.05

(continued)

CHEMICAL CHARACTERISTICS OF VERMONT LAKES (continued)

Lake	Date	Temp. (°C)	Color (true) (PCU)	Sp. Cond. (µS/cm @ 25°C)	pH (field)	ANC	Ca	Mg	Na	K	Al µg/l	SO_4	Cl	NO_3	+/-
						µeq/l						µeq/l			
Levi Pond (cont.)	01/25/83	1	37	28	5.33	20	105	29	37	10	160	139	22	1	0.99
	05/16/83	10	59	18	5.23	4	80	23	31	8	160	121	16	<1	1.01
	06/27/83	21	58	20	5.12	3	70	23	30	8	150	131	11	1	0.90
	08/15/83	22	40	22	5.08	-4	80	24	30	8	110	129	13	<1	1.06
	10/17/83	12	35	18	5.18	-3	75	25	33	8	80	125	6	<1	1.13
Lily Pond	03/05/81	--	--	14	5.10	6	40	27	--	--	--	87	28	--	--
	04/15/81	--	--	17	6.05	38	80	45	--	--	--	37	--	<1	--
	06/10/81	--	--	18	6.51	10	80	46	--	--	--	115	--	<1	--
	07/08/81	--	--	20	6.40	42	85	54	--	--	--	112	--	4	--
	08/05/81	--	--	25	6.30	54	100	46	--	--	--	106	--	<1	--
	10/21/81	--	--	27	6.19	66	80	48	--	--	--	102	--	<1	--
	01/21/82	1	--	36	6.05	110	100	54	--	--	--	121	--	1	--
	05/14/82	16	27	21	6.38	38	66	37	--	--	--	104	--	<1	--
	06/29/82	23	35	20	6.28	38	70	40	--	--	--	104	--	<1	--
	08/24/82	22	36	20	6.56	70	66	44	38	13	--	103	16	<1	0.85
	10/06/82	15	36	20	6.15	54	41	45	43	17	--	94	15	<1	0.90
	01/25/83	1	9	25	5.88	74	95	52	50	20	100	117	23	1	1.01
	05/18/83	15	9	18	6.17	23	75	39	36	13	60	117	16	<1	1.04
	06/30/83	23	23	21	6.05	31	75	43	42	14	40	121	13	<1	1.05
	08/30/83	24	18	23	6.14	42	80	47	43	19	30	115	16	<1	1.09
	11/01/83	6	20	24	6.36	60	75	45	44	19	20	110	6	<1	1.04
Little Averill Pond	02/23/81	--	--	49	6.54	104	160	43	--	--	--	121	10	--	--
	04/24/81	--	--	32	6.44	110	160	45	--	--	--	115	--	6	--
	06/23/81	--	--	23	7.05	126	160	44	--	--	--	127	--	3	--
	07/21/81	--	--	31	6.95	94	160	45	--	--	--	94	--	2	--
	08/18/81	--	--	26	6.91	100	170	44	--	--	--	112	--	2	--
	10/14/81	--	--	31	6.83	110	165	46	--	--	--	112	--	1	--
	02/04/82	1	--	33	6.56	128	200	51	--	--	--	110	--	6	--
	05/29/82	14	40	32	6.95	105	156	44	--	--	--	103	--	2	--
	06/21/82	17	32	32	7.10	117	159	43	--	--	--	103	--	2	--
	08/03/82	20	29	29	7.26	121	--	--	--	--	--	110	8	1	--
	10/13/82	13	29	26	7.08	123	150	44	34	7	--	102	10	<1	1.00
	02/01/83	1	5	25	6.47	120	180	46	34	8	30	112	15	2	1.08
	06/01/83	11	6	25	6.96	114	120	43	32	7	30	96	11	2	0.91
	07/12/83	20	9	28	6.91	118	170	41	32	7	30	110	8	<1	1.06
	08/18/83	22	5	28	6.47	126	160	44	34	8	40	104	9	2	1.02
	10/20/83	10	10	26	6.81	128	165	43	35	7	20	106	6	<1	1.04
Little Pond (Woodford)	03/06/81	--	--	25	4.75	--	55	21	--	--	--	98	20	--	--
	04/24/81	--	--	27	4.98	-10	70	31	--	--	--	115	--	11	--
	06/18/81	--	--	16	4.98	-3	70	29	--	--	--	125	--	5	--
	07/16/81	--	--	19	5.39	8	70	27	--	--	--	121	--	2	--
	08/12/81	--	--	21	4.98	-2	70	25	--	--	--	125	--	1	--
	10/28/81	--	--	20	5.05	-5	65	26	--	--	--	142	--	3	--
	01/28/82	1	--	35	5.16	19	70	33	--	--	--	133	--	4	--
	05/19/82	18	20	22	5.35	2	61	25	--	--	--	96	--	6	--
	07/07/82	22	26	23	4.98	-3	60	22	--	--	--	122	--	2	--
	08/12/82	22	25	18	5.16	-3	54	22	26	8	--	116	4	1	0.97
	11/11/82	5	28	18	5.51	6	69	26	34	14	--	134	8	3	0.95
	02/10/83	1	3	22	4.86	3	80	28	31	15	590	129	14	11	0.99
	05/12/83	9	10	20	4.75	-10	60	20	22	13	360	112	14	7	1.00
	06/22/83	25	3	27	5.08	-5	60	22	26	16	180	121	12	2	0.98
	08/23/83	21	5	19	5.22	-2	60	26	30	14	90	122	11	1	1.01
	10/27/83	4	7	17	5.77	6	60	26	35	13	70	121	6	1	1.00

(continued)

CHEMICAL CHARACTERISTICS OF VERMONT LAKES (continued)

Lake	Date	Temp. (°C)	Color (true) (PCU)	Sp. Cond. (µS/cm @ 25°C)	pH (field)	ANC (µeq/l)	Ca (µeq/l)	Mg (µeq/l)	Na (µeq/l)	K (µeq/l)	Al µg/l	SO_4 (µeq/l)	Cl (µeq/l)	NO_3 (µeq/l)	+/-
Little Pond (Winhall)	01/21/82	1	--	34	5.04	82	115	49	--	--	--	85	--	12	--
	05/18/82	22	33	20	5.76	14	83	31	--	--	--	65	--	11	--
	07/13/82	23	49	24	6.15	33	66	30	24	9	--	68	--	2	--
	08/18/82	22	58	17	6.38	40	65	30	27	9	--	60	13	1	1.15
	11/03/82	13	62	19	6.30	72	75	29	28	12	--	71	16	2	0.89
	02/17/83	1	17	29	5.76	66	130	44	35	14	140	106	14	10	1.14
	05/24/83	17	22	16	5.59	13	75	26	21	10	210	75	13	5	1.25
	07/06/83	21	43	17	5.86	19	70	27	--	11	70	89	15	<1	--
	08/31/83	21	48	17	5.93	34	70	26	27	11	60	77	13	<1	1.08
	11/10/83	6	42	19	6.18	37	70	23	27	12	70	77	14	1	1.02
Little Rock Pond	07/01/82	19	32	29	6.87	137	138	17	--	--	--	112	--	<1	--
	08/25/82	20	29	30	7.02	152	132	110	18	8	--	112	15	<1	0.96
	10/07/82	15	29	30	7.00	160	150	113	21	12	--	111	14	<1	1.04
	01/27/83	1	6	30	6.80	162	150	115	20	13	50	119	19	<1	0.99
	05/25/83	14	11	25	6.75	112	125	99	19	11	180	106	15	1	1.09
	07/08/83	21	19	30	6.87	130	125	99	22	12	120	125	15	<1	0.96
	09/01/83	21	10	30	7.06	134	140	107	18	11	240	117	11	<1	1.05
	11/03/83	7	17	35	6.84	172	150	115	19	12	60	110	6	<1	1.03
Lake Mansfield	02/27/81	--	--	49	5.85	6	175	39	--	--	--	139	15	--	--
	04/17/81	--	--	27	6.21	50	195	45	--	--	--	123	--	14	--
	06/05/81	--	--	31	6.36	54	195	49	--	--	--	81	--	10	--
	07/30/81	--	--	26	6.78	136	220	49	--	--	--	127	--	3	--
	08/28/81	--	--	27	6.18	64	200	40	--	--	--	146	--	4	--
	10/01/81	--	--	26	6.57	72	195	41	--	--	--	162	--	5	--
	02/02/83	1	17	46	6.28	202	274	59	20	9	80	169	17	5	0.92
	05/20/83	12	10	23	6.34	56	155	34	11	6	110	133	11	4	1.01
	07/01/83	22	31	30	6.44	116	130	40	16	8	80	142	8	<1	0.73
	09/06/83	24	59	32	6.60	146	190	43	16	7	80	127	8	1	0.91
	11/09/83	6	32	30	6.60	78	180	37	20	8	140	156	11	2	0.99
Moses Pond	03/05/81	--	--	24	4.63	--	65	40	--	--	--	133	18	--	--
	04/29/81	--	--	10	4.99	-18	50	32	--	--	--	112	--	<1	--
	06/10/81	--	--	14	4.91	-5	60	31	--	--	--	121	--	<1	--
	07/08/81	--	--	15	5.11	-1	55	31	--	--	--	110	--	<1	--
	08/05/81	--	--	22	4.29	-17	50	30	--	--	--	112	--	<1	--
	10/21/81	--	--	24	4.59	-25	55	35	--	--	--	121	--	<1	--
	01/21/82	1	--	27	5.18	58	65	39	--	--	--	117	--	2	--
	05/14/82	15	55	21	4.86	-5	49	28	--	--	--	98	--	<1	--
	06/29/82	23	106	17	5.25	8	61	27	--	--	--	116	--	2	--
	08/24/82	19	87	15	5.00	5	45	29	20	2	--	92	14	--	0.95
	10/06/82	15	70	16	5.15	-2	49	32	20	3	--	112	13	<1	0.89
Lake Ninevah	03/04/81	--	--	25	5.99	52	105	44	--	--	--	127	30	--	--
	04/24/81	--	--	26	6.30	54	115	62	--	--	--	125	--	5	--
	06/10/81	--	--	19	6.42	56	115	48	--	--	--	108	--	<1	--
	07/07/81	--	--	46	6.75	36	110	33	--	--	--	112	--	<1	--
	08/04/81	--	--	26	6.65	70	130	44	--	--	--	110	--	<1	--
	10/21/81	--	--	20	6.50	70	120	50	--	--	--	110	--	<1	--
	01/27/83	1	9	26	6.50	102	140	53	36	21	30	112	23	1	1.05
	06/07/83	17	16	22	6.57	56	105	41	29	17	60	108	18	<1	1.05
	06/30/83	22	28	24	6.75	62	110	43	37	17	40	108	17	1	1.10
	09/07/83	23	54	24	6.77	65	115	49	31	17	20	108	15	<1	1.13
	11/10/83	6	17	25	6.82	71	115	45	31	18	10	121	16	<1	1.00
Osmore Pond	02/01/83	1	17	29	6.74	215	240	52	83	15	50	135	33	<1	1.02
	06/03/83	15	17	20	6.72	80	125	30	123	10	50	121	17	<1	1.32
	06/28/83	20	32	28	7.00	102	135	34	54	10	40	125	17	<1	0.95
	08/17/83	23	30	32	7.24	153	180	37	68	11	40	112	18	<1	1.05
	10/18/83	11	20	22	7.40	144	165	39	74	12	40	117	7	<1	1.08

(continued)

CHEMICAL CHARACTERISTICS OF VERMONT LAKES (continued)

Lake	Date	Temp. (°C)	Color (true) (PCU)	Sp. Cond. (µS/cm @ 25°C)	pH (field)	ANC (µeq/l)	Ca (µeq/l)	Mg (µeq/l)	Na (µeq/l)	K (µeq/l)	Al µg/l	SO_4 (µeq/l)	Cl (µeq/l)	NO_3 (µeq/l)	+/-
Pigeon Pond	02/17/81	--	--	38	5.55	140	215	49	--	--	--	142	25	--	--
	04/22/81	--	--	34	6.40	90	180	44	--	--	--	135	--	5	--
	06/03/81	--	--	27	6.64	76	165	42	--	--	--	137	--	4	--
	07/10/81	--	--	30	7.02	96	180	46	--	--	--	133	--	1	--
	10/07/81	--	--	28	6.60	88	180	42	--	--	--	142	--	1	--
	01/26/83	1	11	32	6.51	143	200	41	44	8	60	125	18	1	1.02
	05/17/83	10	48	25	6.50	86	160	35	35	7	120	123	15	2	1.05
	06/28/83	20	30	27	6.84	89	160	35	45	7	100	129	16	<1	1.06
	08/17/83	22	30	28	6.75	97	170	35	49	6	40	127	13	<1	1.10
	10/18/83	12	13	22	6.83	97	160	38	22	8	10	131	6	<1	0.97
Somerset Reservoir	03/06/81	--	--	26	4.95	5	85	35	--	--	--	115	20	--	--
	04/14/81	--	--	25	5.32	9	80	36	--	--	--	46	--	9	--
	06/17/81	--	--	15	5.83	10	80	34	--	--	--	106	--	7	--
	07/14/81	--	--	23	5.73	6	80	35	--	--	--	29	--	6	--
	08/11/81	--	--	20	5.82	10	80	35	--	--	--	112	--	5	--
	10/27/81	--	--	20	5.44	19	70	33	--	--	--	119	--	5	--
	01/28/82	1	--	32	5.47	15	75	38	--	--	--	106	--	8	--
	05/13/82	15	55	21	5.46	13	76	33	--	--	--	102	--	5	--
	07/08/82	20	43	19	5.58	10	69	30	--	--	--	103	--	4	--
	08/12/82	22	43	19	5.91	15	75	30	25	12	--	96	8	<1	1.19
	11/09/82	8	63	18	5.87	24	77	31	27	13	--	113	11	3	0.98
South Pond	03/04/81	--	--	21	5.66	28	100	39	--	--	--	125	22	--	--
	04/14/81	--	--	17	6.22	32	90	39	--	--	--	40	--	3	--
	06/18/81	--	--	16	6.48	32	95	39	--	--	--	119	--	<1	--
	07/15/81	--	--	21	6.31	24	100	39	--	--	--	112	--	<1	--
	08/12/81	--	--	22	6.38	38	100	39	--	--	--	117	--	<1	--
	10/29/81	--	--	21	6.27	38	95	39	--	--	--	110	--	<1	--
	01/27/82	1	--	32	6.06	48	100	41	--	--	--	115	--	1	--
	05/06/82	10	41	24	6.27	45	100	37	--	--	--	90	--	1	--
	07/06/82	22	21	21	6.53	33	90	36	--	--	--	108	--	<1	--
	08/11/82	23	23	23	6.47	45	105	39	34	8	--	103	19	<1	1.11
	11/08/82	9	31	22	6.47	43	108	40	34	9	--	115	--	<1	--
	02/10/83	1	1	24	6.20	44	104	42	36	10	80	123	24	<1	1.01
	05/11/83	12	39	18	6.24	26	80	33	32	7	50	108	20	<1	0.99
	06/21/83	25	9	27	6.20	23	84	35	32	7	50	115	19	<1	1.01
	08/23/83	21	--	21	6.50	25	90	39	33	8	90	115	20	4	1.04
	10/25/83	10	7	20	6.17	31	90	37	35	8	--	117	6	<1	1.10
Stamford Pond	01/27/82	1	--	36	5.52	46	100	36	--	--	--	121	--	6	--
	07/08/82	22	49	20	5.33	7	64	26	--	--	--	118	--	2	--
	08/10/82	24	43	20	5.49	16	70	27	33	5	--	109	7	<1	1.02
	11/10/82	3	55	21	5.89	26	91	35	47	10	--	131	15	3	1.04
	02/09/83	1	5	26	5.51	11	100	35	41	15	250	135	17	11	1.10
	05/12/83	9	33	20	4.97	-1	70	25	32	12	300	112	16	8	1.10
	06/22/83	25	18	29	5.28	3	65	26	33	10	190	123	14	3	0.94
	08/23/83	21	21	20	5.67	10	60	31	40	9	80	121	14	<1	0.97
	10/26/83	4	43	18	5.98	34	80	34	48	12	130	108	6	1	1.17
Sterling Pond	02/19/82	1	--	39	5.89	78	110	92	--	--	--	144	--	4	--
	06/24/82	13	79	19	5.88	39	83	120	--	--	--	88	--	5	--
	08/05/82	19	84	20	5.92	53	85	39	20	11	--	87	13	2	1.00
	10/01/82	13	95	20	--	84	100	70	10	5	--	81	14	<1	1.03
Stratton Pond	05/18/82	17	37	20	6.03	36	91	32	--	--	--	78	--	4	--
	07/13/82	23	32	24	6.23	17	64	31	24	14	--	95	--	<1	--
	08/18/82	22	29	18	5.86	15	63	33	24	5	--	101	11	1	0.98
	11/03/82	10	32	20	5.90	14	79	35	27	12	--	107	15	<1	1.12

(continued)

CHEMICAL CHARACTERISTICS OF VERMONT LAKES (continued)

Lake	Date	Temp. (°C)	Color (true) (PCU)	Sp. Cond. (µS/cm @ 25°C)	pH (field)	ANC	Ca	Mg	Na	K	Al µg/l	SO_4	Cl	NO_3	+/-
						µeq/l						µeq/l			
Stratton Pond (cont.)	02/17/83	1	15	21	5.70	28	85	38	32	14	300	121	12	3	1.03
	05/24/83	15	17	16	5.97	18	75	28	23	12	120	79	13	3	1.44
	06/07/83	22	25	18	6.10	16	70	29	27	11	60	96	13	<1	1.10
	08/31/83	22	17	16	6.65	36	70	30	25	12	20	77	11	<1	1.10
	11/02/83	6	20	15	6.22	27	65	26	25	11	60	71	6	<1	1.22
Sucker Pond	03/05/81	--	--	25	5.63	34	125	42	--	--	--	127	18	--	--
	04/30/81	--	--	21	5.79	46	115	41	--	--	--	115	--	4	--
	06/16/81	--	--	18	7.15	98	125	42	--	--	--	127	--	--	--
	07/16/81	--	--	26	6.77	66	125	44	--	--	--	106	--	<1	--
	08/13/81	--	--	22	6.84	76	115	44	--	--	--	104	--	<1	--
	10/28/81	--	--	25	6.73	60	120	44	--	--	--	110	--	<1	--
	02/09/83	1	11	29	6.18	95	150	50	39	15	90	127	16	4	1.05
	05/13/83	10	42	21	6.69	52	105	36	30	12	60	106	16	2	1.05
	06/23/83	24	31	29	6.58	61	110	37	35	16	70	112	16	<1	1.05
	08/24/83	21	35	23	6.81	78	110	41	33	14	20	112	13	<1	0.98
	10/27/83	4	12	22	6.91	80	110	43	35	14	20	104	6	<1	1.06
Sunset Lake	03/04/81	--	--	23	5.60	18	75	32	--	--	--	106	34	--	--
	04/14/81	--	--	16	6.25	14	75	32	--	--	--	33	--	1	--
	06/19/81	--	--	16	6.35	26	80	32	--	--	--	94	--	<1	--
	07/15/81	--	--	18	6.41	24	85	32	--	--	--	96	--	<1	--
	08/13/81	--	--	20	6.20	24	80	32	--	--	--	94	--	<1	--
	10/29/81	--	--	19	6.07	30	80	32	--	--	--	92	--	<1	--
	01/28/82	1	--	27	5.90	36	70	35	--	--	--	89	--	<1	--
	08/03/82	24	20	20	6.22	30	72	31	36	6	--	91	19	<1	1.04
	11/08/82	9	23	22	6.28	32	86	33	35	7	--	96	--	2	--
	03/03/83	--	0	20	6.26	61	120	38	38	7	120	--	22	1	--
	05/11/83	12	23	17	6.11	15	100	30	35	5	40	98	22	1	1.25
	06/21/83	25	0	25	6.14	15	70	31	35	5	40	104	21	<1	1.01
	08/23/83	10	3	20	6.18	17	75	30	35	6	30	104	21	<1	1.03
	10/25/83	10	3	18	5.96	14	75	30	37	6	40	106	6	<1	1.17
Unknown Pond (Avery's Gore	06/21/82	16	51	22	5.67	18	92	30	--	--	--	107	--	3	--
	08/17/82	20	51	21	5.76	18	106	32	12	12	--	117	12	<1	1.10
	10/13/82	10	72	19	6.06	28	104	31	24	6	--	128	12	1	0.98
	02/03/83	1	44	25	5.62	31	140	35	28	7	330	156	21	3	1.00
	06/02/83	11	39	18	5.42	8	90	25	18	10	180	115	13	3	1.05
	07/14/83	19	--	20	6.11	14	95	30	21	9	250	135	9	<1	0.98
	08/19/83	21	20	28	6.16	28	95	30	24	8	220	129	10	<1	0.94
	10/21/83	5	50	20	5.94	36	165	38	27	8	110	129	6	<1	1.39
Wheeler Pond	02/01/83	1	87	31	5.92	99	170	50	52	15	240	160	21	2	1.02
	06/01/83	14	73	26	6.13	71	145	41	43	16	180	135	16	1	1.10
	07/13/83	22	77	30	6.31	94	150	45	46	16	160	152	16	<1	0.98
	08/18/83	22	50	31	6.17	105	150	47	54	16	150	142	16	<1	1.02
	10/20/83	10	97	30	6.46	132	175	51	62	18	180	133	6	<1	1.13

New York

Catskill Mountains

Principal Investigator: Peter Murdoch, U.S. Geological Survey, P.O. Box 1350, Albany, New York 12201.

The USGS report on the Catskill sites, with the exception of the tabulated stream chemistry data, was not received in time for inclusion in this report. The area is important economically, containing some of the premier trout streams of the northeastern United States. Average precipitation pH in 1982 at the Stillwell Lake NADP site, about 65 km south, was 4.31; average sulfate deposition was 26.4 kg/ha. At the Knobit site, about 100 km northeast, these values for 1982 were 4.40 and 16.2, respectively. Precipitation quantity and chemistry monitoring on both weekly and event bases are funded and implemented by USGS at the Catskill study sites, but data are not available at this time.

Locational and water chemistry data for the Catskill streams appear in Tables 17 and 18. Data provided by the Geological Survey for this report are provisional and subject to revision by that agency.

Adirondack Mountains

A monitoring study of twelve Adirondack lakes was initiated in October 1983 through an agreement with the State University of New York at Oswego. A move by the principal investigator soon after, however, necessitated termination of the project. A proposal from Syracuse (New York) University for monitoring sixteen Adirondack lakes is expected to be funded early in FY85. Data from the October 1983 study will be included with those from the new project in the next annual report.

Average 1982 deposition data from the Huntington Wildlife NADP site in Essex County reflect a pH of 4.38 and sulfate deposition of 24.1 kg/ha.

TABLE 17

STREAMS MONITORED IN THE CATSKILL MOUNTAINS AREA OF NEW YORK

Stream	Latitude (°N)	Longitude (°W)	Drainage Area (ha)	Flow Range (m^3/sec)
Biscuit Brook	41°59'34"	74°30'11"	9.8	0.04-16.34
Pigeon Brook	41°59'13"	74°30'11"	6.9	0.02- 3.12
High Falls Brook	41°58'33"	74°31'19"	7.1	0.02- 5.95
Woodland Creek	42°02'22"	74°20'01"		0.04-12.80
Rondout Creek	41°56'12"	74°22'35"	14.2	0.10- 7.80
Beaverkill River	42°01'02"	74°34'55"	20.9	0.10- 2.66
East Branch Neversink River	41°57'48"	72°27'19"	34.4	0.37-13.59

TABLE 18

CHEMICAL CHARACTERISTICS OF CATSKILL MOUNTAINS STREAMS

Stream	Date	Flow m^3/sec	Flow gage ht (ft)	Temp. (°C)	Sp. Cond. (µS/cm @ 25°C)	pH (field)	ANC (µeq/l)	Ca (µeq/l)	Mg (µeq/l)	Na (µeq/l)	K (µeq/l)	Al µg/l	SO_4 (µeq/l)	Cl (µeq/l)	NO_3 (µeq/l)	+/-
Biscuit Brook	04/10/83	0.57*	0.97	4.5	25	5.8	9	125	40	22	6	210	128	13	26	1.10
	04/10/83	2.92*	1.65	5.0	22	5.4	8	125	40	9	7	150	114	10	24	1.16
	04/11/83	1.02	1.20	5.0	23	5.7	10	130	50	48	9	180	125	15	29	1.32
	04/11/83	1.36	1.34	5.0	23	5.6	6	110	40	17	7	190	121	18	47	0.91
	05/19/83	0.20	0.63	8.5	29	6.2	17	130	44	17	6	100	149	15	11	1.03
	07/08/83	0.09	0.51	14.2	27	6.6	--	145	58	30	5	30	160	22	19	--
	08/12/83	0.51	1.00	--	28	6.3	23	155	54	22	7	90	148	16	31	1.09
	08/15/83	0.04	0.32	14.0	28	6.4	23	145	50	26	5	60	163	20	27	0.97
	10/06/83	0.10	0.53	--	30	6.4	31	145	58	30	12	20	146	29	11	1.13
	11/02/83	0.03	0.45	5.0	25	6.4	36	145	58	35	6	20	159	31	8	1.04
	11/10/83	0.05	0.38	7.5	29	6.4	36	145	60	26	6	20	156	32	11	1.01
	11/10/83	0.07	0.44	6.5	28	6.3	34	145	61	26	7	20	154	29	11	1.05
	11/11/83	0.09	0.51	--	30	6.6	-4	150	58	35	7	20	159	30	13	1.24
	11/11/83	0.19	0.52	9.0	30	6.4	42	145	59	30	8	--	151	29	12	1.03
	11/16/83	0.22	0.85	5.0	30	6.5	30	165	52	22	7	70	153	29	18	1.07
	11/30/83	0.49	0.96	3.5	28	6.1	12	145	54	26	5	80	154	22	15	1.13
	12/13/83	3.37	2.02	--	22	5.1	-12	115	38	17	7	230	120	15	20	1.19
	12/14/83	2.44	1.70	5.0	23	5.6	2	115	41	22	6	210	139	16	19	1.06
	01/12/84	0.12	0.61	0.0	28	6.5	32	155	56	22	5	30	156	21	23	1.03
	02/01/84	0.16	0.65	0.0	30	6.2	16	145	58	22	5	50	155	19	24	1.07
	03/06/84	0.45	0.85	0.5	29	6.1	14	130	50	17	5	10	152	20	24	0.96
	03/21/84	0.42	--	1.5	25	6.0	16	125	47	17	5	30	137	18	24	0.99
	03/21/84	0.79	--	1.0	26	5.9	16	125	46	17	5	50	134	17	27	0.99
	03/28/84	0.29	0.81	1.5	29	6.3	20	130	46	17	5	50	143	18	16	1.01
	04/03/84	0.32	0.84	1.5	23	5.2	22	90	34	13	7	200	100	11	26	0.91
	04/03/84	0.32	0.84	4.5	31	6.1	22	130	49	17	5	50	142	16	14	1.04
	04/04/84	0.37	0.88	2.0	26	6.2	24	125	50	17	5	80	141	16	16	1.00
	04/05/84	0.42	0.94	2.5	27	6.2	20	130	45	17	5	80	138	16	17	1.03
	04/05/84	16.34	2.61	2.0	26	4.9	-12	80	31	13	9	220	100	10	30	1.04
	04/06/84	2.52	--	2.5	24	5.2	2	100	34	17	7	220	117	14	26	1.03
	04/06/84	6.57	2.14	2.0	26	5.0	-4	90	31	13	7	210	109	10	29	1.02
	04/10/84	0.53	1.02	3.5	21	5.9	4	115	40	13	5	70	145	16	18	0.95
	04/17/84	1.53	1.52	5.5	20	5.4	2	105	36	13	6	140	131	11	16	1.02
	05/30/84	4.33	1.94	8.5	20	5.3	4	90	35	63	6	--	122	8	9	1.04
	06/12/84	0.16	--	--	24	6.4	24	115	42	13	--	--	142	15	11	--
	07/20/84	0.10	--	--	30	6.5	32	--	--	--	--	--	--	--	--	--
E. Branch Neversink	08/15/83	0.35	0.74	16.0	22	5.0	-4	80	55	22	5	60	152	19	19	0.91
	11/02/83	0.37	0.80	--	22	5.1	0	75	61	17	6	160	138	23	13	0.96
	11/16/83	1.87	1.37	5.0	27	5.1	-12	85	55	17	7	240	140	24	17	0.95
	12/14/83	12.74	2.62	5.0	25	4.5	-32	60	36	17	7	420	115	16	19	1.01
	02/01/84	0.57	0.94	0	29	5.2	-2	90	63	26	6	180	147	19	31	0.97
	03/06/84	1.05	1.45	0.5	32	5.1	-8	80	55	17	6	160	140	19	27	0.89
	03/21/84	1.23	1.20	1.0	24	5.1	-6	75	57	17	6	140	134	19	26	0.91
	03/21/84	2.55	1.53	1.0	24	4.9	-12	75	53	17	6	160	133	18	29	0.91
	04/03/84	0.88	1.09	1.0	31	5.2	4	80	57	17	6	160	138	17	25	0.90
	04/05/84	53.8	3.84	1.5	26	4.5	-20	50	31	13	9	360	88	11	27	1.07
	04/05/84	110.4	5.30	1.5	28	4.5	-27	44	25	9	12	320	80	7	29	1.05
	04/06/84	9.63	2.39	2.0	26	4.6	-17	55	33	13	8	320	107	11	25	0.94
	04/17/84	7.08	2.17	3.5	24	4.6	-24	55	40	13	6	--	123	12	19	0.90
	05/30/84	13.59	2.67	8.5	26	4.6	-28	50	34	13	7	--	112	9	9	0.99
	06/13/84	0.68	--	--	--	5.1	--	70	49	17	6	--	138	15	11	--
	07/20/84	--	--	--	21	5.1	-8	--	--	--	--	--	--	--	--	--
Pigeon Brook	04/11/83	0.02	--	5.0	23	6.0	16	130	41	30	6	140	125	12	23	1.18
	08/15/83	0.03	--	14.5	33	6.6	70	195	55	26	5	60	165	19	24	1.01
	11/02/83	0.02	--	6.0	30	6.8	90	200	60	30	7	<10	160	30	6	1.04
	12/14/83	1.64	--	5.0	22	5.6	6	115	44	17	6	200	126	18	18	1.08

* When two or more observations were made on the same date (usually during a runoff event), data corresponding with the lowest and highest instantaneous flows are given here.

(continued)

CHEMICAL CHARACTERISTICS OF CATSKILL MOUNTAINS STREAMS (continued)

Stream	Date	Flow m³/sec	Flow gage ht (ft)	Temp. (°C)	Sp. Cond. (µS/cm @ 25°C)	pH (field)	ANC (µeq/l)	Ca (µeq/l)	Mg (µeq/l)	Na (µeq/l)	K (µeq/l)	Al µg/l	SO_4 (µeq/l)	Cl (µeq/l)	NO_3 (µeq/l)	+/-
Pigeon Brook (cont.)	02/01/84	0.08	--	0.0	29	6.5	50	180	50	22	5	50	157	19	23	1.03
	04/03/84	0.20	--	4.5	30	6.5	40	155	42	17	5	80	139	16	12	1.06
	04/05/84	1.25	--	2.0	23	5.8	16	105	31	13	6	150	100	12	18	1.06
	04/05/84	3.12	--	1.5	25	5.2	0	100	31	13	9	200	100	10	30	1.14
	04/06/84	0.68	--	3.0	25	5.5	6	110	31	13	6	150	115	11	26	1.01
	04/17/84	0.92	--	5.5	19	5.8	16	115	33	13	6	100	133	12	17	0.94
	05/30/84	0.68	--	8.5	18	5.7	16	105	28	13	6	--	119	8	7	1.01
	06/12/84	0.16	--	--	25	6.7	46	140	42	17	5	--	145	17	10	0.94
	07/20/84	0.07	--	--	28	6.8	51	--	--	--	--	--	--	--	--	--
High-falls Brook	08/15/83	0.03	--	14.5	38	7.1	136	265	54	30	5	60	169	17	25	1.02
	11/03/83	0.02	--	6.0	35	7.1	179	280	68	30	8	<10	158	23	9	1.05
	12/14/83	1.39	--	5.0	21	5.9	13	145	33	17	6	120	129	17	18	1.14
	02/01/84	0.10	--	0.0	39	6.8	97	235	57	22	5	30	162	18	26	1.05
	04/03/84	0.21	--	4.0	36	6.7	70	190	47	13	5	40	144	16	14	1.05
	04/05/84	5.95	--	2.0	26	5.2	-1	110	27	13	8	190	106	10	30	1.12
	04/17/84	1.08	--	5.5	23	5.9	22	145	31	30	8	70	126	32	18	1.08
	06/13/84	0.16	--	--	--	6.9	84	195	42	22	6	--	146	20	12	1.01
	07/20/84	0.07	--	--	33	7.2	114	--	--	--	--	--	--	--	--	--
Woodland Creek	08/15/83	0.04	--	15.0	28	6.5	12	120	64	26	5	60	147	21	31	1.04
	11/01/83	0.07	--	7.5	27	6.3	26	110	74	30	8	10	145	22	13	1.08
	12/15/83	2.63	--	5.5	15	6.5	11	115	63	22	7	10	125	22	29	1.31
	02/02/84	0.17	--	0.0	33	6.2	20	115	70	26	6	30	142	21	29	1.02
	04/02/84	0.54	--	5.0	25	6.7	24	110	67	22	6	50	133	22	19	1.04
	04/16/84	12.8	--	4.5	20	6.1	14	90	50	13	7	20	110	12	22	1.01
	06/12/84	0.22	--	11.5	23	6.4	28	105	54	17	7	--	131	16	14	0.97
	07/17/84	0.08	--	--	23	6.4	27	--	--	--	--	--	--	--	--	--
Roundout Creek	08/16/83	0.10	--	13.0	27	6.2	24	120	62	30	7	50	146	20	26	1.01
	11/01/83	0.14	--	4.5	28	6.0	12	100	60	22	9	50	146	22	13	0.99
	12/14/83	3.96	--	5.0	26	4.7	-24	70	37	22	9	390	112	16	21	1.06
	02/02/84	0.31	--	0.0	31	5.6	-2	100	61	26	6	130	146	18	30	1.01
	04/03/84	0.76	--	4.0	28	5.4	6	90	55	17	7	30	135	16	24	0.96
	04/17/84	1.90	--	5.5	24	4.8	-10	70	39	13	7	290	133	13	23	0.86
	05/30/84	7.82	--	9.0	25	4.7	-18	60	32	13	8	--	122	8	13	0.93
	06/11/84	0.48	--	15.5	23	5.2	4	85	46	17	6	--	138	13	14	0.91
	07/17/84	0.06	--	--	24	5.5	2	--	--	--	--	--	--	--	--	--
Beaver-kill River	11/03/83	0.10	--	--	36	7.0	140	260	47	22	7	<10	152	20	21	1.01
	12/15/83	2.66	--	4.0	23	6.1	26	180	35	13	5	60	139	15	23	1.15
	01/31/84	0.19	--	0.0	37	6.6	82	240	51	17	5	20	156	17	34	1.08
	04/02/84	0.57	--	4.0	34	6.5	80	220	43	13	5	60	146	16	22	1.06
	04/16/84	28.3	--	4.5	20	5.8	16	130	25	9	7	130	112	9	26	1.05
	06/13/84	0.37	--	14.5	36	7.6	110	210	42	13	5	--	145	12	14	0.96
	07/19/84	0.10	--	--	34	7.2	134	--	--	--	--	--	--	--	--	--

Appalachian-Piedmont Region

Laurel Ridge Area, Allegheny Mountains, Pennsylvania

Principal Investigator: James Barker, U.S. Geological Survey, P.O. Box 1107, Harrisburg, Pennsylvania 17108.

This project was initiated in August 1983 on six low alkalinity streams in southwest Pennsylvania (Laurel Ridge). Unanticipated clearcutting in the watershed of Gross Run has necessitated the elimination of that stream as of July 1984. The region is underlain by sandstone formations, with sandy and silty loam soils. A reconnaissance of the entire Laurel Ridge area preceded selection of the monitored streams. The watersheds are not pristine but are probably as near an undisturbed condition as can be found in that part of the United States.

There are no NADP precipitation sites in the immediate vicinity of Laurel Ridge. The Geological Survey, however, operates a wet-dry sampler, following NADP procedures, at the Ben's Creek sampling site. Data for 1982 from the Parsons, West Virginia, NADP site (Table 2), approximately 112 km to the south, show an average pH of 4.31 and sulfate deposition of 40.1 kg/ha (a very high value). Average 1982 values for pH and sulfate deposition from the Leading Ridge, Pennsylvania, NADP site (Table 2), about 100 km east of Laurel Ridge, are 4.16 and 36.6 kg/ha, respectively. Data from the Ben's Creek station for the period September 1983-June 1984 show weekly pH values ranging between 3.9 and 4.7. Averages and deposition values are not yet available.

Locational and chemical data for the Laurel Ridge streams appear in Tables 19 and 20. As noted previously, these are Geological Survey data which must be considered provisional and subject to revision, according to USGS procedure and policy.

TABLE 19

STREAMS MONITORED IN THE LAUREL RIDGE AREA OF PENNSYLVANIA

Stream	Latitude (°N)	Longitude (°W)	Drainage Area (ha)	Flow Range (m^3/sec)
South Fork Bens Creek	40°13'41"	79°02'49"	8.5	0.01-0.51
North Fork Bens Creek	40°16'21"	78°58'43"	8.9	0.01-0.40
North Branch Quenahoning Creek	40°06'38"	79°08'04"	6.9	<0.01-0.62
Gross Run	40°01'55"	79°13'30"	3.0	<0.01-0.60
Cole Run	39°58'00"	79°17'25"	3.2	<0.01-0.26
Garys Run	39°58'25"	79°17'51"	3.4	<0.01-0.26

TABLE 20

CHEMICAL CHARACTERISTICS OF LAUREL RIDGE, PENNSYLVANIA, STREAMS

Stream	Date	Flow m^3/sec	Temp. (°C)	Sp. Cond. (µS/cm @ 25°C)	pH (field)	µeq/l ANC	Ca	Mg	Na	K	Al µg/l	µeq/l SO_4	Cl	NO_3	+/-
N. Fork Bens Creek	08/02/83	0.01	18.0	46	6.1	21	185	82	91	14	80	189	166	11	0.96
	09/13/83	0.05	16.0	46	6.3	35	205	91	113	15	10	189	141	9	1.13
	10/18/83	0.01	10.0	44	6.3	52	185	82	74	9	60	179	24	4	1.35
	11/16/83	0.34	5.0	46	5.7	17	205	91	61	19	70	250	82	10	1.05
	12/20/83	0.19	1.0	44	5.0	--	90	53	22	13	460	208	37	8	--
	01/17/84	0.03	0.5	45	6.0	41	175	81	87	16	60	192	121	5	1.00
	02/23/84	--	3.0	46	5.5	-2	165	82	70	17	120	206	110	--	--
	03/29/84	0.40	3.5	44	5.4	-3	165	81	61	16	210	229	76	--	--
	04/24/84	0.37	6.5	44	5.6	-9	170	82	44	16	110	208	79	--	--
North Branch Quemahoning Creek	08/02/83	0.004	19.0	33	4.6	--	75	46	22	12	300	181	31	4	
	09/13/83	0.03	16.5	34	4.6	--	80	59	48	17	220	183	37	--	
	10/18/83	0.003	10.0	34	4.8	--	80	59	39	20	240	189	31	<1	
	11/16/83	0.40	7.0	47	4.7	--	245	90	57	20	40	250	39	13	
	12/20/83	0.10	0.0	39	4.5	--	175	77	78	17	80	200	102	--	
	01/18/84	0.03	0.5	36	4.7	--	90	60	26	10	580	204	31	6	
	02/23/84	0.20	3.0	40	4.6	--	90	53	22	13	690	229	31	--	
	03/29/84	0.62	2.5	41	4.6	--	90	51	22	12	840	229	24	--	
	04/26/84	0.31	5.5	40	4.6	--	90	53	17	13	750	208	26	--	
Gross Run	08/03/83	0.001	17.5	33	4.5	--	75	49	17	13	400	183	27	3	
	09/14/83	0.001	14.0	32	4.5	--	70	48	35	13	320	183	31	2	
	10/19/83	0.02	10.0	44	4.7	--	105	55	30	24	650	229	37	4	
	11/23/83	0.12	7.5	41	4.6	--	125	73	35	16	730	271	39	--	
	01/18/84	0.02	0.5	36	4.6	--	75	45	22	10	80	196	31	5	
	02/22/84	0.09	3.0	39	4.6	--	80	45	22	11	740	200	26	--	
	03/28/84	0.13	4.5	36	4.6	--	75	45	17	12	730	200	21	--	
	04/25/84	0.16	6.0	38	4.6	--	75	44	13	11	780	200	22	--	
Gary's Run	08/03/83	0.005	16.0	29	6.4	60	120	91	26	12	80	158	31	6	0.98
	09/14/83	0.002	14.0	32	6.8	47	120	82	39	11	20	148	24	5	1.12
	10/19/83	0.01	9.0	31	6.1	28	120	91	30	28	70	167	28	5	1.18
	11/22/83	0.16	7.0	38	5.0	-1	115	72	30	15	600	229	31	11	0.89
	01/19/84	0.008	0.0	11	5.8	30	115	91	22	11	110	183	29	7	0.96
	02/22/84	0.09	3.0	32	5.3	2	105	82	17	13	450	198	25	--	--
	03/28/84	0.15	4.5	32	5.2	-6	100	79	13	12	400	204	21	--	--
	04/25/84	0.26	5.5	34	4.9	--	95	72	13	12	610	208	19	--	--
Cole Run	08/03/83	0.001	17.5	32	4.6	--	80	60	17	12	320	194	27	3	
	09/14/83	0.001	16.0	28	4.5	--	85	63	30	12	250	200	25	3	
	10/19/83	0.03	10.0	44	4.8	--	125	91	30	41	420	271	50	1	
	11/22/83	0.13	7.0	41	4.7	--	100	45	26	12	850	250	31	--	
	01/19/84	0.003	0.0	32	4.8	--	80	55	30	9	440	198	26	3	
	02/22/84	0.11	3.0	36	4.6	--	80	53	26	10	720	208	25	--	
	03/28/84	0.14	4.5	36	4.7	--	80	53	13	9	680	208	23	--	
	04/25/84	0.26	5.5	37	4.6	--	--	--	--	--	--	--	--	--	
S. Fork Bens Creek	08/02/83	0.01	18.0	46	6.3	134	230	91	30	20	80	144	31	7	1.17
	09/13/83	0.02	17.5	50	7.0	223	304	115	70	26	10	171	31	10	1.18
	10/20/83	0.01	8.5	58	7.0	218	344	140	48	5	20	229	37	4	1.12
	11/17/83	0.18	6.5	46	6.5	50	309	132	65	28	90	354	42	10	1.17
	12/21/83	0.16	2.5	34	6.3	--	160	79	35	19	30	164	39	18	--
	01/17/84	0.07	1.5	39	6.5	187	190	82	26	17	30	171	31	13	0.78
	02/21/84	0.57	7.0	36	6.0	21	150	80	22	19	50	179	28	--	--
	03/27/84	0.45	9.0	36	6.3	24	150	81	17	18	20	175	25	--	--
	04/24/84	0.51	8.5	34	6.2	28	155	82	17	17	20	173	25	--	--

Sandhills Area, North Carolina

Principal Investigator: Kent Crawford, U.S. Geological Survey, P.O. Box 2857, Raleigh, North Carolina 27602.

The USGS report on the Sandhills sites, with the exception of the tabulated data, was not received in time for inclusion in this report. The project began in September 1983 on five streams in the Sandhills Region of south-central North Carolina. The area is characterized by deep highly-sandy soils covered predominantly by pine and scrub oak. Waters tend to be colored and of low pH.

NADP sites at Piedmont Station (about 100 km west-northwest) and at Clinton Station (about 100 km east) (Table 2) bracket the study area. In addition, the Geological Survey initiated an NADP site at Jordan Creek in October 1983. Average 1982 pH and sulfate deposition at Piedmont Station were 4.35 and 29.1 kg/ha, respectively, and at Clinton Station 4.53 and 21.2. Average weekly pH values from the Jordan Creek station ranged from 3.97 to 6.90 between October 1983 and June 1984.

Locational and chemical data for the Sandhills streams are given in Tables 21 and 22. Again, these USGS data are provisional and subject to revision.

Southern Blue Ridge Province (Tennessee, North Carolina, Georgia)

Principal Investigator: Harvey Olem, Tennessee Valley Authority, 248 401 Building, Chattanooga, Tennessee 37401.

Fifty-four reservoirs were surveyed by TVA in 1982-83 in this southern Appalachian region. Twelve were selected for long-term monitoring to provide a range of alkalinity, color, elevation, surface area, and drainage area. Because of the absence of natural lakes in most of the Southeast, reservoirs are predominant and important components of the aquatic environment and economy.

TABLE 21

STREAMS MONITORED IN THE SANDHILLS AREA OF NORTH CAROLINA

Stream	Latitude (°N)	Longitude (°W)	Surface Area (ha)	Elevation (m)
Suck Creek	35°20'17"	79°33'57"	~1.9	<0.01-0.07
Mill Creek	35°09'23"	79°22'04"	~0.5	<0.01-0.01
White Cedar Branch	35°05'45"	79°34'58"	1.1	0.01-0.02
Joe's Creek	35°04'49"	79°35'58"	~1.3	0.01-0.03
Deep Creek	35°11'57"	79°32'45"	0.6	<0.01-0.01
Jordan Creek	34°58'12"	79°31'34"	~0.3	0.01-0.03

TABLE 22

CHEMICAL CHARACTERISTICS OF NORTH CAROLINA SANDHILLS STREAMS

Stream	Date	Inst. Flow (m^3/sec)	Temp. (°C)	Sp. Cond. (µS/cm @ 25°C)	pH (field)	µeq/l ANC	µeq/l Ca	µeq/l Mg	µeq/l Na	µeq/l K	Al µg/l	µeq/l SO_4	µeq/l Cl	µeq/l NO_3
Suck Creek Tributary	10/24/83	0.03	--	24	4.3	--	--	--	--	--	--	--	--	--
	11/14/83	0.03	--	25	5.8	--	80	107	130	33	30	200	76	1
	12/19/83	1.20	--	26	4.5	--	39	54	83	20	120	98	70	1
	01/23/84	2.30	--	20	5.2	--	26	52	61	15	120	73	59	1
	02/13/84	1.10	--	17	5.7	--	30	55	61	15	70	73	61	--
	04/09/84	2.20	--	18	5.7	--	24	46	52	16	80	58	42	--
	06/04/84	0.58	--	17	5.8	--	26	41	57	14	30	49	55	--
Mill Creek Tributary	09/21/83	0.09	--	11	4.2	--	--	--	--	--	--	--	--	--
	10/24/83	0.09	--	30	4.2	--	--	--	--	--	--	--	--	--
	11/15/83	0.11	--	17	4.5	--	11	26	83	6	80	19	102	1
	12/21/83	0.10	--	16	4.4	--	8	21	78	4	110	17	98	1
	01/25/84	0.25	--	18	4.5	--	8	28	78	4	110	23	105	1
	02/15/84	0.29	--	19	4.5	--	12	28	87	7	160	33	107	--
	04/11/84	0.29	--	19	4.5	--	9	24	78	4	80	29	73	--
	06/06/84	0.21	--	18	4.5	--	10	25	74	3	90	17	86	--
Jordan Creek	09/20/83	0.25	--	13	3.6	--	--	--	--	--	--	--	--	--
	10/25/83	0.29	--	28	3.6	--	--	--	--	--	--	--	--	--
	11/16/83	0.30	--	19	3.4	--	7	21	44	3	80	27	44	1
	12/20/83	0.33	--	16	4.4	--	6	10	49	6	80	19	41	--
	01/24/84	0.33	--	18	4.5	--	4	10	39	5	70	25	40	1
	02/14/84	1.20	--	42	4.0	--	18	42	39	10	420	50	32	--
	04/10/84	0.72	--	22	4.4	--	8	15	39	4	130	37	32	--
	06/05/84	0.36	--	15	4.5	--	6	12	35	2	10	18	42	--
White Cedar Br.	09/22/83	0.44	--	6	3.7	--	--	--	--	--	--	--	--	--
	10/25/83	0.35	--	18	4.2	--	--	--	--	--	--	--	--	--
	11/15/83	0.46	--	11	4.2	--	9	22	57	6	50	12	45	5
	12/20/83	0.47	--	15	4.3	--	9	17	61	5	70	12	49	5
	01/24/84	0.53	--	18	4.5	--	7	18	52	6	70	15	45	5
	02/14/84	0.61	--	20	4.5	--	12	28	52	7	230	27	42	--
	04/10/84	0.77	--	15	4.5	--	10	19	48	6	20	21	35	--
	06/05/84	0.57	--	14	4.6	--	7	15	48	3	10	12	44	--
Joes Brook	09/20/83	0.56	--	12	3.7	--	--	--	--	--	--	--	--	--
	10/25/83	0.53	--	12	4.3	--	--	--	--	--	--	--	--	--
	11/15/83	0.56	--	12	4.3	--	9	17	44	4	80	17	46	1
	12/20/83	0.51	--	25	4.2	--	8	14	44	5	100	21	45	1
	01/24/84	0.59	--	12	4.4	--	7	19	39	4	90	25	43	1
	02/14/84	1.20	--	24	4.4	--	22	39	44	7	350	48	38	--
	04/10/84	1.10	--	17	4.5	--	11	18	39	5	120	35	32	--
	06/05/84	0.96	--	14	4.4	--	12	21	35	4	60	25	32	--
Deep Creek Tributary	09/21/83	0.13	--	24	3.7	--	--	--	--	--	--	--	--	--
	10/24/83	0.16	--	42	3.8	--	--	--	--	--	--	--	--	--
	11/14/83	0.10	--	17	4.3	--	6	11	39	2	90	17	46	1
	12/19/83	0.28	--	24	4.2	--	8	12	52	6	190	21	45	1
	01/23/84	0.39	--	23	4.0	--	5	14	48	7	170	25	43	--
	02/13/84	0.24	--	20	4.3	--	4	13	39	3	180	49	38	--
	04/09/84	0.41	--	21	4.3	--	6	15	35	3	150	35	32	--
	06/04/84	0.21	--	20	4.3	--	5	13	35	3	110	25	32	--

The Southern Blue Ridge Province is located in the eastern portion of the Tennessee Valley and includes sections of Georgia, North Carolina, Tennessee, and Virginia. The Unaka Mountains, Iron Mountains, and Great Smoky Mountains straddle the North Carolina-Tennessee border on the western front and the Blue Ridge Mountains lie along the Basin Divide on the eastern front. The region contains two major groups of geological formations: crystalline rocks of Precambrian age consisting mainly of gneisses and schists cut by later series of granites, pegmatites, and basic intrusives; and highly-metamorphosed sedimentary rocks of the Cambrian period, principally slates, quartzites, conglomerates, sandstones, graywacks, and marble. Neither of these formations render significant buffering capacity to area surface waters.

The 1982 average pH and sulfate deposition values for the three NADP sites representing the reservoir monitoring area (Table 2) were: Elkmont, Tennessee -- pH 4.66, sulfate 21.7 kg/ha; Walker Branch, Tennessee -- pH 4.33, sulfate 36.9 kg/ha; and Coweeta, North Carolina -- pH 4.66, sulfate 23.6 kg/ha. Data from the four TVA precipitation sites will be available for future reports.

Locational and chemical data for the twelve monitored reservoirs are given in Tables 23 and 24. Chemical data for all 54 survey reservoirs appear in Table 25.

TABLE 23

RESERVOIRS MONITORED IN THE SOUTHERN APPALACHIANS
(NORTH CAROLINA, TENNESSEE, GEORGIA)

State	Lake	Latitude (°N)	Longitude (°W)	Surface Area (ha)	Elevation (m)
Georgia	Blue Ridge	34°52'54"	84°16'47"	1332	515
	Winfield Scott	34°44'25"	83°58'28"	6	875
North Carolina	Chatuge	35°01'01"	83°47'30"	2854	587
	Ravenel (Cull R.)	35°04'55"	83°09'56"	5	1177
	Santeetlah	35°22'37"	83°52'34"	1154	591
	Wolf Creek	35°16'05"	82°58'10"	2	1073
	Logan	35°25'14"	82°55'32"	39	887
	Mars Hill	35°56'44"	82°29'39"	2	1158
	Thunder	35°07'57"	82°39'46"	20	899
Tennessee	Miller	36°10'42"	82°09'23"	3	1097
	Price	36°08'18"	81°43'55"	15	1030
	Watauga	36°19'12"	82°07'31"	2603	597

TABLE 24

CHEMICAL CHARACTERISTICS OF SOUTHERN APPALACHIAN RESERVOIRS SELECTED FOR MONITORING

Reservoir	Date	Temp. (°C)	Sp. Cond. (µS/cm @ 25°C)	pH (field)	µeq/l ANC	Ca	Mg	Na	K	Al µg/l	µeq/l SO_4	Cl	NO_3	Color (true) (PCU)	+/-
Blue Ridge	10/82	19.7	15	6.00	150	50	39	44	15	<50	25	25	2	3	0.73
	04/83	11.1	13*	6.10	100	44	37	41	14	<50	25	25	4	6	0.88
Chatuge	10/82	19.0	15	5.90	130	70	53	48	16	<50	27	31	3	4	0.98
	04/83	11.2	13	6.40	100	55	46	52	16	<50	27	28	6	6	1.05
Winfield Scott	10/82	14.5	19	6.10	150	80	59	48	17	<50	27	28	6	12	0.95
Ravenal (Culla.	10/82	11.7	21	5.90	80	85	45	44	25	<50	67	45	4	90	1.02
R.)	04/83	8.5	19	6.20	70	80	39	52	10	<50	56	48	8	31	0.99
Santeetlah	10/82	19.2	20	6.00	100	80	39	36	13	<50	31	20	4	5	1.08
	04/83	10.4	13*	6.60	80	60	35	52	12	<50	29	20	5	2	1.19
Wolf Creek	04/83	4.9	18	5.80	110	26	20	29	8	<50	17	18	3	3	0.60
Logan	04/83	13.5	22	5.52	50	38	30	33	10	<50	25	14	11	4	1.10
Mars Hill	10/82	13.1	21	5.85	110	70	42	44	13	<50	25	20	2	23	1.08
	04/83	6.1	17	5.06	70	60	32	39	12	<50	17	17	18	6	1.17
Thunder	04/83	11.5	13	4.65	20	12	12	27	5	<50	33	17	<1	23	0.80
Miller	10/82	10.6	28	6.01	180	130	33	57	13	<50	29	20	2	50	1.01
Price	10/82	9.5	23	6.37	120	85	35	52	14	<50	31	37	1	32	1.00
Watauga (0.5 meters)	10/82	17.1	73	6.67	500	344	296	91	36	<50	108	73	40	2	1.06
Watauga (40 meters)	10/82	8.7	76	6.23	510	344	296	91	36	<50	108	76	40	2	1.04

* Field value missing; lab value shown.

TABLE 25

CHEMICAL CHARACTERISTICS OF SOUTHERN APPALACHIAN RESERVOIRS

Reservoir	Date	Temp. (°C)	Sp. Cond. (µS/cm @ 25°C)	pH (field)	µeq/l ANC	Ca	Mg	Na	K	Al µg/l	µeq/l SO_4	Cl	NO_3	Color (true) (PCU)	+/-
Apalachia	10/82	18.4	25	6.20	160	110	63	57	20	<50	42	34	13	2	1.00
Blue Ridge	10/82	19.7	15	6.00	150	50	39	44	15	<50	25	25	2	3	0.73
	04/83	11.1	13*	6.10	100	44	37	41	14	<50	25	25	4	6	0.88
Chatuge	10/82	19.0	15	5.90	130	70	53	48	16	<50	27	31	3	4	0.98
	04/83	11.2	13	6.40	100	55	46	52	16	<50	27	28	6	6	1.05
Hiwassee	10/82	19.6	25	6.10	160	110	63	61	17	<50	44	31	8	2	1.03
	04/83	12.0	19	6.60	120	90	53	52	13	<50	35	56	11	6	0.94
Winfield Scott	10/82	14.5	19	6.10	150	80	59	48	17	<50	27	28	6	12	0.95
Nottely	10/82	19.8	25	5.90	130	85	57	87	23	<50	40	62	2	7	1.08
Woody	10/82	13.2	20	6.10	130	70	50	57	61	<50	31	51	7	17	1.09
Brush Creek	04/83	9.0	19	6.20	10	6	17	30	8	<50	21	23	2	9	1.09
Calderwood	10/82	17.1	20	5.80	150	85	50	48	14	<50	37	25	9	2	0.89
Cheoah	10/82	17.5	20	5.70	150	90	52	48	14	<50	33	23	8	2	0.95
Chilowee	10/82	17.1	25	5.90	150	105	54	52	15	<50	50	25	10	2	0.96
	04/83	10.9	43	6.60	120	85	48	52	15	<50	40	23	7	6	1.05
Cliffside	10/82	13.4	10	5.90	40	24	21	32	10	<50	19	20	<1	33	1.10
Club	04/83	8.5	23	6.30	80	90	41	83	37	<50	50	79	21	37	1.09
Falls Branch	04/83	11.5	39	6.60	160	95	61	52	14	<50	23	25	3	9	1.05
Fontana	10/82	20.3	20	5.90	120	75	44	61	14	<50	35	23	7	4	1.05
Higdon	04/83	9.0	11	6.30	60	39	26	41	8	<50	21	28	19	8	0.89
Sequoyah	10/82	13.4	18	6.00	70	75	33	61	19	<50	42	48	7	50	1.13
Mirror	10/82	12.9	19	5.90	90	110	73	48	15	<50	46	56	8	50	1.23
Moore No. 1	10/82	12.3	20	6.10	170	95	73	48	15	<50	35	23	<1	16	1.01
Moore No. 2	10/82	11.7	20	6.00	130	90	72	48	13	<50	29	23	1	9	1.22
Nantahala	10/82	18.3	12	6.00	90	55	39	32	9	<50	21	17	1	5	1.05
	04/83	10.4	12	6.15	60	43	32	31	8	<50	19	17	1	3	1.18
Queens	10/82	16.1	23	6.30	240	165	67	44	14	<50	27	17	1	5	1.02
	04/83	10.5	18	6.50	140	80	42	33	9	<50	23	14	<1	3	0.93
Ravenel (Culla. R.)	10/82	11.7	21	5.90	80	85	45	44	25	<50	67	45	4	90	1.02
	04/83	8.5	19	6.20	70	80	39	52	10	<50	56	48	8	31	0.99
Ravenel (Mill Cr.)	04/83	8.0	15	6.00	30	28	28	39	8	<50	42	34	3	14	0.94
Santeetlah	10/82	19.2	20	6.00	100	80	39	36	13	<50	31	20	4	5	1.08
	04/83	10.4	13*	6.60	80	60	35	52	12	<50	29	20	5	2	1.19
Thorpe	10/82	16.9	15	6.00	70	55	26	48	12	<50	21	39	1	6	1.08
	04/83	10.2	15	5.90	60	45	26	52	11	<50	25	34	10	6	1.04
Unnamed (Allens Br.)	04/83	20.0	26	6.80	150	105	61	74	59	<50	42	37	33	14	1.14
Watkins Cr.	04/83	8.5	6*	5.10	30	12	18	20	5	<50	21	14	1	2	0.83
Webb	04/83	9.0	10	5.80	20	21	18	27	6	<50	25	20	5	14	1.03
Wolf Creek	04/83	4.9	18	5.80	110	26	20	29	8	<50	17	8	3	3	0.60
Assembly	04/83	17.1	28	6.42	110	75	27	57	10	<50	27	23	<1	6	1.06
Banks	10/82	15.6	15	5.40	70	22	15	52	12	<50	9	23	<1	26	0.99
Boot	04/83	10.3	16	5.52	40	9	11	38	6	<50	17	17	<1	3	0.86
Burnett	04/83	13.1	25	6.10	60	48	36	32	9	<50	40	20	14	1	0.93
Deer Park	04/83	14.6	31	6.21	130	70	77	61	11	<50	37	31	1	6	1.10
Flat Top	10/82	12.5	20	5.87	130	48	29	57	15	<50	12	25	1	23	0.89
Jeffers	10/82	13.9	23	5.65	180	80	15	74	19	<50	19	37	<1	12	0.80
Arrowhead	10/82	13.0	16	5.03	60	41	22	36	12	<50	27	20	<1	55	1.04
Junaluska	04/83	9.3	49	6.80	200	145	197	87	22	<50	167	51	37	11	0.99
Logan	04/83	13.5	22	5.52	50	38	30	33	10	<50	25	14	11	4	1.10
Long	10/82	13.9	13	4.91	60	33	14	42	10	<50	12	23	<1	20	1.04
Mars Hill	10/82	13.1	21	5.85	110	70	42	44	13	<50	25	20	2	23	1.08
	04/83	6.1	17	5.06	70	60	32	39	12	<50	17	17	18	6	1.17
Sayler	04/83	15.4	62	7.58	360	225	206	100	25	<50	85	96	14	6	1.00
Thunder	04/83	11.5	13	4.65	20	12	12	27	5	<50	33	17	<1	23	0.80
Unnamed (N. Toe R.)	04/83	15.4	37	6.09	200	110	107	70	13	<50	33	37	3	6	1.10
Miller	10/82	10.6	28	6.01	180	130	33	57	13	<50	29	20	2	50	1.01
Price	10/82	9.5	23	6.37	120	85	35	52	14	<50	31	37	1	32	1.00
Ripshin	10/82	11.3	33	6.02	230	150	53	78	17	<50	29	25	<1	25	1.05
Sims Pond	10/82	7.3	28	5.98	100	105	36	65	13	<50	23	76	2	37	1.09
Unnamed (Lance Cr.)	10/82	8.4	28	6.28	200	90	77	52	15	<50	15	39	<1	34	0.92

(continued)

CHEMICAL CHARACTERISTICS OF SOUTHERN APPALACHIAN RESERVOIRS (continued)

Reservoir	Date	Temp. (°C)	Sp. Cond. (µS/cm @ 25°C)	pH (field)	µeq/l ANC	Ca	Mg	Na	K	Al µg/l	µeq/l SO_4	Cl	NO_3	Color (true) (PCU)	+/-
Unnamed	10/82	7.7	22	5.49	20	38	19	70	8	<50	42	79	1	42	0.95
(Boone Fk.)	04/83	15.9	27	5.35	30	46	23	87	7	<50	29	104	4	8	0.98
Upper Lance Cr.	10/82	8.4	26	6.23	120	85	47	57	18	<50	25	45	1	34	1.08
Watauga (0.5 meters)	10/82	17.1	73	6.67	500	344	296	91	36	<50	108	73	40	2	1.06
Watauga (40 meters)	10/82	8.7	76	6.23	510	344	296	91	36	<50	108	76	40	2	1.04
Wilbur	10/82	9.3	78	6.74	560	394	313	87	33	<50	121	71	40	3	1.04

* Field value missing; lab value shown.

Appendix I. Sampling and Analysis Protocol for Long-Term Chemical Monitoring of Lakes and Streams Relative to Effects of Acidic Deposition.

(Note: For the EPA Long-Term Surface Water Monitoring Program, this protocol has been replaced by the "Working Protocol" presented as Appendix IV).

NOTICE

This document is a preliminary draft. It has not been formally released by the U.S.E.P.A. and should not at this stage be construed to represent Agency policy. It is being circulated for comment on technical accuracy and policy implications.

SAMPLING AND ANALYSIS PROTOCOL FOR LONG-TERM CHEMICAL MONITORING OF LAKES AND STREAMS RELATIVE TO EFFECTS OF ACIDIC DEPOSITION

prepared for

The Aquatic Effects Task Group
Interagency Task Force on Acid Precipitation

Revised March 1984

The program for long-term monitoring of the nation's surface waters had its inception in July 1982, when an ad hoc committee from NAPAP Task Group E (Aquatic Effects of Acid Precipitation) was organized to scope out a national program and develop a standardized sampling/analysis protocol for chemical monitoring. The committee, with representation from EPA, USGS, TVA, USDA-FS, USFWS, USNPS, and Brookhaven National Laboratory, produced a draft protocol in January 1983 entitled "Sampling and Analysis Protocol for Chemical Characteristics of Lakes and Streams Sensitive to Acidic Deposition." The draft document was circulated widely for peer review. The present revision has been guided by the many thoughtful and helpful comments which were received. In addition, the recent development of the "Methods Manual for the National Surface Water Survey -- Phase I" (Hillman et al., undated), has provided further guidance. This revision attempts to achieve compatibility with the survey protocol to the extent possible.

This monitoring protocol addresses measurements to be made, selection of study sites (Appendix B), sampling protocols, sample storage and preservation, analytical methods, quality assurance, and data management. Consideration of these topics is limited here to studies of water chemistry only. We recognize also the need for concurrent biological studies in long-term monitoring programs where the primary objective is detection of ecosystem change. Approaches to biological monitoring in lakes and streams were considered at an

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EPA-sponsored workshop, and work on a protocol is being pursued by another group.

Those primarily responsible for the content of the original version of the protocol were Owen Bricker, U.S. Geological Survey; George Hendrey, Brookhaven National Laboratory; Raymond Herrmann, U.S. National Park Service; Vance Kennedy, U.S. Geological Survey; Harvey Olem, Tennessee Valley Authority; Charles Powers, U.S Environmental Protection Agency; Arthur Schipper, U.S. Department of Agriculture -- Forest Service; and Kent Schreiber, U.S. Fish and Wildlife Service.

We thank the many other persons who contributed their expertise during the evolution of this protocol, and those who provided reviews.

I. Measurements

A. Fundamental Variables

The variables to be measured depend in part on the objectives of the study. For general monitoring, the following measurements provide sufficient characterization of stream or lake water quality for assessment of sensitivity and changes related to acidification:

pH	true color
total alkalinity	Ca, Mg, Na, K, Al
specific conductance	SO_4, NO_3, Cl
temperature	secchi disc transparency (lakes)

These "core" measurements provide documentation of the status of a stream or lake. Buffering capacity and acidity are determined by measurement of pH, alkalinity, and conductivity. Presence of color may indicate natural acidity (as well as possible interferences in sulfate determination), and presence of naturally-occurring chelators. Measurement of the major ions provides data for modeling exercises, cation-anion balance calculations, and indication of strong acids.

Aluminum is the metal of greatest concern because of its role as a toxicant and buffer. General agreement does not exist as to the form of aluminum most appropriate for measurement in monitoring and survey programs. Choices include total aluminum, total soluble aluminum, and extractable aluminum. Total aluminum is a gross measurement that includes both dissolved and particulate forms, a

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great deal of which is non-reactive. Dissolved aluminum entails filtration, ideally through a 0.1 μm filter to retain the maximum amount of particulate material, which can be extremely difficult in some waters. Determination of extractable aluminum does not require that degree of filtration, and yields a useful approximation of the quantity of reactive aluminum present. Procedures for determination of both the total soluble and extractable forms are given in this document.

B. Additional Variables

It was the opinion of a number of the contributors to this document that long-term monitoring studies should include additional measurements to provide an understanding of the processes involved in observed changes and to facilitate relation of those changes in water chemistry to observed effects on biota. These measurements largely focus on metals and metals chemistry. The recommended additions are:

Mn	Total P (dissolved)
Fe	DOC (dissolved organic carbon)
SiO_2	ammonia
F	weak and strong acidity

(Note: all metals determinations are for the dissolved forms; see Section III).

These additional measurements, together with the core set, were considered to constitute a minimal group for evaluation of geochemical kinetics and toxicity at extended study sites. Information on aluminum together with silica is necessary to understand silicate mineral weathering and precipitation processes. There is some evidence that manganese may be toxic to biota at levels observed in acidified waters. Both dissolution and precipitation of iron and manganese oxides may have significant effects on the concentrations of other metals. Fluoride, phosphate, and DOC are important in complexing aluminum and hence affect its action as a toxic agent.

These additions add to the complexity and expense of a monitoring program and would have to be carefully justified in terms of the use for which the data were intended. Process studies imply use of

calibrated watersheds, with development of input-output budgets; monitoring sites do not have to be this elaborate. Systematic measurement of the core variables can yield useful information on changes in lakes and streams related to acidic deposition. The additional variables allow investigation and interpretation of the processes associated with these changes, but are not necessary for detection of the change itself. Consequently, some monitoring efforts will include all or some of the additional protocol, while others will consist of the core measurements only. Programs following the latter course would be able to add collection of additional information in the event that biotic effects, for example, began to appear.

II. Selection of Study Sites (see Appendix B)

A. A detailed written description of each site is required. This should include catchment area, bedrock geology and soil class(es) of the watershed, stream order, mean annual discharge of stream, size of lake or pond (area, depth, volume), residence time of lake or pond (if known), whether seepage or flow-through, altitude of site, general existing land use in watershed, and available historical data on land use and water quality. In the field, any recent changes in land use should be noted, together with an estimate of percent of bedrock exposure in the watershed, and descriptions of any other features such as pollution sources, old mine workings, and nearby emission sources. (Such features, of course, would probably eliminate the site as a monitoring location). Detailed geologic and soils maps should be made for extended study sites, if such maps are not otherwise available. Meteorological features should also be noted, including mean annual precipitation, percent precipitation as snowfall, evaporation and transpiration, and air temperature.

B. Lake Monitoring

Each long-term lake monitoring project will consist of a set of lakes located in the same geographical area, in geologically similar conditions, exposed to essentially the same precipitation regime. They should be "headwater" lakes, selected to provide a range of

alkalinity values representative of the area, with average total alkalinity values less than 200 μeq/l. Lakes in the 200-500 μeq/l alkalinity range, while less sensitive, should be included for comparison with those of lower alkalinities. This can be particularly important with respect to fish populations, where decreases in numbers could result from causes other than acidification.

C. Stream Monitoring

Monitoring is more complex for streams than for lakes because of the influence of discharge and season. Base flow tends to display uniform, representative composition, but storm flow and snowmelt runoff may significantly alter stream chemistry. Some recent observations have shown severe pH depressions in streams following storm events, after which conditions return to base flow conditions. Proper stream monitoring, therefore, requires continuous recording of flow and sampling over a complete range of discharge. This should include sampling during and following storm events and snowmelt. This may necessitate the use of automated sampling equipment, the occurrence of meteorological events often being difficult or impossible to anticipate sufficiently far ahead of time to permit adequate manual sampling.

III. Sampling and Analysis

A. Streams

1. General

Sampling will be confined to headwaters. No attempt is made here to specify order of stream; selection should be a function of the particular area of interest. Large streams and rivers are poor sites because the effects of acidic deposition are frequently masked downstream by the mixing of waters from various tributaries and by other riverine processes.

As previously pointed out, the chemistry of streams is strongly influenced by discharge and season. Base flow usually displays the most uniform composition and represents water that has had maximum interaction with watershed materials. For survey purposes, sampling of base flow may be adequate, but in

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monitoring samples should also be taken during events (storm, snowmelt) to provide information on changes in stream chemistry as a function of discharge and of season. A range of flows and seasons should be sampled.

2. Sampling

Streams should be sampled according to the following procedures (which apply to grab sampling only, not automatic sampling):

(a) Measure or estimate stream discharge at time of sampling, and note whether rising or falling.

(b) Collect sufficient sample for requirements listed below from mid-depth of main flow channel. Rinse container thoroughly three times with stream water before taking sample.

(c) Pour appropriate amount of sample into plastic beaker for pH measurement.

(d) Record temperature and measure pH in the field as soon after sampling as possible.

(e) Obtain sample for anion analysis (including SO_4, NO_3, Cl): Rinse a 250 ml (acid washed and distilled water rinsed) polyethylene bottle (see Section IV) three times with sample water which has been filtered directly into the sample bottle (discarding each rinse). Then fill to 250 ml with filtered sample. Use a 0.45 μm pore size membrane filter (e.g., Nucleopore polycarbonate). If filtration cannot be done in the field, samples should be iced or refrigerated immediately and filtered in the laboratory as soon as possible. A good portable unit for filtering samples at field sites is described by Kennedy *et al.* (1976).

(f) Obtain sample(s) for metals analyses (including Ca, Mg, Na, K: Filter 100 ml of sample into an acid-washed plastic bottle after rinsing by passing 100 ml of sample through filter and discarding (three times). Add 1 ml ampoule of concentrated ultrapure nitric acid to the

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sample. Ice or refrigerate. For dissolved Al, Mn, and Fe a 0.1 μm pore size filter is recommended to achieve the greatest possible degree of separation of particulate and dissolved material. (In reporting results, always specify filter size, brand, and model number).

(g) PROVISIONAL. Obtain samples for extractable aluminum (reference: Hillman et al.). In the field:

(1) Filter about 60 ml of sample through a 0.45 μm polycarbonate filter.

(2) Rinse a clean plastic 50 ml graduated centrifuge tube with three 10 ml portions of the filtered sample, then fill to the 25.0 ml mark.

(3) Add 2-3 drops phenol-red indicator and 5.0 ml of 8-hydroxy-quinoline sodium acetate reagent.

(4) Add 2.0 ml of the NH_4^+/NH_3 buffer. This should adjust the pH to 8.3 and the solution should turn red. If it does not turn red, rapidly adjust the pH by dropwise addition of 1 M NH_4OH until the solution changes color to red. Add 6.0 ml of methyl isobutyl ketone (MIBK), cap, and shake vigorously for 7-10 seconds using a rapid, end-to-end motion (note: successful extraction depends on good agitation).

(5) Allow the phases to separate (10-15 seconds), then remove the MIBK layer with a 1 ml micropipet, transfer to a 10 ml centrifuge tube, and cap tightly.

See Appendix A for preparation of extractable aluminum reagents.

(h) Sample blanks should be included with every tenth field sample, both acidified and non-acidified, using high quality deionized water (conductivity < 0.1 μmho/cm). For blanks to accompany acidified samples, prepare one acidified deionized water sample and one non-acidified deionized water sample. The total number of blanks of each type should be ≧ 3 for any given "set" of samples.

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B. Lakes

1. General

Lakes should be sampled near their deepest points at least 20 m from shore. If the water column is not thermally stratified, one sample should be collected approximately one-half meter beneath the water surface. If the water body is stratified, one sample should be collected approximately one-half meter beneath the water surface and a second half-way between the thermocline and the lake bottom. A plastic closing sampling device of the Van Dorn type should be used to obtain samples at depth; do not use a metal sampler. A means for measuring subsurface temperature is necessary to locate the thermocline; this requires an instrument capable of *in situ* measurement, such as a thermistor equipped with a sufficiently long lead. Samples should be collected from the sampling device in plastic bottles treated according to the procedure described in Sections III-A and V-A. Near-surface samples can be taken by simply dipping the plastic bottle directly into the lake (taking care not to sample the surface film).

Minimum sampling intervals for lakes are (1) prior to summer stratification (for ice-covered lakes, the period of snowmelt runoff); (2) during summer stratification; and (3) during the completely mixed conditions following summer stratification (fall overturn). Spring sampling of northern lakes during snow-melt is not an easy task. Access to lakes can be difficult, and proper timing is uncertain. However, data from Adirondack lakes show that the period of pH and alkalinity depression during snowmelt may last for approximately two weeks, increasing the probability of obtaining data during that event. The importance of this period in the acidification history of lakes emphasizes the desirability of its inclusion in the sampling schedule.

2. Sampling

Follow steps c - g under "Stream Sampling" (Section III-A-2) for processing of samples.

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IV. Sample Containers

Linear polyethylene bottles with polypropylene [redacted] caps are recommended. Because of the very dilute waters being considered here, and the consequent enhancement of contamination problems, acid rinsing of all bottles used for major ion chemistry samples, as well as for metals samples, is required. All plasticware will be rinsed three times with deionized water, rinsed three times with 3N HNO_3 (prepared from Ultrex HNO_3), then rinsed six times with deionized water. Let stand for 48 hours with deionized water. Empty and refill with deionized water; keep filled until use in field, preferably refrigerated in the dark. Check 10 percent of the containers for adequacy of rinsing by measuring the conductivity; it should be < 2 μmho/cm. If any containers fail the check, rerinse all and retest 5 percent.

V. Sample Preservation and Maximum Holding Times (Reference: USEPA, 1979; Hillman *et al.*)

A. Refrigeration at 4°C is the only recommended method of perservation for the following constituents. (Maximum allowable holding time appears in parentheses.) For present purposes, icing must be considered equivalent to 4°C refrigeration.

- specific conductance (14 days)
- color (48 hr)
- pH (no approved holding time; sample should be analyzed in the field as quickly as possible)
- alkalinity (14 days)
- extractable aluminum (7 days)
- sulfate (28 days) ← Chloride (28 days)
- silica (28 days)
- nitrate-nitrogen (7 days)

B. Refrigeration at 4°C plus acidiication with sulfuric acid to pH < 2 is recommended for the following constituents.

- calcium (6 months)
- magnesium (6 months)
- sodium (6 months)
- potassium (6 months)
- total dissolved phosphorus (28 days)*

ammonium (28 days)*

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VI. Analytical Procedures (Core Measurements)

A. Temperature and pH must be measured immediately upon sampling. (pH may also be air-equilibrated and measured a second time in the laboratory; see below.)

B. pH

1. Field Measurement

pH should be measured to ± 0.02 units using a high quality pH meter with an expanded or digital scale. A good electrode is the Corning No. 476182 glass combination. The electrode should be calibrated in the field in pH 4 and 7 buffer solutions and checked with a sulfuric acid solution with a theoretical pH of 4 (5×10^{-5} molar H_2SO_4). Rinse probe copiously with sample or distilled water and immerse in sample. Do not stir. The electrode should remain in the sample until there is no discernable drift in the pH reading, but no longer than 15 minutes. Upon completion of measurement, recheck pH of acid solution, rinse, and calibrate with buffer. Perform in replicate.

2. Laboratory (Air-Equilibrated) Measurement

For normalization of pH values obtained by various participating investigators, air-equilibrated pH measurements should be obtained in the laboratory. Equilibration is achieved by bubbling samples with standard air containing 300 ppm CO_2 for 20 minutes while stirring on a magnetic stirrer. Use an acid-washed fritted glass diffuser for dispersal of air in the sample. Measure pH immediately following equilibration, following procedure in B-1 (above).

* USGS and NPS preserve with $HgCl_3$.

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3. Specific Conductance (μmho/cm at 25°C)

Measured in the laboratory on a wheatstone bridge type conductivity meter. After calibration and prior to measuring the first sample, measure the conductance of a standard with a theoretical or certified conductance of about 50 μmho/cm (0.0005 M KCl has a conductance of 73.90 μmho/cm at 25°C). It must be prepared from a stock solution which is different from that from which the calibration standard is prepared. If the measured conductivity does not lie within ± 10 percent of the certified value, then restandardize the meter and cell and repeat the measurement.

Remeasure the conductance of the standard at least every 10 samples. If the measured value does not lie within ± 10 percent of the certified value, restandardize the meter and cell, repeat step 1, then reanalyze the previous 10 samples (reference: Hillman et al.).

4. True color. Comparison of centrifuged sample with platinum-cobalt color standards. (Reference: USEPA, 1979)
5. Total alkalinity. Titration with 0.020 N H_2SO_4 using Gran plot calculations. Fixed endpoint titration is not acceptable. (References: Gran, 1950, 1952; Golterman and Clymo, 1969; Zimmerman and Harvey, 1978-1979)
6. Calcium, magnesum, sodium, and potassium. Atomic absorption spectrometry, direct aspiration. (Reference: USEPA, 1979)
7. Sulfate, chloride, nitrate. Ion chromatography.
8. Phosphorus. Colorimetric, automated, block digestor AAII (USEPA, 1979), or USGS colorimetric, phosphomolybdate, automated (Hillman et al.).
9. Ammonia. Colorimetric, automated phenate (USEPA, 1979).
10. Kjeldahl nitrogen. Colorimetric, automated phenate (USEPA, 1979).

VII. Quality Assurance

Quality assurance and quality control procedures regularly followed by each of the participating agencies will be a regular part of that agency's monitoring program. All projects supported by EPA that collect

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environmental data are required to submit a QA/QC plan addressing the following points:

1. The intended use of the data and the associated acceptance criteria for data quality;
2. Description of how precision, accuracy, representativeness, completeness, and comparability will be assessed;
3. Procedures for selection of samples or sampling sites and collection or preparation of samples;
4. Procedures for sample handling, identification, preservation, transportation, and storage;
5. Description of measurement methods or test procedures with statement of how the performance characteristics are determined if methods are non-standard;
6. Standard QA/QC procedures to be followed;
7. Data reduction and reporting procedures, including description of statistics used.

Comparability of results among various monitoring projects requires the use of audit samples distributed by a central, independent laboratory. The EPA monitoring program will follow procedures developed by the National Surface Water Survey for an audit sample program. Samples with known concentrations of the core variable, representative of the concentration ranges normally encountered, will be supplied to each project about three times each year. Results will be compiled and cross-checked by EPA to determine comparablity of chemical results across the program.

VIII. Data Management

Each supporting agency is responsible for its own sample collection and analysis, data analysis, data management, and data storage. Data may be delivered to STORET, WATSTORE, ACID (Brookhaven National Laboratory) or other data bases, providing that the data are of a routine survey or monitoring nature which does not preclude their release. EPA will employ the Oak Ridge National Laboratory ADDNET data base (Acid Deposition Assessment Data Network) as a repository for monitoring data, beginning in FY85. Annual reports will be prepared by the Principal Investigators responsible for the monitoring projects.

IX. Additional Information

Requests for additional information or copies of this document should be forwarded to Charles F. Powers, U.S.E.P.A., Environmental Research Laboratory, 200 S.W. 35th Street, Corvallis, Oregon 97333.

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APPENDIX A

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EXTRACTABLE ALUMINUM REAGENTS

A. 2.5 M HCl -- Dilute 208 ml 12 M Ultrex HCl to 1 liter with deionized water.

B. 1 M NH_4OH -- Dilute 20 ml 5 M NH_4OH to 100 ml with deionized water.

C. 5 M NH_4OH -- Approximate concentration of Ultrex NH_4OH.

D. NH_4^+/NH_3 Buffer Solution -- Adjust the pH of 21 ml 5 M NH_4OH to 8.3 with 2.5 M HCl (determine pH by testing a drop with Whatman pH paper (it should take about 30-35 ml), add an additional 32 ml of 5 M NH_4OH, then dilute to 100 ml.

E. 8-Hydroxyquinoline Solution -- Dissolved 5 g 8-hydroxyquinoline in 12.5 ml glacial acetic acid, then dilute to 500 ml.

F. 1.0 M Sodium Acetate -- Dissolve 8.20 g sodium acetate in deionized water and dilute to 100 ml.

G. 8-Hydroxyquinoline Sodium Acetate Reagent (HO_x Reagent) -- Mix in order, 10 ml 1.0 M NaOAc, 50 ml deionized water, and 10 ml 8-hydroxyquinoline solution. This solution must be prepared daily.

H. Phenol-red indicator -- 0.04%.

APPENDIX B

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CRITERIA FOR SELECTION OF LONG-TERM MONITORING SITES

A. The criteria for site selection must be consistent with the objectives of the monitoring program, which are:

1. Determine, within a sensitive region, the response (if any) of the chemistry and biology of lakes or of streams representing a range of alkalinity values.
2. Compare, between different sensitive regions, the response (if any) of lakes and streams of similar sensitivities when those different regions receive similar hydrogen ion or sulfate loading.
3. Compare the chemistry of lakes and streams from a variety of regions which exhibit various degrees of precipitation quantity and acidity.

It is important to recognize that it may not always be possible to locate monitoring sites which satisfy all the suggested requirements which follow; the need for flexibility must be recognized. The objective is to choose situations in which any observed chemical or biological change could most reasonably be attributed to effects of atmospheric deposition; within these guidelines, the best possible efforts should be made to achieve this. Specialized objectives of individual agencies may act to modify certain criteria.

B. Criteria for Selecting Monitoring Sites

1. Selection of Region
   (a) Geographic Location
      (1) Should be a "sensitive" region with surface waters commonly less than 200 μeq/l total alkalinity, since such conditions would be the most likely to produce detectable effects. The national alkalinity map (EPA-600-D-82-333) is useful in locating such regions.
      (2) Major representative national sensitive regions will be included: New England-New York, Appalachians, Upper Midwest, Rockies, Cascades, Sierra Nevadas.

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(b) Atmospheric H^+ and SO_2^- Loading

(1) Deposition gradients should be adequately represented; both geographically separate sensitive regions with similar loadings, and sensitive regions with different loadings should be sampled. A region selected for monitoring should receive precipitation as uniform with respect to chemistry and quantity as possible, to facilitate comparisons of effects at monitoring sites within regions and of effects between regions. Areas with local effects on weather patterns should be avoided.

(c) Selected areas should not have a history of recent land use changes, nor any prospects of future changes.

(d) The region must afford remote sites, unaffected by past human use, and which can be protected against future disruptive use.

(e) There can be no local atmospheric pollution sources.

(f) Sites must be accessible at key times of year, including snow melt-ice out period.

(g) There should be no recent history of forest fires, logging, chemical spraying or treatment, or fish management.

(h) If possible, choose sites where concurrent research will provide related data.

2. Selection of Lakes or Streams Within an Approved Area

(a) Following selection of a suitable sensitive area, a set of lakes and/or streams is selected for long-term monitoring. A group of water bodies (rather than a single site) is monitored because of expected lack of uniformity of response in both chemical and biological parameters. Lakes or streams situated close together may behave quite differently under the same precipitation regime. Variation can occur between lakes or streams with respect to seasonal averages, yearly averages, diel response, year to year, etc.

The following criteria apply to selection of lakes or streams within an approved region.

(1) Watershed Characteristics

(a) Location -- headwaters only.

(b) Size -- Lakes: 100 mi^2 or less, preferably 50 mi^2 or less.

Streams: headwater streams with small watersheds.

(c) Minimal Human Disturbance

(d) No Local Air or Water Pollution Sources

(2) Accessibility. Should be able to transport equipment to lake or stream on foot during non-winter seasons.

(3) Average total alkalinity 200 μeq/l or less, except for a few higher alkalinity lakes or streams (if present) as reference points.

(4) When other factors are equal, lakes for which historical data are available will be chosen.

(5) Sites should be located on "protected" land, which will not be logged, developed, farmed, or managed for any other purposes.

(6) Elevation should be considered, where appropriate, to give a representative range of heights above sea level.

(7) There should be an NTN site, or its equivalent, representative of the study site.

3. Where monitoring projects include "process" studies, measurements on ground water, as well as surface waters, should be included. Most of the foregoing site selection criteria would apply to ground water monitoring.

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Appendix II. Quality Assurance/Quality Control Procedures and Data as Reported by Cooperating Agencies and Institutions.

Montana State University

Surface Water Analysis Assessment

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July 1984

The following presents data and assessment of the analytical parameters currently being utilized to analyze the surface water samples. The fourteen parameters include: temperature, pH, specific conductance, color, Na, K, Ca, Mg, Al, NH_4^+, HCO_3^-, SO_4^{2-}, Cl^- and NO_3^-. Temperature: Typical values fall in the 0° to 20° centigrade range. The reproducibility of the measurement utilizing thermometers is ±0.5°C.

pH: Both field and laboratory pH meters are standardized; pH = 4.00 and 7.00 at 25.0°C. The electrodes (e.g. Altex) are effective at low ionic strength and a reproducibility of 0.02 units is obtainable provided there is not temperature variation. Field calibration and measurement are conducted at temperatures other than 25.0°C and thus a corresponding adjustment needs to be made to report the value for 25.0°C.

Specific Conductance: The specific conductance instrument is calibrated with 1.0×10^{-4} M KCl. The conductance values are converted to the 25.0°C specific conductance values using the 0.010 M KCl data.

Color: The color is obtained by comparison to the platinum-cobatores-chloride standard. The waters have low concentrations of colorful molecules and thus the standard curve goes from 0 to 10 units. The pH is monitored but in general does not vary. The experimental variability is ± 1 color unit.

Ca, Mg, Na and K: These metals are determined using atomic absorption spectrophotometry. The results of representative triplicate analysis are summarized in the following table. The range represents the average deviation from the mean.

Metal	Sample mg/l	Analysis mg/l
Ca	6.00	5.96 ± 0.09
	3.00	2.64 ± 0.02
Mg	4.00	3.99 ± 0.01
	2.00	1.94 ± 0.02
Na	4.00	3.78 ± 0.02
	2.00	1.94 ± 0.03
K	1.00	0.96 ± 0.01
	0.50	0.48 ± 0.01

Aluminum: A spectrophotometric procedure (Eriochrome Cyanine R Method) is utilized as described in Standard Methods;triplicate analysis was conducted.

Sample ug/l	Analysis, ug/l
6.00	6.34 ± 0.08
12.00	12.96 ± 0.08

Ammonia: A spectrophotometric procedure (phenate method) is utilized; triplicate analysis.

Sample, μeqv/l	Analysis, μeqv/l
0.20	0.24 ± 0.02
0.40	0.46 ± 0.03

Bicarbonate: This is determined by Gran Plot, triplicate analysis.

Sample, ~~mg/l~~ μeq/l	Analysis, ~~mg/l~~ μeq/l
60.0	63.4 ± 3.0

Cl^-, NO_3^-, SO_4^{2-}: These were determined utilizing ion chromatography, triplicate analysis.

Cl^-:	Sample, mg/l	Analysis, mg/l
	2.0	2.14 ± 0.49
	4.0	3.97 ± 0.34

NO_3^-:	Sample, mg/l	Analysis, mg/l
	2.0	2.17 ± 0.23
	4.0	3.86 ± 0.33

SO_4^{2-}:	Sample, mg/l	Analysis, mg/l
	2.0	2.02 ± 0.29
	4.0	4.15 ± 1.01

University of Minnesota

Results

The fall 1983 survey of cluster lakes in the Upper Great Lakes states began November 1, when seven lakes were sampled in Minnesota. The 13 Michigan lakes were sampled between November 3 and 5, and 11 of the 13 Wisconsin lakes were sampled between November 6 and 8. Stormy weather delayed sampling the remaining two lakes (Long and Camp Twelve) until November 14. Total ice cover conditions were narrowly averted on Camp Twelve Lake; extensive shore ice was broken through to obtain the samples.

Only one lake (Cruiser, MN) was not well-mixed at the time of sampling. Temperature was decreased, oxygen partially depleted and conductivity slightly elevated below 15 m. A bottom sample was collected at this lake. Profiles of temperature, dissolved oxygen, and conductivity for all other lakes indicated uniform conditions throughout the water column except for readings just off the bottom. Dissolved oxygen concentrations generally were near saturation.

Field data are summarized for each state cluster and for the entire data set in Table 3. The Secchi disk was visible at the bottom in nine lakes: four in Michigan and five in Wisconsin. "Field" measurements of pH and conductivity were made each day immediately on return from the field (maximum elapsed time 10 h), without bringing the samples to room temperature.

Results for physical and chemical analyses on the cluster lakes samples collected in fall 1983 are compiled in Table 4. Because the results represent only one point in time, little can be said regarding environmental interpretation of the results, and obviously it is premature to discuss temporal trends. Table 5 presents results for pH, alkalinity and conductivity on the lakes for fall 1982 (sampling by ERL-D) and mean values for all previous data on the lakes (from previous ERL-D studies). In general, previous results compare favorably with those from fall 1983. One exception was noted in the case of Lake Vandercook (R232), which had a higher alkalinity in fall 1983. Raw data from this titration were rechecked, and the result reported is correct for the sample. We will continue to closely monitor data from this lake in ensuing sampling periods to determine whether the change is real or the sample was nonrepresentative.

Results from the quality assurance program are summarized in Tables 6-9. Duplicate samples were obtained on three lakes as part of the fall 1983 sampling, and results for the pairs of samples are listed in Table 6. (Results for these lakes reported in Table 4 are averages of the sample duplicates.) In general, sample duplicates compare quite favorably, except for parameters near the analytical detection limits (ammonium and SRP) and for sodium, for which there seems to be a contamination problem of unresolved origin. Analytical duplicates are very good in all cases; representative results are summarized in Table 7. These results represent pairs of analyses performed on the same sample bottle during the same analytical run. In all cases analytical

duplicates agree within a few percent.

Sums of cations and anions (in ueq/L) are listed in Table 8. along with the difference between cation and anion equivalents. Fairly large differences were noted in some cases. These differences may result from several factors, and reasons for individual cases cannot be delineated at this time. In brief, the differences may reflect (i) the presence of other inorganic cations and/or anions in the samples besides the ones included in the summations, (ii) analytical errors, (iii) differential contamination problems between anion bottles and cation (metal) bottles, and (iv) presence of organic color in varying concentrations, which contributes an unmeasured amount of anionic equivalents to samples. Based on analysis of potential causes, it appears that analytical errors per se are not the major cause for the observed differences. Analytical precision was high, and good agreement was obtained with EPA quality control samples (see Table 9). Sample contamination likely is a partial factor; some sample "blanks" (Table 9) were high for some parameters (Ca^{2+} and Na^{+}) contributing to the general over-abundance of cations. We traced some of the problem of high blanks to distilled water from the DNR lab and have replaced this with UM deionized water in 1984 samplings. Blank problems also may be caused by the filters used for the various samples; we are currently evaluating the need for prewashing of all filters used in the sampling scheme. At least part of the differences between cation and anion equivalents stems from the occurrence of organic color in many of the lake samples. A correlation between color and the difference between cation and anion equivalents explained about 50% of the variance in the data.

We recently received a voluminous printout of all data from the lake sampling program conducted at ERL-D since 1979, and we expect to receive a tape of the data in the near future. Consequently, we will be able to compare results from the present monitoring program with previous monitoring data in the next report and determine whether any trends or inconsistencies exist. Interpretation of the results wil become increasingly more meaingful and assignment of causes to apparent outliers will become easier as the temporal record on the lakes increases.

Table 6. Results for sample duplicates taken from three lakes in fall 1983.

SNUM	LAKE NAME	(DNR) pH	pH	(DNR) EC 25 (umho/c	EC @25C (umho/c	COLOR (pcu)	ALK (ueq/l)	Ca (mg/l)	Mg (mg/l)	Na (mg/l)	K (mg/l)
U456	GARLING	4.54	4.58	24.1	23.0	29	-6	1.24	0.47	1.25	0.33
U456	GARLING	4.54	4.51	24.1	23.0	31	-17	1.29	0.45	2.32	0.32
U627	NEVINS	7.01	6.95	29.5	30.4	14	151	3.86	0.80	1.74	0.17
U627	NEVINS	7.03	6.94	28.9	31.4	14	172	3.96	0.82	1.28	0.18
R301	GREATER	5.84	5.81	18.2	19.9	39	32	1.44	0.54	2.37	0.40
R301	GREATER	5.85	5.75	18.0	18.8	37	27	1.39	0.56	1.71	0.43

SNUM	LAKE NAME	SO4 (mg/l)	Cl (mg/l)	NO3 (ug/l)	NO2 (ug/l)	NH4 (ug/l)	PO4 (ug/l)	F (mg/l)	SiO2 (mg/l)	Al (ug/l)	Mn (ug/l)	Fe (ug/l)	DOC (mg/l)
U456	GARLING	4.77	0.46	126	ND	55	1	0.05	0.10	21.9	25.5	20.7	7.6
U456	GARLING	4.84	0.33	114	ND	20	3	0.04	0.12	20.7	24.2	22.2	5.5
U627	NEVINS	6.18	0.35	32	ND	19	2	0.03	0.18	8.3	0.2	5.4	10.7
U627	NEVINS	6.18	0.37	39	ND	2	1	0.05	0.18	10.0	0.4	7.0	6.5
R301	GREATER	5.02	0.90	9	ND	20	1	0.03	0.42	27.7	0.7	100.0	7.2
R301	GREATER	5.08	1.03	12	ND	12	4	0.04	0.36	26.5	0.7	87.9	4.5

Table 7. REPRESENTATIVE RESULTS FOR LAB DUPLICATES FOR CLUSTER LAKES FALL 1983 SAMPLES:

SNUM	Ca	Mg	Na	K	SO4	PO4
S1	2.55	1.13	1.60	0.73	4.42	3.1
	2.53	1.14	1.59	0.74	4.48	3.0
S2	4.56	1.65	3.02	0.68	3.19	1.8
	4.56	1.64	3.02	0.69	3.19	1.9
S3	1.27	5.16	2.53	0.66	4.57	0.3
	1.29	4.90	2.51	0.67	4.57	0.3
S4	1.32	1.16	2.47	0.56	3.58	0.3
	1.32	1.16	2.49	0.56	3.70	0.3
S5	1.07	1.02	1.78	1.00	4.06	
	1.07	1.02	1.78	1.02	4.06	

Table 8. Sums of cation and anion equivalents and differences between sums for the fall 1983 cluster lakes samples

SNUM	LAKE NAME	TOTAL CATIONS (meq/l)	TOTAL ANIONS (meq/l)	C-A
B300	CRUISER	0.2185	0.2080	0.0105
B300	CRUISER	0.2557	0.2028	0.0529
B303	SPRING	0.3998	0.3941	0.0056
B308	SHOEPAC	0.3594	0.3104	0.0489
B312	LOITEN	0.3575	0.3356	0.0218
B313	LOCATOR	0.3541	0.2908	0.0633
B504	FRANKLI	0.6314	0.6098	0.0215
B505	LONG	1.1144	1.0596	0.0548
U456	GARLING	0.1966	0.1022	0.0943
U474	MONOCLE	0.4014	0.3850	0.0163
U501	JOHNSON	0.1545	0.1420	0.0124
U502	ANDRUS	0.2109	0.1691	0.0418
U553	KELLY	0.1847	0.1154	0.0692
U555	MURRAY	0.1651	0.1103	0.0548
U556	BASS	0.2402	0.2088	0.0313
U557	BUCKEYE	0.3241	0.2712	0.0529
U565	STUART	0.1593	0.0921	0.0672
U567	CHRIS BR	0.3545	0.3152	0.0392
U625	CUSINO	0.1853	0.1171	0.0681
U627	NEVINS	0.3459	0.3023	0.0436
U717	McNEARN	0.1713	0.1323	0.0390
R033	LONG	0.1468	0.1064	0.0403
R033	LONG	0	0.015	-0.015
R086	SUNSET	0.1466	0.1356	0.0110
R146	CLARA	0.3251	0.2717	0.0533
R232	VANDERC	0.1522	0.2002	-0.047
R301	GREATER	0.2250	0.1638	0.0611
R434	SAND	0.1870	0.1808	0.0062
R473	CLEAR	0.1807	0.1138	0.0668
R513	NICHOLS	0.2366	0.1325	0.1040
R701	LUNA	0.2127	0.1353	0.0773
R803	C TWELVE	0.1171	0.1110	0.0060
R817	McGRATH	0.1457	0.1245	0.0212
R825	SUGAR C	0.1775	0.1746	0.0028
R861	MORGAN	0.1866	0.1510	0.0356

Table 9. Results for "blank bottles" and EPA quality control reference sample for fall 1983 cluster lakes analyses

SNUM	LAKE NAME	pH	COLOR (pcu)	ALK (ueq/l)	Ca (mg/l)	Mg (mg/l)	Na (mg/l)	K (mg/l)	SO4 (mg/l)	Cl (mg/l)	NO3 (ug/l)	NO2 (ug/l)	NH4 (ug/l)
U101	BLANK		3		0.47	0.08	2.02	0.00	0.00	0.20	8	ND	12
U102	BLANK		3		0.10	0.00	0.00	0.00	0.00	0.00	1	ND	98
U103	BLANK				0.27	0.07	0.43	0.00					
R101	BLANK		3		0.44	0.07	1.23	0.00	0.00	0.27	5	ND	12
R101	BLANK		1		0.29	0.06	0.35	0.00	0.00	0.00	6	ND	0
R102	BLANK		1		0.11	0.00	0.00	0.00	0.00	0.02	3	ND	32
R102	BLANK		3		0.09	0.00	0.00	0.00	0.00	0.05	2	ND	136
R103	BLANK				0.19	0.03	0.11	0.00					
R103	BLANK				0.19	0.03	0.14	0.00					
T.V.EPAQC *		5.70			0.81	1.80	4.65	0.98	7.20	8.53	140		
LAB EPAQC		5.70			0.82	1.77	4.79	0.99	7.13	7.89	152		

SNUM	LAKE NAME	PO4 (ug/l)	F (mg/l)	SiO2 (mg/l)	Al (ug/l)	Mn (ug/l)	Fe (ug/l)	DOC (mg/l)
U101	BLANK	1	0.01	0.06	4.2	0.0	0.0	3.4
U102	BLANK	3	0.02	0.06	2.3	0.0	0.7	1.8
U103	BLANK				1.1	0.0	0.0	1.7
R101	BLANK	2	0.03	0.02	1.7	0.0	0.0	1.6
R101	BLANK	1	0.02	0.02	1.5	0.0	0.0	0.6
R102	BLANK	1	0.01	0.02	0.0	0.0	0.0	0.2
R102	BLANK	5	0.02	0.02	0.0	0.0	0.0	BROKEN
R103	BLANK				0.0	0.0	0.0	2.6
R103	BLANK				0.0	0.0	0.0	0.3
T.V.EPAQC *			0.43		450.0	15.0	15.0	
LAB EPAQC			0.43		414.0	13.9	16.6	

*T.V. = "true value" as reported by EPA; lab = our result

Appendix A

Analytical Methods

Parameter	Method
Alkalinity	Gran titration with 0.020 N H_2SO_4
Color	Absorbance at 420 nm compared to Pt-Co std.
Conductance	Wheatstone bridge conductivity meter standardized with 0.0100 M KCl
Cations (major)	Flame atomic absorption spectrophotometry (AAS)
Chloride	Automated ferricyanide method with cross-comparison to ion chromatography
Ammonium	Automated indophenol (Solorzano) method
Nitrate plus nitrite	Automated cadmium reduction/diazotization method
Soluble reactive P	Automated ascorbic acid/molybdate method
Silica	Automated oxalic acid/molybdate procedure
Fluoride	Ion selective electrode
Dissolved organic carbon	Photochemical procedure with Barnstead/Syburon carbon analyzer
Fe, Mn, Al	Flame AAS Flame-less AAS for Al_t automated colorimetric method for monomeric Al
Chlorophyll	Acetone/DMSO extraction and spectrophotometry
Turbidity	Hach turbidimeter with formazin standards
Sulfate	Automated methyl thymol blue procedure with cross-comparison to ion chromatography (changed to ion chromatography as primary method in 1984)

USFWS, University of Maine

METHODS

The six lakes selected for the monitoring program are located in Township T10SD, Hancock County, Maine (Table 1 and Figure 1). Individual bathymetric maps of each lake are presented in Appendix 1. All lakes are underlain by the Tunk Lake Pluton, a medium grained hornblende-aegerine-augite-perthite granite. The surficial material is almost exclusively granitic and was probably locally derived. The soils are generally well-drained spodosols of the Hermon and Lyman series, formed in till. Soils thickness ranges from 0 to >30 cm with a 3-10 cm organic mat.

The watersheds are entirely forested with mixed hard and softwood species. Hardwood species include paper birch, oak, beech, and red maple; softwood species are red spruce, fir, and white pine. There are a few seasonal dwellings on Spring River Lake, and one seldom-used seasonal dwelling on Anderson Pond. There is no other human habitation or disturbance in the watersheds. The northern half of the Anderson Pond watershed burned about 1960, otherwise the vegetation in all watersheds has been undisturbed for at least 50 years.

Each lake was sampled three times: spring overturn, summer stratification, and fall overturn. An inflatable raft was anchored over the deepest portion of the lake. Water samples were collected from 0.1 m depth directly into acid-washed, distilled water rinsed and soaked linear polyethylene bottles. A second sample was collected about 1 m above the bottom with a clear plastic Van Dorn type water sampler and transferred to bottles. Each sample consisted of a set of three bottles: one 500 ml, one 250 ml, and one 60 ml that contained 0.6 ml 1+1 HNO_3. Water temperature was measured immediately with a pocket thermometer. The samples were then

carried to the road, placed in an ice chest, and transported to Orono (ca 1 hr drive).

Upon arrival at the laboratory the 250 ml sample was split into two subsamples. One fraction was frozen for future anion analysis. The other fraction was pressure filtered (0.40μ Nucleopore polycarbonate filter). Half of the filtered fraction was frozen for future anion analysis, and half was acidified with nitric acid (1 ml 1+1 HNO_3 per 100 ml), and stored at room temperature, along with the unfiltered acidified sample, for future cation analysis.

The 500 ml sample was warmed to room temperature and used for pH, alkalinity, specific conductance, and color analyses. The pH was measured with two different meters (Fisher model 107, Cole-Parmer Digi Sense) equipped with Beckman Altex Futura liquid-filled combination electrodes and recorded separately. Alkalinity was also determined in replicate by inflection-point titration (Stumm and Morgan 1981) using the two different meters. The pH meters were standardized against pH 7.00 and 4.01 NBS certified buffers and checked against 5×10^{-5} M H_2SO_4 (theoretical pH 4.00).

Specific conductance was measured in replicate (Markson model 10 meter). The meter was standardized with the internal standard before each reading. Color was determined in replicate by comparison of unfiltered sample with platinum cobalt standard solution (La Motte Chemical Co., Chestertown, MD).

The cations sodium, potassium, iron, and zinc were measured by air-acetylene flame atomic absorption spectrophotometry (Perkin-Elmer model 703). Calcium and magnesium were determined by nitrous oxide-acetylene flame AAS, and aluminum and manganese by graphite furnace AAS. The instrument was calibrated according to manufacturer

specifications. Every tenth sample was analyzed in duplicate, and a standard was included with every 10 samples.

Chloride, nitrate, sulfate, and fluoride were measured using an ion chromatograph (Dionex model 16). The instrument was calibrated at the start of each run with 5 standards, and standards were rerun at the end of a batch of 10 samples.

The accuracy of analytical instruments was verified by analysis of U.S. Environmental Protection Agency Water Pollution Quality Control Samples for Trace Elements and Minerals and spiked samples. Precision and bias were assessed by analysis of known standards, and replicate analysis of known standards and unknown samples.

Fish were collected once, at fall overturn, by use of a light weight trap net, minnow traps, and an experimental gill net. Because of the remoteness of the lakes standard trap nets could not be used. In consultation with a professional net designer (Sterling Marine Products, Montclair, NJ) we arrived at a light weight, portable trap net design (Figure 2). Two nets were to be manufactured, one with 1/2 in. square mesh and one with 1/4 in. square mesh. Only the 1/2 in. mesh net was delivered, and that deviated from specifications. Preliminary testing was not possible because the net was not delivered until October, 1983.

We decided to use the trap net we received in conjunction with our standard netting protocol to establish the efficiency of the trap net. The standard protocol included one experimental nylon monofilament gill net (four 50 ft. by 6 ft. sections of square mesh sizes 1/2 in., 3/4 in., 1 in., 1 1/4 in.), and four standard 1/4 in. square mesh galvenized wire minnow traps. The gill net was set perpendicular to the shore of the lake with the small mesh end next to the shore. The net covered both the littoral zone and deeper water. The minnow traps were placed in a variety

of littoral areas. The trap net was set perpendicular to shore with the lead attached to the lake shore. It was set at least 100 m from the gill net in a similar area. The nets were set in late afternoon and lifted in mid-morning the following day.

All fish caught were identified to species by at least two trained fisheries scientists. The number of fish species captured was small and most species were easily identifiable. Only a few minnow species were difficult to identify, especially for very small individuals. Accordingly, a few small individuals were identified only to genus. Identifiable individuals were weighed (nearest gram) and measured (nearest mm), and scales were removed from individuals larger than 10 cm. If more than 25 individuals of one species were captured, only the first 25 were weighed, measured, and scale sampled. As many fish as possible were returned to the lake alive.

RESULTS AND DISCUSSION

Quality Assurance

The analysis of EPA Water Pollution Quality Control Samples and spiked samples (Table 2) indicates that the measurement systems used are accurate. Bias was generally less than ±5%. The bias for potassium sample #2 was 9.18% but this concentration (46.5 mg/l) is far higher than our normal operating range. Potassium concentrations in our samples never exceeded 1 mg/l. the bias for aluminum results based on the EPA true value was high for sample #4 and 5. However, other laboratories reported values similar to ours. Bias calculated using the mean value reported by other laboratories rather than the "true value" were less than ±5%. This suggests that the quality control samples are contaminated, probably by aluminum leached from the glass ampules. This is not a problem for the high aluminum concentration in sample #6. Bias was also somewhat high for iron (-10.0%) and zinc (-7.31%). These elements were present at very low concentrations.

The standard deviation and precision of replicate analyses of randomly selected samples (Table 3) also are generally quite low. Precision is poorest for iron, zinc, and manganese, all of which are present only at low concentrations. Precision is variable for aluminum, ranging up to ±16%, but the average is less than ±10%. Precision for other factors is generally less than ±5%.

Water Chemistry

The water chemistry data are presented in Appendix 2. Samples are identified by lake name, depth (surface or depth in meters), and date of collection. Filtered samples are denoted by an asterisk following depth.

Table 2. Results from analysis of EPA Water Pollution Quality Control samples.

Factor (Units)	EPA Sample Number	True Value	Laboratory Results Value	Laboratory Results Bias
pH (units)	1	5.70	5.64	-1.05%
	2	7.80	7.75	-0.64%
alkalinity (mg/l as $CaCO_3$)	1	74.7	72.4	-3.08%
	2	21.7	21.2	-2.30%
calcium (mg/l)	1	40.6	42.0	3.45%
	2	5.3	5.2	-1.89%
magnesium (mg/l)	1	8.4	8.7	3.57%
	2	1.8	1.8	0
potassium (mg/l)	1	9.8	10.7	9.18%
	2	2.1	2.1	0
sodium (mg/l)	1	46.5	47.7	2.58%
	2	8.2	8.5	3.66%
aluminum (μg/l)	4	60	79	31.66%
	4	83[a]	79	-4.82%
	5	450	479	6.44%
	5	460[a]	479	4.13%
	6	800	826	3.25%
	6	819[a]	826	0.85%
manganese (μg/l)	-[b]	26	25	-4.23%
iron (mg/l)	-[b]	0.13	0.12	-10.0 %
zinc (μg/l)	-[b]	26	24	-7.31%

[a]Mean value from reporting laboratories.

[b]Recovery from 10 spiked samples.

Table 3. Results from replicate analysis of randomly selected samples.

Factor (units)	N	Laboratory Results Mean	Standard Deviation	Precision
Calcium (mg/l)	7	0.67	0.009	± 2.69%
	7	1.29	0.010	± 1.55%
	3	1.32	0.010	± 1.52%
	7	1.98	0.026	± 2.63%
	8	0.97	0.007	± 1.44%
	10	0.85	0.007	± 1.65%
	5	0.90	0.010	± 2.22%
magnesium (mg/l)	7	0.32	0.004	± 2.50%
	7	0.43	0.005	± 2.33%
	3	0.33	0.006	± 3.64%
	7	0.44	0.005	± 2.27%
	8	0.41	0.003	± 1.46%
	10	0.45	0.003	± 1.33%
	5	0.40	0.002	± 1.00%
potassium (mg/l)	7	0.25	0.005	± 4.00%
	7	0.36	0.005	± 2.78%
	3	0.26	0.006	± 4.62%
	7	0.36	0.001	± 0.72%
	8	0.27	0.007	± 5.19%
	10	0.22	0	± 0
	5	0.25	0.006	± 4.80%
sodium (mg/l)	7	2.46	0.015	± 1.22%
	7	3.05	0.027	± 1.77%
	3	2.32	0.020	± 1.72%
	7	2.95	0.030	± 2.03%
	8	2.41	0.029	± 2.41%
	10	2.53	0.018	± 1.42%
	5	2.31	0.020	± 1.73%
aluminum (µg/l)	7	432	14.6	± 6.76%
	7	251	8.6	± 6.85%
	3	93	2.5	± 5.38%
	7	88	5.4	±12.27%
	7	45	2.6	±11.56%
	6	287	6.6	± 4.60%
	7	24	2.0	±16.67%
manganese (µg/l)	7	23	1.49	±12.96%
	7	8	0.69	±17.25%
	3	9	0.57	±12.67%
	7	38	3.08	±16.21%
	8	16	1.01	±12.63%
	10	0	1.44	-

Table 3 continued.

	5	14	0.71	±10.14%
iron (mg/l)	7	0.04	0.012	±60.0 %
	7	0.14	0.012	±17.14%
	3	0	0	0
	7	0.01	0	0
	8	0.01	0.004	±80.0 %
	10	0.04	0.015	±75.0 %
zinc (µg/l)	7	13	1.50	±23.1 %
	7	35	0.075	± 0.43%
	3	0	1.52	-
	7	27	0.090	± 0.67%
	8	0	0.019	-
	10	10	1.20	±24.0 %
	5	12	1.30	±21.67%
	5	50	1.78	± 7.12%
	4	0	0	0
pH (units)	2	6.24	0.014	± 0.45%
	2	5.64	0	0
	2	5.68	0.007	± 0.25%
	2	4.54	0	0
	2	4.46	0	0
	2	6.52	0.028	± 0.86%
	4	5.65	0.059	± 2.09%
	2	6.62	0.007	± 0.21%
alkalinity (µeq/l)	4	13	1.30	±20.0 %
	2	8	0.21	± 5.25%
	2	54	0.21	± 0.78%
	2	-26	0.56	± 4.26%
	2	12	0.57	± 9.83%
	2	44	0.71	± 3.25%
	3	-3	0.56	±36.13%
	2	33	0.07	± 0.43%

State of Vermont

ACID RAIN LAKES

SAMPLING DUPLICATES

Lake	Conductance (umhos/cm)		pH (standard units)		Ca (mg/l)		Mg (mg/l)		Na (mg/l)		K (mg/l)		Diss. Al (ug/l)	
Little Rock	30	30	6.81	6.79	3.06	2.92	1.45	1.39	0.460	0.460	0.495	0.495	0.052	0.047
Cow Mt.	30	28	5.89	5.99	3.43	3.36	0.833	0.833	0.914	0.894	0.513	0.503	0.104	0.095
Unknown	24	26	5.60	5.64	2.84	2.80	0.435	0.427	0.647	0.635	0.292	0.295	0.326	0.326
Somerset	22	20	5.63	5.62	1.68	1.70	0.425	0.428	0.679	0.681	0.534	0.536	0.161	0.205
Sunset	16	17	6.12	6.10	1.58	2.38	0.375	0.373	0.795	0.803	0.209	0.216	0.048	0.033
Beebe	20	20	4.78	4.80	1.00	0.98	0.325	0.325	0.577	0.577	0.392	0.326	0.382	0.386
Stratton	16	16	6.01	5.92	1.55	1.45	0.341	0.343	0.556	0.530	0.459	0.432	0.108	0.115
Little	27	27	5.10	5.05	1.16	1.18	0.267	0.267	0.601	0.605	0.653	0.568	0.143	0.208
Mansfield	30	30	6.46	6.43	2.60	2.67	0.490	0.498	0.355	0.355	0.310	0.307	0.070	0.095
Grout	18	18	6.06	5.92	1.37	1.39	0.378	0.382	0.660	0.720	0.273	0.273	0.055	0.057
Osmore	32	32	7.24	7.24	3.60	3.56	0.452	0.444	1.68	1.45	0.443	0.436	0.025	0.031
Little	19	19	5.23	5.21	1.16	1.15	0.309	0.302	0.712	0.710	0.564	0.530	0.082	0.100
Branch	19	19	4.66	4.67	0.725	0.765	0.272	0.274	0.510	0.520	0.393	0.393	0.135	0.137
Little Averill	26	26	6.76	6.86	3.31	3.36	0.524	0.524	0.803	0.800	0.287	0.287	0.018	0.020
Sunset	18	18	5.96	5.96	1.47	1.49	0.363	0.365	0.870	0.898	0.225	0.225	0.038	0
Grout	19	19	6.32	6.29	1.54	1.48	0.363	0.363	0.592	0.586	0.501	0.501	0.018	0.026
Cole	29	29	6.37	6.40	1.98	1.96	0.585	0.585	1.67	1.70	0.691	0.695	0.024	0.022
Hardwood	20	20	6.03	6.02	1.84	1.82	0.465	0.465	0.456	0.462	0.170	0.158	0.095	0.053
S	0.60		0.0396		0.139		0.0104		0.0406		0.0196		0.0173	
n (pairs)	18		18		18		18		18		18		18	
95% C.I.	±1.26		±0.083		±0.291		±0.0218		±0.085		±0.0412		±0.0364	

ACID RAIN LAKES

SAMPLING DUPLICATES

Lake	Color (Spectro) (Pt-Co, units)		Color (Visual) (Pt-Co, units)		Alkalinity (mg/l)		NO_2-NO_3 (mg/l)		SO_4 (mg/l)		Cl (mg/l)		TP (mg/l)	
Little Rock	6	6	10	10	8.16	8.07	0.018	0.029	5.71	5.72	0.67	0.69	0.009	0.007
Cow Mountain	46	46	40	40	6.74	7.09	0.081	0.077	6.14	6.28	0.68	0.67	0.018	0.024
Unknown	44	44	40	40	1.54	1.56	0.172	0.166	7.43	7.61	0.71	0.75	0.005	0.003
Somerset	37	37	20	20	0.94	0.84	0.184	0.194	5.49	5.50	0.63	0.62	0.024	0.011
Sunset	23	23	10	10	0.75	0.71	0.044	0.067	4.69	4.72	0.78	0.77	0.005	0.007
Beebe	85	85	30	30	-0.91	-0.94	0.217	0.216	5.19	5.32	0.58	0.56	0.013	0.012
Stratton	17	—	10	10	0.92	0.90	0.206	0.205	3.78	3.75	0.47	0.45	0.012	0.013
Little	25	25	0	0	-0.22	-0.25	0.141	0.145	5.76	5.74	0.44	0.44	0.008	0.007
Mansfield	31	31	20	20	5.85	5.70	0.023	< 0.020	6.83	6.86	0.29	0.28	0.009	0.010
Grout	28	28	10	10	0.99	1.01	< 0.020	< 0.020	4.69	4.74	0.49	0.49	0.007	0.008
Osmore	30	30	20	20	7.36	7.94	< 0.020	< 0.020	5.38	5.38	0.63	0.66	0.030	0.026
Little	0	0	0	0	-0.19	-0.03	0.056	0.044	5.90	5.92	0.42	0.38	0.016	0.014
Branch	30	30	30	30	-0.84	-0.83	< 0.020	<0.020	5.01	5.10	0.34	0.31	0.014	0.015
Little Averill	10	10	0	0	6.50	6.31	< 0.020	<0.020	5.12	4.99	< 0.20*	<0.20*	0.008	0.008
Sunset	3	3	0	0	0.72	0.69	< 0.020	<0.020	5.08	5.06	0.22*	0.21*	0.008	0.009
Grout	10	10	10	10	1.75	1.76	< 0.020	<0.020	4.23	4.20	<0.20*	<0.20*	0.006	0.008
Cole	11	11	0	0	2.18	2.15	< 0.020	< 0.020	6.31	6.76	1.72	1.21	0.007	0.006
Hardwood	25	25	10	10	1.05	1.02	< 0.020	<0.020	5.59	5.55	0.35	0.35	0.017	0.019
S	0		0		0.126		0.0073		0.092		0.094		0.0026	
n (pairs)	17		18		18		9		18		15		18	
95% C.I.	0		0		±0.264		±0.0166		±0.193		±0.201		±0.0056	

* = value may be in error

ACID RAIN LAKES

SPIKED SAMPLES

	NO_2-NO_3 (mg/l)			SO_4 (mg/l)			Cl (mg/l)			Ca (mg/l)			Mg (mg/l)			Na (mg/l)			K (mg/l)		
	Lake Value	Spiked Value	% R	Lake Value	Spiked Value	% R	Lake Value	Spiked Value	% R	Lake Value	Spiked Value	% R	Lake Value	Spiked Value	% R	Lake Value	Spiked Value	% R	Lake Value	Spiked Value	% R
Big Mud	0.10	1.02	101	7.8	9.84	74.8	0.88	2.60	94.6	2.4	3.18	78	0.50	0.642	71.0	0.64	1.05	82.0	0.44	0.793	88.3
Holland	0.07	1.01	103	6.7	9.29	95.0	0.62	2.14	83.6	4.2	5.05	85	0.52	0.667	73.5	0.77	1.12	70.0	0.27	0.640	92.5
Little	0.59	1.38	86.9	5.1	7.80	99.0	0.49	2.21	94.6	2.6	3.4	80	0.53	0.658	64.0	0.80	1.12	64.0	0.54	0.890	87.5
Cole	0.02	0.237	95.5	5.7	7.69	73.0	1.9	3.56	91.3	1.9	2.85	95	0.57	0.693	61.5	1.59	1.89	60.0	0.61	0.946	84.0
Wheeler	0.06	0.272	93.3	6.5	8.60	77.0	0.58	2.23	90.8	2.9	3.85	95	0.50	0.650	75.0	0.99	1.40	82.0	0.62	0.932	78.0
Lily	<0.02	0.201	--	5.8	8.52	99.7	0.46	2.06	88	1.5	2.38	88	0.52	0.692	86.0	0.97	1.40	86.0	0.54	0.835	73.8
Unknown	<0.02	0.219	--	6.2	8.44	82.1	0.34	2.05	94.1	1.9	2.70	80	0.37	0.530	80.0	0.56	0.899	67.8	0.31	0.701	97.8
Stamford	0.03	0.212	80.1	5.8	8.08	83.6	0.50	2.60	115.5	1.2	2.10	90	0.38	0.537	78.5	0.93	1.35	84.0	0.36	0.757	99.3
Osmore	<0.02	0.208	--	5.6	8.07	90.6	<0.26*	1.76	--	3.3	3.90	60	0.48	0.625	72.5	1.69	2.12	86.0	0.45	0.823	93.3
Sucker	<0.02	0.238	--	5.0	7.35	86.2	<0.020*	1.50	--	2.2	2.99	79	0.52	0.650	65.0	0.80	1.19	78.0	0.54	0.884	87.3

* = value may be in error

ACID RAIN LAKES

SPIKES OF NANOPURE WATER

	NO_2-NO_3 (mg/l)	SO_4 (mg/l)	Cl (mg/l)	Ca (mg/l)	Mg (mg/l)	Na (mg/l)	K (mg/l)
	--	2.61	1.94	.975	.206	.475	.395
	--	2.82	1.79	1.05	.202	.527	.400
	--	2.62	2.05	1.03	.192	.534	.458
	--	3.36	1.81	1.02	.197	.497	.396
	--	--	1.78	.830	.197	.502	.396
	.250	2.58	.28	1.05	.200	.503	.418
	.251	3.24	2.01	1.10	.208	.810	.656
	.217	2.62	1.70	.983	.203	.520	.407
	.250	2.63	1.61	1.02	.204	.861	.400
	.087	2.69	1.74	.912	.201	.655	.415
	.231	2.77	1.63	.975	.223	.500	.412
	.854	2.45	1.64	1.03	.197	.860	.408
	.231	5.73	1.74	1.06	.220	.540	.415
	.159	2.49	1.57	1.10	.209	.514	.424
	.189	2.67	1.44	1.03	.201	.514	.386
	.216	2.51	1.73	.90	.196	.525	.403
	.196	2.51	1.67	.963	.201	.489	.397
Estimated Value	0.227	2.73	1.82	1.00	0.20	0.50	0.40

USGS, Albany, New York

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Table 5.--Quality-control data on field alkalinity measurements by Gran's Plot.
[Data in μeq/L]

Date	pH	Measurement 1	Measurement 2	Measurement 3	Average
			Biscuit Brook		
5-17-83	6.21	17	--	--	17
8-15-83	6.32	23	--	--	23
10-06-83	6.37	31	--	--	31
11-02-83	6.36	36	36	--	36
11-11-83	6.43	42	42	42	42
11-16-83	6.47	32	28	--	30
11-30-83	6.13	12	12	--	12
12-13-83	5.14	-12	--	--	-12
12-14-83	5.61	0	4	--	2
1-12-84	6.54	32	--	--	32
2-01-84	6.16	20	12	--	16
2-06-84	6.12	14.8	--	--	14.8
3-28-84	6.25	20	20	--	20
4-03-84	6.14	24	20	--	22
4-10-84	5.92	4	4	--	4
4-17-84	5.41	2	--	--	2
5-30-84	5.30	4	4	--	4
6-12-84	6.41	24	--	--	24
7-20-84	6.49	32	32	--	32
			Beaverkill Creek		
11-03-83	6.99	140	140	--	140
12-15-83	6.13	26	26	--	26
1-31-84	6.61	80	84	--	82
4-02-84	6.81	80	78	--	79
4-16-84	5.83	16	16	--	16
6-13-84	6.97	110	110	--	110
7-19-84	7.15	114	--	--	114
			Woodland Creek		
8-15-83	6.41	32	--	--	32
11-01-83	6.31	32	24	24	26.7
12-15-83	6.24	10	12	--	11
2-02-84	6.18	20	20	--	20
4-02-84	6.35	20	28	--	24
4-16-84	6.10	14	14	--	14
6-12-84	6.45	28	28	--	28
7-19-84	6.43	27.2	27.2	--	27.2

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Table 5.--Quality-control data on field alkalinity measurements by Gran's Plot (continued)
[Data in μeq/L]

Date	pH	Measurement 1	Measurement 2	Measurement 3	Average
			Rondout Creek		
8-16-83	6.25	2.4	--	--	24.4
11-01-83	6.06	9.6	10.4	16.0	12.0
12-14-83	4.65	-24	-24	--	-24.0
2-02-84	5.5	0	-4	--	-2.0
4-03-84	5.39	4	8	--	6.0
4-17-84	4.83	-9.2	-9.2	--	-9.2
5-30-84	4.74	-18	-18	--	-10.0
6-11-84	5.24	4	4	--	4.0
7-11-84	5.45	2	2	--	2.0
			High Falls Brook		
8-15-83	7.05	136	--	--	136
11-03-83	7.07	178.8	178.8	--	178.8
12-14-83	5.92	12.0	12.8	12.0	12.3
2-01-84	6.77	92.0	102.0	--	97.0
4-03-84	6.75	68	72	--	70.0
4-05-84	5.24	-4.0	+2.0	--	-1.0
4-17-84	5.98	20	24	--	22.0
6-13-84	6.92	80	88	--	84.0
7-20-84	7.17	114	114	--	114.0
			Pigeon Brook		
4-11-83	6.04	16	--	--	16
8-15-83	6.58	6.92	--	--	6.92
11-02-83	6.78	90	90	--	90
12-14-83	5.55	6	6	--	6
2-01-84	6.49	50	50	--	50
4-03-84	6.52	40	40	--	40
4-05-84	5.84	12	20	--	16
4-05-84	5.21	0	0	--	0
4-06-84	5.49	5.6	5.6	--	5.6
4-17-84	5.77	16	16	--	16
5-30-84	5.73	16	16	--	16
6-12-84	6.68	46	46	--	46
7-20-84	6.78	46	56	56	53

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Table 5.--Quality-control data on field alkalinity measurements by Gran's Plot (continued).
[Data in μeq/L]

Date	pH	Measurement 1	Measurement 2	Measurement 3	Average
			East Branch Neversink River		
8-15-83	5.00	-8.8	--	--	-8.8
11-02-83	5.13	0	0	--	0
11-16-83	5.07	-12.0	-12.0	--	-12.0
12-14-83	4.49	-32	-32	--	-32
2-01-84	5.24	-2	-2	--	-2
3-06-84	5.07	-8	--	--	-8
3-21-84	5.09	-6	-6	--	-6
3-21-84	5.01	0	0	--	0
3-21-84	4.99	-10	-10	--	-10
3-21-84	4.96	-10	-10	--	-10
3-21-84	4.95	-4	-4	--	-4
3-21-84	4.91	-12	-12	--	-12
3-21-84	4.88	-7.2	-7.2	--	-7.2
4-03-84	5.16	4	4	--	4
4-05-84	4.53	-20	-20	--	-20
4-05-84	4.51	-26.8	-26.8	--	-26.8
4-05-84	4.50	-32	-32	--	-32
4-06-84	4.60	-14	-20.8	--	-17.4
4-17-84	4.62	-24	-24	--	-24
5-30-84	4.57	-27.6	-27.6	--	-27.6
6-13-84		Equipment malfunction - electrical storms.			
7-20-84	5.10	-8	-8	--	-8

USGS, Harrisburg, Pennsylvania

GENERAL CLIMATOLOGICAL INFORMATION

The Laurel Ridge area of southwestern Pennsylvania is under the general influence of a continental climate and prevailing westerly winds. Precipitation averages 46 inches per year and is well distributed between the growing and non-growing seasons. There are an average of 35 thunderstorms each year. Average snow accumulation is 66 inches with 102 days per year of snow cover. The period of ice cover is approximately October 1 to May 1.

NOAA meteriological stations relevent to the study area are located at Johnstown, Boswell, Somerset, and Laurel Mt. Village. A Pennsylvania Department of Environmental Resources/Penn State University (PaDER/PSU) Atmospheric Deposition Monitoring Network site is maintained at Laurel Hill State Park (fig. 1). The nearest National Atmospheric Deposition Program (NADP) site is located approximately 65 miles to the northeast at Leading Ridge, Penn State University Forest Experiment Station in northern Huntingdon County.

METHODS

Sampling Procedures and Frequency

Sampling of the six study sites is accomplished within a two day period every month. Discharge, temperature, pH, and specific conductance of each stream is determined at the site. Samples are collected in polyethylene bottles and kept chilled until they are taken back to the field laboratory at the South Fork Bens Creek (primary site). Since the streams are small and well mixed it was found that a transect and use of a calibrated hand held sampler was not necessary. Therefore, a dip sample at about mid-stream has been employed throughout the study. Within two hours of collection, the samples are analyzed for alkalinity and acidity.

The site with the most attention is the primary site. Every week the stream is sampled for pH and specific conductance. Significant storms are sampled with an ISCO* automatic water-quality sampler. This sampler is pre-programmed to take samples at various time intervals upon an rise in stage. A total of twenty-four samples can be taken during a storm period. Immediately, at the completion of the sampling sequence, the samples are tested for pH and specific conductance. Then among the twenty-four samples about ten are selected from the rise and recession of the event for analysis at the USGS Central Analytical Laboratory. The primary site is also the precipitation monitoring site. Every Tuesday at 9:00 A.M. the wet bucket of the precipitation collector is removed and its contents analyzed for pH, specific conductance and volume. Provided there is enough sample available, the prescribed laboratory schedule is used for analysis at the USGS Central Analytical Laboratory. Precipitation sampling for this study closely follows the protocol established by the National Atmospheric Deposition Program.

Sample Storage and Preservation

Consistency in storage and preservation technique is as important as the actual sampling technique. Therefore all storage bottles and fixing agents are supplied by the USGS Central Analytical Laboratory. Precipitation and stream samples are both preserved for a laboratory schedule 291. Stream samples have an added schedule 353. Under schedule 291 collected samples are divided into three areas of concern: (1) dissolved metals determiniation, (2) ion determination, (3) raw analysis for pH, specific conductance, and alkalinity. Schedule 353 is concerned with nutrient analysis and dissolved organic carbon (DOC) content.

* "Use of the brand name ISCO in this report is for identification purposes only and does not consitiute endorsement by the U.S. Geological Survey."

Sample processing is completed at the primary site within two hours of collection. All filtering apparatus is washed and rinsed with distilled water between filter changes and sample sites. A 40-ml portion of distilled water is passed through each membrane prior to use. Samples to be analyzed for dissolved metals are filtered through a 0.1 micron MFS* cellulose nitrate membrane filter directly into acid rinsed bottles. Dissolved-metals samples are each treated with a 1-ml ampule of ultra-pure nitric acid. Nutrient analysis samples are filtered through a 0.45 micron cellulose nitrate membrane filter directly into amber polyethylene bottles. The nutrient samples are each treated with a 185 mg tablet of mercuric chloride and chilled to 4 degrees centigrade for shipping. DOC samples are filtered through a 0.45 micron silver membrane filter using a pressurized Gelman* stainless steel filter assembly accompanied by a cylinder of high grade nitrogen. The DOC samples are transferred directly from the filter assembly into pre-sterilized 100-ml glass bottles and chilled to 4 degrees centigrade for shipping. Raw unfiltered stream or precipitation samples are also sent for analysis to fulfill concern number three.

Analytical Procedure

Field

Water Quality Instruments

Temperature.--Temperature is measured with a NBS* certified mercury thermometer on an aliquot of the collected sample as a precursor to measurement of pH and specific conductance.

Specific Conductance.-- Specific conductance is measured on an aliquot of the collected sample prior to measurement of pH. The instrument used is a Beckman RB-5* with a cell constant of 0.1. Prior to use the cell is rinsed with distilled water and shaken dry. The cell is checked against a standard KCL solution of the appropriate value (<50 μmhos) prior to measurement. The cell constant is reconfirmed each month during calibration using a Beckman Model CEL-RB1-Y8F* laboratory standard cell.

pH.--The pH meter is an Orion model 399A* equipped with a Ross Combination Electrode which is specifically designed for use in low ionic strength solutions. Electrodes are generally replaced every six months and quality assurance checks are made three times a year. The pH meter is calibrated before each use by means of a carbon dioxide buffer preparation (Hydrolab Corporation, 1982). This method provides a low ionic strength solution similar to that of the stream and precipitation samples being studied.

Event Sampler.--Storm events are sampled at the primary site using an ISCO* water-quality sampler. This instrument is pre-programmed to collect samples at specific time intervals upon its initiation at the first increase in stream stage. A range of samples are generally taken over the complete period of the storm event. All sample bottles within the ISCO are open to the atmosphere until the completion of the cycle. Concurrent analysis of stream samples taken during the operation of the ISCO and the subsequent analysis of samples at the completion of its sequence have shown data to be consistent.

Precipitation Instruments.--This study follows the National Atmospheric Deposition Program (NADP) guidelines for the collection and handling of precipitation samples with the exception of the laboratory analysis which is completed at the USGS Analytical Laboratory.

The precipitation collector is a Wet/Dry Geotech Environmental Equipment Model 0600*. Several problems developed with this equipment during the first year of data collection which made it necessary to collect bulk samples in lieu of event samples. Winter operation of the Geotech equipment has proven very inconsistent. The sampler is equipped with two polyethylene buckets that are rinsed with distilled water between samples. A thorough acid rinse will be implemented into the cleaning process as soon as supplies become available.

Rainfall is recorded by a Belfort* weighing bucket type gage. This recorder is equipped with an event marker to indicate the initiation of the Geotech model 0600 wet/dry collector. A National Weather Service standard rain gage is roughly ten meters from the Belfort recorder. This gage gives the total inches of precipitation that has occurred during the span of a week and it can be used to check the accuracy of the Belfort. The entire precipitation monitoring station is fenced in and placed approximately 100 meters from the stream.

Surface-water Instruments.--All study sites are measured for discharge at the time of sampling. Either a standard AA or a pygmy current meter is used depending on flow conditions. The five synoptic sites are measured on an instantaneous basis only. There are no staff gages or reference marks at any of these sites. The primary site is fully instrumented with a manometer stage indicator, Stevens graphic recorder, and an Analytical Digital Recorder. The manometer is integrated via a selonoid switch with the ISCO water-quality sampler. During a storm event the ISCO will initiate an increase in stage of the manometer for a short period to mark the sample time and stage on the graphic recorder. All surface water data are processed at the Pittsburgh Subdistrict Office of the U.S. Geological Survey.

LABORATORY

Laboratory analytical methods are indicated in table 2.

Table 2.--(caption on next page) belongs near here

QUALITY ASSURANCE/QUALITY CONTROL

The ultimate goal of any sampling technique is to collect representative samples free of contamination and to preserve their integrity for analysis. The techniques followed to attain or approach this goal are described in papers by Topol and Ozdemir (in press) and the Aquatic Effects Task Force Groups of the Interagency Task Force on Acid Precipitation, 1983. Laboratory quality assurance/quality control procedures followed by the U.S. Geological Survey Central Laboratory are detailed by Friedman and Erdmann, 1982.

All sample containers are linear polyethylene with polyseal caps. Sample bottles are rinsed three times with high quality deionized water (conductivity <0.1 μmhos/cm), filled with distilled water, and let stand for several hours prior to use. The bottles are then rinsed three times with sample water.

Acidified and nonacidified sample blanks are submitted each month with the regular samples. As this program was initiated in June 1984, there are no data to report.

MONITORING DATA

Data collection was initiated in August 1983 at the six headwater streams and one precipitation site listed in table 1. Monitoring data include monthly base flow water quality at all six streams, storm sampling at the primary site, weekly precipitation water quality, and continuous streamflow measurement at the primary site.

This report presents streamflow and precipitation data collected during the first nine months of operation. More recent data have not been reported by the central laboratory. Because the data have not been verified, they should be considered provisional at this time.

USGS, Raleigh, North Carolina

Analytical Procedures

Analytical procedures are outlined in table 3. Most analyses are performed using standard procedures. However, samples for aluminum, iron, and manganese are filtered through 0.1 um filters in the field. Aluminum is extracted in the lab with methyl isobutyl ketone (MIBK) after chelation with 8-hydroxyquinoline and prior to analysis by atomic absorption spectrometry. Alkalinity is determined in the field using the Gran plot technique. Acidity also will be determined in the field begining in FY 1985. Six constituents, bromide, chloride, fluoride, nitrate, phosphate, and sulfate, are analyzed by ion chromatography.

QA/QC INFORMATION AND DATA

Quality-assurance and quality-control measures have been addressed previously in three separate documents. Those documents were from the Project Chief (Kent Crawford) to the EPA Project Officer (Charles Powers) on February 2, 1984 and August 27, 1984, and from the Project Chief to Owen Bricker (USGS research program) on August 30, 1984. Each of these documents is reproduced and appended to this report (Attachment 2). Published references that detail quality control practices and results and that have previously been sent to the EPA Project Officer are not included with this report. A more recent quality-assurance report from the USGS Central Laboratories than the one previously sent is also attached (Attachment 3). This report covers the period January 1 - march 31, 1984.

QA/QC data from blanks and duplicates submitted in association with the August, 1984 sampling are not yet available.

Table 3.--Analysis techniques for parameters included in the Sandhills project

Constituent	Parameter Code	Lab Code	Method Number	Detection Limit	Field Treatment	Technique	Reference
Dissolved aluminum	01106	4	I-1052-78	10.0 ug/L	Filter (0.1 um) acidify	Chelate with 8-hydroxyquinoline, extract with methyl isobutyl ketone (MIBK), determine aluminum by A.A.S.*	Skougstad and others, 1979 (p. 39)
Dissolved calcium	00915	12	I-1152-78	0.1 mg/L	Filter (0.45 um)	Add lanthanum chloride to mask interference, determine by A.A.S.	Skougstad and others, 1979 (p. 107)
Dissolved iron	01046	172	I-1381-78	10.0 ug/L	Filter (0.1 um) acidify	A.A.S.	Skougstad and others, 1979 (p. 153)
Dissolved magnesium	00925	40	I-1447-78	0.1 mg/L	Filter (0.45 um)	Add lanthanum chloride, A.A.S.	Skougstad and others, 1979 (p. 177)
Dissolved manganese	01056	42	I-1454-78	10.0 ug/L	Filter (0.10 um) acidify	A.A.S.	Skougstad and others, 1979 (p. 187)
Dissolved potassium	00935	54	I-1630-78	0.1 mg/l	Filter (0.45 um)	A.A.S.	Skougstad and others, 1979 (p. 229)
Dissolved sodium	00930	59	I-1735-78	0.1 mg/L	Filter (0.45 um)	A.A.S.	Skougstad and others, 1979 (p. 255)
Dissolved bromide	71870	656	--	0.1 mg/L	Filter (0.45 um)	I.C.**	Fishman and Pyen, 1979
Dissolved chloride	00940	292	--	0.1 mg/L	Filter (0.45 um)	I.C.	Fishman and Pyen, 1979
Dissolved fluoride	00950	651	--	0.01 mg/L	Filter (0.45 um)	I.C.	Fishman and Pyen, 1979
Dissolved nitrate	00618	225	--	0.05 mg/L	Filter (0.45 um)	I.C.	Fishman and Pyen, 1979
Dissolved phosphate	00671	650	--	0.1 mg/L	Filter (0.45 um)	I.C.	Fishman and Pyen, 1979

Table 3.--Analysis techniques for parameters included in the Sandhills project--Continued

Constituent	Parameter Code	Lab Code	Method Number	Detection Limit	Field Treatment	Technique	Reference
Dissolved sulfate	00945	538	--	0.1 mg/L	Filter (0.45 um)	I.C.	Fishman and Pyen, 1979
Dissolved silica	00955	56	I-2700-78	0.1 mg/L	Filter (0.45 um)	Reduce sample to less than pH 2.5, add ammonium molybdate, A.A.S	Skougstad and others, 1979 (p. 497)
Total acidity (lab)	71826	1	I-1020-78	1.0 mg/L (as $CaCO_3$	Chill	Automated electrometric titration to pH 8.3	Skougstad and others, 1979 (p. 515
Total alkalinity (lab)	90400	70	I-2020-78	1.0 mg/L (as $CaCO_3$)	Chill	Automated electrometric titration to pH 4.5	Skougstad and others, 1979 (p. 519)
pH (lab)	00403	68	I-2587-79	0.1 pH units	Chill	Automated electrometry, glass electrode	Skougstad and others, 1979 (p. 543)
Specific conductance (lab)	90095	69	I-2781-81	1.0 umho/cm	Chill	Wheatstone bridge, automated	Skougstad and others, 1979 (p. 545)
Dissolved ammonia nitrogen	00608	830	--	0.002 mg/L	Filter (0.45 um)	Sal. hypochlorite, automated colorimetry	--
Dissolved orthophosphate phosphorus	00671	828	--	0.001 mg/L	Filter (0.45 um)	Phosphomolybdate addition, automated colorimetry	--
Dissolved organic carbon	00681	113	0-0002-78	0.1 mg/L	Filter (0.45 um) chill	Wet oxidation in carbon analyzer, measurement of carbon dioxide	Goerlitz and Brown, 1972 (p. 4)

*A.A.S. = Atomic Absorption Spectrometry

**I.C. = Ion Chromatography

Tennessee Valley Authority

Laboratory Quality Assurance Program for the Project: Long-Term Monitoring of Reservoirs in the Southern Appalachians

1.0 OBJECTIVES

The objective of the quality assurance program was to assure that valid and reliable analytical data were reported and to assess the accuracy and precision of the values generated so that accurate interpretation could be made.

2.0 SCOPE

The program covered the analytical activities affecting the data generated by the laboratory for the subject project.

3.0 REFERENCES

3.1 "Preparation of Sample Containers," NRS-LB-AS-3.1, Laboratory Branch, Division of Natural Resource Services, Tennessee Valley Authority, April 1980.

3.2 "Performing Intralaboratory Quality Control Analyses," NRS-LB-AS-3.9, Laboratory Branch, Division of Natural Resource Services, Tennessee Valley Authority, May 1980.

3.3 "Preparing Worksheets and Forms," NRS-LB-AS-3.6, Laboratory Branch, Division of Natural Resource Services, Tennessee Valley Authority, March 1980.

3.4 "Performing Routine Analysis," NRS-LB-QAP-3.1, Laboratory Branch, Division of Natural Resource Services, Tennessee Valley Authority, March 1980.

3.5 "Methods of Chemical Analysis of Water and Wastes," Environmental Protection Agency, Cincinnati, Ohio (1979).

3.6 "Recording, Checking, and Approving Analytical Data," NRS-LB-AS-3,10, Laboratory Branch, Division of Natural Resource Services, Tennessee Valley Authority, June 1980.

3.7 "Preparing Reports of Results," NRS-LB-AS-3.12, Laboratory Branch, Division of Natural Resource Services, Tennessee Valley Authority, June 1980.

3.8 "Conductance, pH, Strong and Weak Acidity," NRS-LB-AP-10.377.1.

3.9 "Acid Titration of Polar Snow," Legrand, et. al., Anal. Chem., 1982, 54, 1336-1339.

3.10 "Metals by Atomic Emission," NRS-LB-AP-30.200.2.

3.11 "Multiparameter Analysis of Rainwater by Ion Chromatography," NRS-LB-AP-10.200.1.

4.0 ABBREVIATIONS AND DEFINITIONS

4.1 LB--Tennessee Valley Authority's Laboratory Branch

4.2 PL--Project Leader of Laboratory Branch

4.3 PM--Project Manager

5.0 PROCEDURES AND RESPONSIBILITIES

5.1 Sample Collection and Receiving (A flowchart displaying these steps is given in Attachment 1.)

5.1.1 A maintenance program which involved periodic inspection, servicing, and calibration of field equipment was utilized.

5.1.2 Sample containers were cleaned and labeled. Each batch of containers was checked by randomly selecting several sample containers for quality control analyses (reference 3.1). Containers were filled with deionized water and container contents were analyzed for the required parameters.

5.1.3 Samples were collected and preserved as described in reference 3.1. All samples were identified using a unique numbering system.

5.1.3.1 Filtration blanks were collected for nonfilterable (dissolved) anions and cations and shipped to the LB for analysis.

5.1.4 Samples were recieved by the LB and all necessary information regarding the samples was recorded.

5.1.5 The PL checked all samples and records for any irregularities.

5.1.6 The PL notified the PM of any irregularity regarding the samples.

5.1.7 The PL resolved all problems or questions before the samples were released for analysis.

5.1.8 The PL prepared laboratory worksheets (reference 3.3) and submitted the samples and worksheets to their proper locations.

5.2 Laboratory Analysis and Data Reporting (A flowchart displaying these steps is given in Attachment 2.)

5.2.1 Samples and appropriate blanks were analyzed for the parameters listed in Attachment 3. Analytical references, description of methodology, and detection limits for the analytical procedures are also listed in Attachment 3.

5.2.2 Where possible, the LB Intralaboratory Quality Control Program (reference 3.2) was followed by analyzing 10 percent of the samples in duplicate and spiking 10 percent of the samples.

5.2.3 All analytical data were recorded in laboratory notebooks (reference 3.6), calculations checked, analysis approved, and results forwarded to the PL.

5.2.4 Results from the accuracy and precision quality control samples were reviewed by the PL. If a result was outside the control limits, the sample was resubmitted for anlaysis.

5.2.5 If any data indicated a problem, the PL took corrective action.

5.2.6 Data were tabulated, reviewed, and approved by the PL.

5.2.7 Data were keypunched and stored in the STORET data system.

5.2.8 Completed printouts of data were forwarded to the PM for review and approval.

6.0 QUALITY CONTROL METHODS

6.1 Blanks

6.1.1 Filtration blanks were prepared by field personnel, submitted to laboratory, and were analyzed to determine the adequacy of the filtration manipulation as well as the cleanliness of the dissolved anion/cation sample container (250 mL-LPE bottle). Membrane filtrates of deionized water were analyzed for the dissolved species of fluoride, chloride, phosphate, nitrate, sulfate, sodium, potassium, calcium, magnesium, and aluminim. Sixteen filtration blanks were prepared, submitted, and analyzed.

6.1.2 Container blanks for unfiltered parameters were performed to check the adequacy of the 1-quart cubitainer as a sample container. Unfiltered parameters included pH, true and apparent color, conductance, strong and weak acidity, and alkalinity. Virgin 1-quart cubitainers were used as containers for unfiltered sample aliquots.

6.2 Evaluation of Precision

6.2.1 Precision data were generated by analyzing actual samples in duplicate. Difference between the two observed values was multiplied by 0.89 to approximate the standard deviation (SD). The standard deviation divided by the mean of the duplicate values and multiplied by 100 yielded the relative standard deviation (RSD) in percent. RSD values were used to assess the adequacy of precision observations.

6.3 Evaluation of Accuracy

6.3.1 Accuracy data were generated by fortifying actual samples with known amounts of analyte, analyzing the spiked aliquot, and calculating the percent recovery. Bias values in percent were obtained by subtracting 100 from the percent recovery. Bias values were used to assess the adequacy of accuracy observations.

6.3.2 Accuracy data were also generated by analysis of control solutions. Control solutions are stable, synthetic working solutions of known concentration that are analyzed after the calibration or optimalization of an analytical procedure. Bias values obtained from these observations were also used to assess the adequacy of accuracy.

7.0 RESULTS AND DISCUSSION

7.1 Blanks

7.1.1 Filtration blanks confirmed the acceptability of the membrane filtration process for dissolved components. Filtration blank values also established the adequacy of the 250-mL LPE bottle as a sample container. Results of filtration blank analyses are described in Attachment 4. All values for fluoride, phosphate, and aluminum parameters were less than detectable concentrations. Detected concentrations of chloride, nitrate, sulfate, calcium, and magnesium were within expected and acceptable ranges. Two observations of potassium, 0.10 and 0.12 mg/L, were of a marginal magnitude; however, these two values did not raise the mean concentration above the detection limit of 0.01 mg/L. Only the mean concentration of the sodium parameter was greater than the detection limit of the analytical procedure. Detection limit for the sodium method was 0.01 mg/L. The observed mean concentration of 0.01 mg/L matched the detection limit of 0.01 mg/L. A single observation of sodium, at the 0.13 mg/L level, served to raise the mean concentration to the detection limit.

7.1.2 Container for the unfiltered parameters was the standard 1-quart cubitainer. Eight deionized water blank samples were prepared, submitted, and analyzed. Results of the analyses are detailed in Attachment 5. All observations of unfiltered parameters were within or below expected values. Previously accumulated quality control data for the 1-quart cubitainer had also demonstrated its contaminant-free reliability.

7.2 Precision Observations

7.2.1 Relative standard deviation (RSD) values for all parameters were excellent. See Attachment 6 for details of the precision observations. Average RSD values ranged from a low of 0.2 percent for pH and conductance parameters to a high of only 3.7 percent for fluoride determinations.

7.3 Accuracy Observations

7.3.1 Spiked or fortified data.

7.3.1.1 Bias values for anion and cation parameters are detailed in Attachment 7. All average bias values were acceptable. Values ranged from -7.5 percent for sulfate to 12 percent for chloride. Bias values for anions were generally greater because of the very low spike concentrations used to fortify the sample aliquots. Conductance, pH, color, acidity, and alkalinity parameters were not assessed for accuracy by spiking with known concentrations of analytes.

7.3.2 Control solution data-anion parameters.

7.3.2.1 Bias values for dissolved anion parameters are detailed in Attachment 8. All average bias values were acceptable. Values ranged from -0.3 percent to 2.6 percent for fluoride.

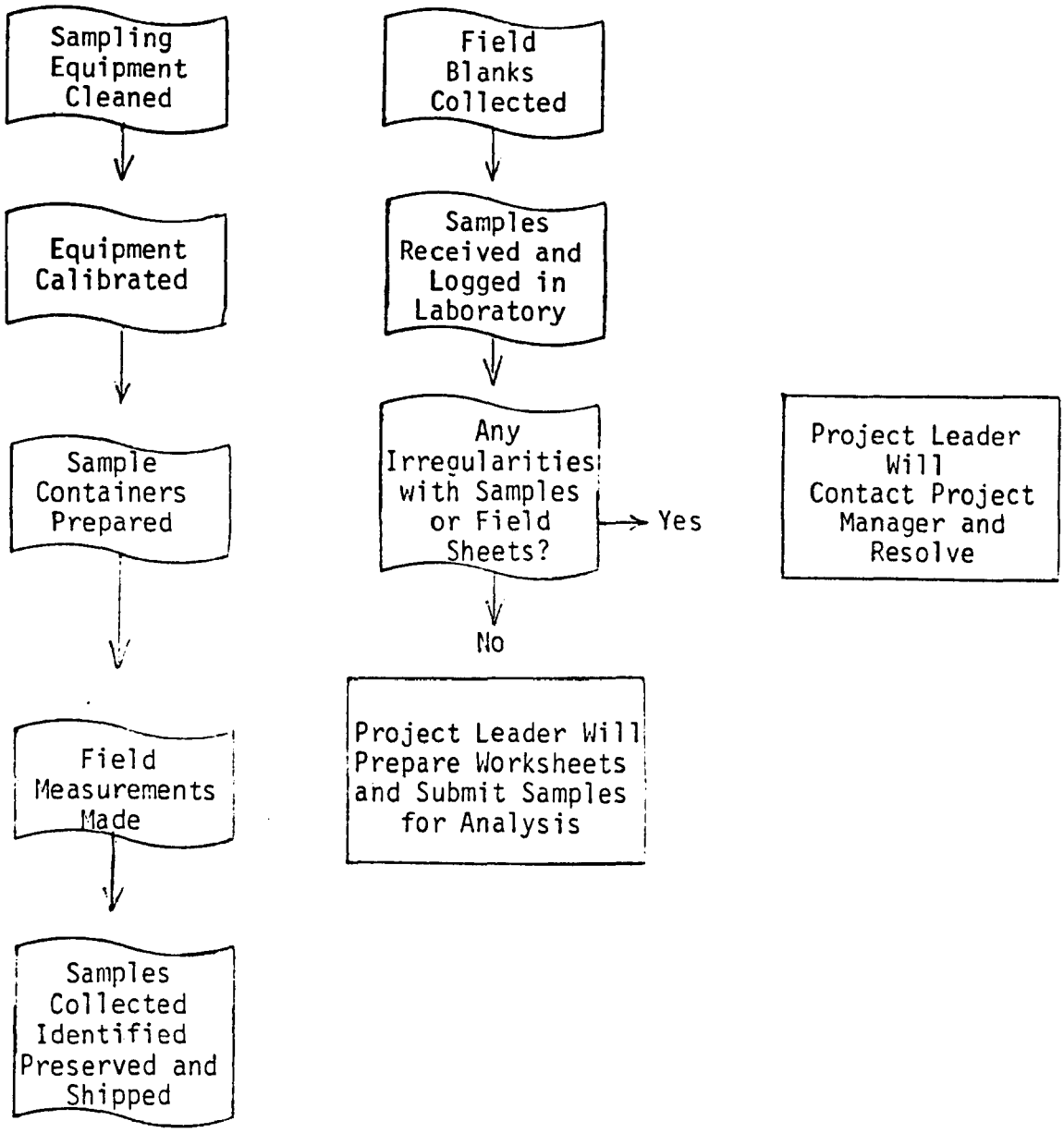
8.0 CONCLUSIONS

8.1 Overall accuracy and precision of data generated during the 1982-1983 phases of the project were adequate and within the interpretative requirements of the study.

8.2 Preparation of sample containers and filtration manipulations were satisfactory.

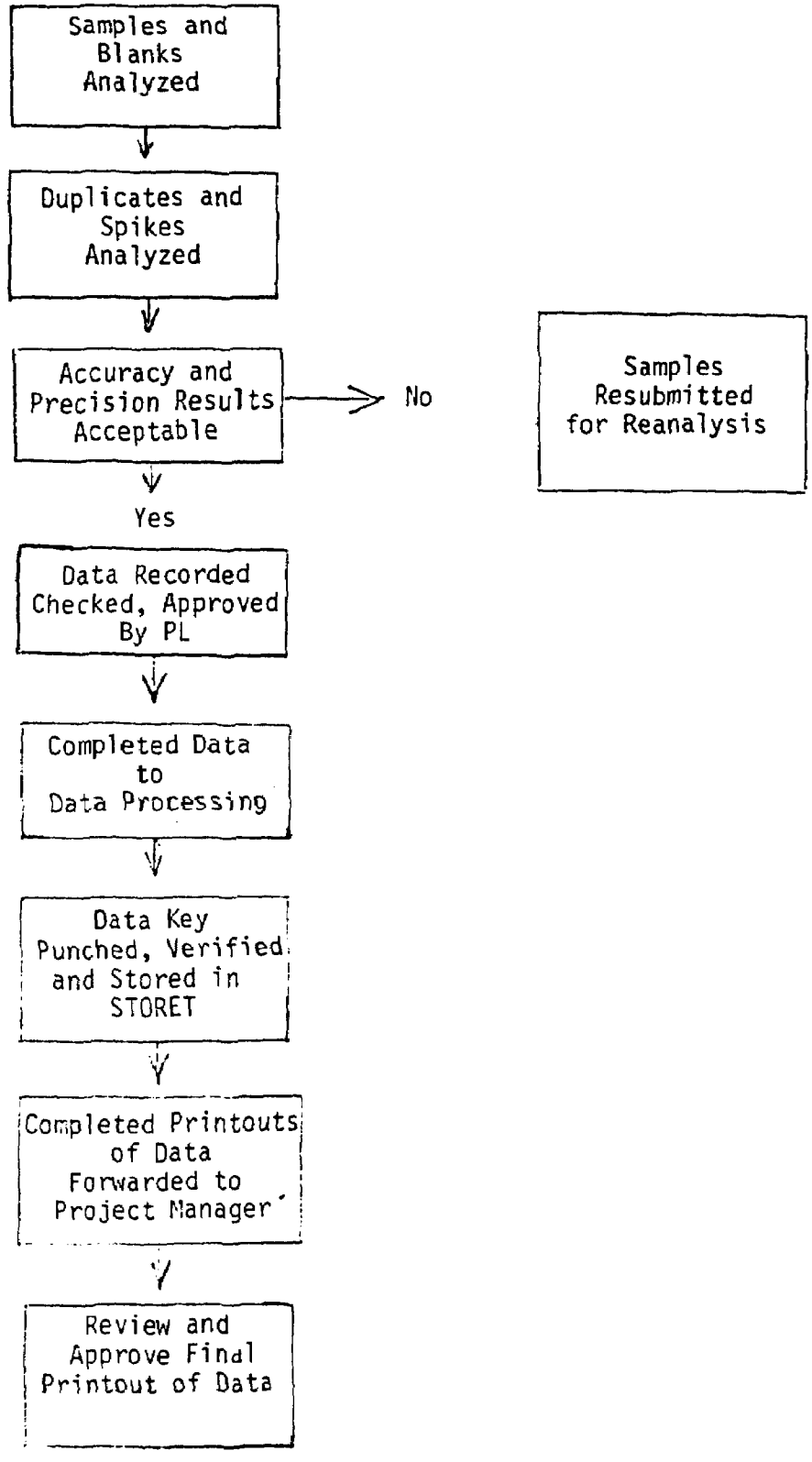
Attachment 1

Sample Collection and Receiving



Attachment 2

Laboratory Analysis and Data Reporting



Attachment 3

Analytical Methodology

Parameter	Reference	Method Description	Minimum Detectable Concentration
pH	3.8	Electrometric	N/A
Acidity (weak and strong)	3.8	Titrimetry, Gran's plot	10 μeq H^+/L
Alkalinity	3.9	Titrimetry, Gran's plot	10 μeq H^+/L
Calcium, dissolved	3.5, Method 215.1	Atomic absorption - direct aspiration	0.05 mg/L
Magnesium, dissolved	3.5, Method 242.1	Atomic absorption - direct aspiration	0.01 mg/L
Sodium, dissolved	3.5, Method 273.1	Atomic absorption - direct aspiration	0.01 mg/L
Potassium, dissolved	3.5, Method 258.1	Atomic absorption - direct aspiration	0.01 mg/L
Aluminum, dissolved	3.10	Atomic emission	0.05 mg/L
Fluoride, dissolved	3.11	Ion Chromatography	0.02 mg/L
Chloride, dissolved	3.11	Ion Chromatography	0.10 mg/L
Phosphate, dissolved	3.11	Ion chromatography	0.04 mg/L
Nitrate, dissolved	3.11	Ion Chromatography	0.04 mg/L
Sulfate, dissolved	3.11	Ion Chromatography	0.10 mg/L
Color, True, and Apparent	3.5, Method 110.2	Chloroplatinate, visual	1 unit

Attachment 4

Results of Container Blanks for Dissolved Parameters
(250 mL-LPE Bottle)

Dissolved Parameter	Number of Observations	Number of Observations Less Than Detection Limit	Range of Values (mg/L)	Average Concentration (mg/L)
Fluoride	16	16	all were <0.02	<0.02
Chloride	16	9	<0.1 to 0.3	<0.1
Phosphate	16	16	all were <0.04	<0.04
Nitrate	16	10	<0.04 to 0.09	<0.04
Sulfate	16	13	<0.1 to 0.5	<0.1
Calcium	16	14	<0.05 to 0.09	<0.05
Magnesium	16	9	<0.01 to 0.02	<0.01
Sodium	16	12	<0.01 to 0.13	0.01
Potassium	16	13	<0.01 to 0.12	<0.01
Aluminum	16	16	all were <.05	<0.05

Attachment 5

Results of Container Blanks for Unfiltered Parameters
(1-Quart Cubitainer)

Unfiltered Parameter	Number of Observation	Range of Values	Average Concentration
pH	8	6.48 - 5.21 units	5.62
Acidity, strong	8	All <10 μeq H+/L	<10
Acidity, weak	8	30 - 60 μeq H+/L	40
Alkalinity	8	All <10 μeq H+/L	<10
Conductance	8	1.4 - 2.8 μmhos/cm	2.0
Color, true	0	-	-
Color, apparent	0	-	-

Attachment 6

Results of Precision Observations

meter	Number of Duplicate Analyses	Range of RSD Values (%)	Average RSD (%)
	2	0.1 - 0.3	0.2
or, true	8	0.0 - 15.4	3.4
or, apparent	8	0.0 - 10.4	1.6
idity, strong	2*	-	-
idity, weak	2	0.0 - 5.0	2.5
kalinity	2	0.0 - 1.9	1.0
onductance	2	0.1 - 0.2	0.2
luoride	6	0.0 - 17.7	3.7
Chloride	6	0.0 - 1.9	0.8
Phosphate	6	0.0 - 2.9	0.7
Nitrate	6	0.0 - 15.4	2.8
Sulfate	6	0.0 - 2.2	0.8
Calcium	1**	2.1	2.1
Magnesium	1**	2.4	2.4
Sodium	3	0.0 - 0.6	0.3
Potassium	3	0.0 - 3.0	1.8
Aluminum	7	0.0 - 2.8	0.8

*All observations were less than minimum detectable concentration.
**Lost record for all 1982 raw data.

Attachment 7

Results of Accuracy Observations

Parameter	Number of Accuracy Observation	Concentration of Spike (mg/L)	Range of Bias (%)	Average Bias (%)
Fluoride	4	0.098	-12 to +30	7.8
Chloride	4	0.49	-2 to +39	12.
Phosphate	4	0.49	-10 to 0.0	-3.
Nitrate	4	0.49	0.0 to 16	7.5
Sulfate	4	0.98	-11 to -3	-7.5
Calcium	1*	2.0	4.0	4.0
Magnesium	1*	0.2	4.0	4.0
Sodium	3	2.0	+1.0 to 2.0	2.0
Potassium	3	0.2	-2.0 to +2.0	1.0
Aluminum	7	0.5	-3 to +7.0	2.0

*Lost record for all 1982 raw data.

Attachment 8

Results of Accuracy Observations - Control Solution
Data for Dissolved Anions

Parameter	Number of Observations	Concentration mg/L	Range of Bias (%)	Bias (%)	Average Bias (%)
Fluoride	5	0.10	0.0 to 40	12	
	5	0.20	0.0 to -17	-3.4	2.6
	5	0.40	0.0 to -2	-0.8	
Chloride	5	0.5	-5.0 to 20	5.8	
	5	1.0	-8.0 to 2.0	1.6	2.4
	5	2.0	0.0	0.0	
Phosphate	3	0.20	-10 to 10	0.0	
	4	0.40	-15 to -2	-5.2	-0.3
	5	0.80	-2.0 to 9.0	4.4	
Nitrate	5	0.20	-10 to 4.9	-1.8	
	5	0.50	-2.0 to 5.0	3.0	0.4
	5	2.0	-2.0 to 2.0	0.0	
Sulfate	5	1.0	-2.0 to 20	5.4	
	5	5.0	-2.0 to 0.0	-1.6	1.7
	5	10.	0.0 to 2.0	1.2	

Appendix II I. Data Quality Objectives: Long-Term Surface Water Monitoring Program.

DATA QUALITY OBJECTIVES: LONG-TERM SURFACE WATER MONITORING PROGRAM

Stage I. Initial Input by EPA Senior Management and Task Group E

The program for the long-term monitoring of the nation's surface waters had its inception in a request from EPA Headquarters in June 1982 to plan, develop, and implement a program to quantify the effects of current deposition levels on sensitive aquatic ecosystems. Reduction of precursor emissions has been urged as a means of curtailing the rate of deposition of acidic materials. In order to determine acceptable loadings, however, it is first necessary to quantify current effects over a range of loading rates and geographical regions. To evaluate the overall effect of emission controls, one must know: (1) the response of lakes and streams of similar sensitivity to various deposition rates; (2) the differences in response of lakes and streams of differing degrees of sensitivity to a given deposition rate; and (3) whether there are regional differences in the way sensitive lakes and streams respond to various deposition rates.

This task was undertaken within the NAPAP organizational framework. An *ad hoc* committee was organized in July 1982 within Task Group E to consider approaches to monitoring and develop a standardized sampling/analysis protocol. The committee, with representation from EPA, USGS, TVA, USDA-FS, USFWS, USNPS, and Brookhaven National Laboratory, produced a draft protocol in January 1983 as the basis for a national surface water chemistry monitoring effort. This document received extensive peer and inhouse review and has served as the basis for the EPA lake and stream monitoring program.

Stage II. Clarification of the Problem

A program was developed by EPA to monitor the quality of lakes and streams in regions of low alkalinity to determine whether detectable changes in water chemistry are occurring in those regions and, if so, whether they can be related to atmospheric inputs. In planning this program, it was necessary to take into consideration certain factors concerning the distribution and regionality of acidic deposition, which is known to occur in all states east of the Mississippi River but is much less uniformly distributed in the West. Some regions receiving acidic deposition contain lakes and/or streams of low alkalinity (hence, presumably sensitive to acidification); in other regions, surface water alkalinities are uniformly high and acidification from atmospheric deposition is not expected. Sensitive waters also occur in regions not now receiving acidic deposition, or where acidic deposition is minimal, but it cannot be assumed that precipitation chemistries in those regions will remain unchanged in the future. There is evidence from studies in, for example, the Adirondacks, Maine and Vermont, and the Muskoka-Haliburton region of Ontario that decreases in alkalinity (hence, acidification) have occurred in some North American lakes. There is also evidence that alkalinity may actually be increasing in the Northeast in response to decreases in sulfate emissions.

Although precipitation chemistry may be essentially uniform within a given geographical region, we know that not all lakes or streams can be expected to respond identically. There are probably even greater uncertainties with respect to comparability of response of surface waters between regions. For example, although average precipitation pH and SO_4 deposition in the southern Appalachians and in New England fall within the same range (pH, 4.4-4.2; SO_4, 20-30 kg/ha/yr), significant differences exist between those regions. New England was glaciated and the southern Appalachians were not; New England

contains many hundreds of small natural lakes, but southern Appalachian surface waters are characterized by streams and artificial reservoirs; soils in New England are quite young, while those in the South are much older, on the order of millions of years. Low alkalinity waters occur in both regions, but there is no good reason to expect that the effects of acidic deposition on aquatic systems in the two regions would be the same. Based on present knowledge, results probably should not be extrapolated from one region to another.

Objectives

The objectives of the long-term surface water monitoring program are:

1. detect and measure long-term trends in the chemistry of low alkalinity surface waters that are related to atmospheric deposition; and
2. compare the response of low alkalinity waters (1) over a geographic gradient of H^+ and sulfate deposition and (b) in different major sensitive geographic areas that receive comparable deposition.

Sites would be in locations where annual sulfate deposition averaged 0-10, 10-20, 20-30, and 30-40 kg/ha, with average volume-weighted pH ranging from about 5.3 to 4.2. Sites would at the same time be chosen to provide observations in geographically separate regions (e.g., New England and the southern Appalachians) receiving comparable sulfate and hydrogen ion deposition.

Questions to be answered relative to Objective 2 are:

1. At what level(s) of sulfate and hydrogen ion deposition do measurable changes in lake or stream chemistry occur?
2. Do lakes or streams of comparable alkalinity located in different geographical regions respond the same to similar levels of sulfate and hydrogen ion deposition?

Stage III. Development of Conceptual Approach

Monitoring sites were selected so as to best satisfy the objectives of the program, that is, to detect trends relatable to effects of deposition, and to compare responses of surface waters over deposition chemistry gradients and between sensitive areas receiving comparable deposition. The first of these two objectives requires sites in sensitive areas receiving acidic deposition, as removed from disruptive anthropogenic influences (land use, local pollution, fire) as possible. The second objective requires, in addition, the selection of sites from a variety of locations exposed to various degrees of precipitation acidity. Accordingly, monitoring sites are situated where surface waters are commonly less than 200 μeq/l total alkalinity (ANC). The national and regional alkalinity maps generated by EPA have assisted in the identification of these locations. Areas selected for monitoring to date include the Northern Rocky Mountains; the Upper Midwest lake district (Minnesota, Wisconsin, Michigan); Maine; Vermont; the Adirondack Mountains of New York; the Catskill Mountains in southeastern New York; the Allegheny Mountains of southwestern Pennsylvania; the southern Appalachians (Southern Blue Ridge Province of North Carolina, Tennessee, and Georgia); and the Sandhills of south-central North Carolina. These locations not only provide a broad sampling of low alkalinity waters, but lie across a gradient of precipitation chemistry from essentially background chemical concentrations in the northern Rockies to the acidic precipitation of the East. Individual sites were selected to minimize disruptive effects of past or future land use, local atmospheric pollution, forest fires, logging, and fish management. When possible, sites where concurrent research will provide related data are chosen, and sites with good historical data are preferred over those without, other factors being equal. Accessibility is also carefully considered.

The rationale for the selection of the particular monitoring sites presently comprising the program was as follows. First, it was evident from the geographic distribution of lakes, reservoirs, and streams in the United States that natural lakes are the dominant resource of concern in the northern tier of states (south to the limit of Pleistocene glaciation) and in the mountainous West, but are replaced by streams and reservoirs in the South. In comparing this distribution with known distributions of low alkalinity waters and deposition chemistry, it became further evident that monitoring sites should be identified in the mountainous West, the upper Great Lakes region, the Adirondacks, New England, and the Appalachians. Emphasis would be on lakes in all areas except the Appalachians where the focus would be on streams and reservoirs.

Proceeding on these premises, opportunities for initiation of monitoring were sought which (1) would provide lake, stream, or reservoir monitoring sites in locations corresponding to the criteria for geographical location, low alkalinity, and deposition chemistry and (2) were sites where ongoing work could be modified or adapted to EPA's monitoring needs.

In the Upper Great Lakes region, the EPA-Duluth laboratory, together with universities and state agencies, had begun a broad scale survey of lakes in 1978. Three subsets of these lakes plus six streams in upper Minnesota (in the vicinity of the Boundary Waters Canoe Area and Voyageurs National Park), in northeast Wisconsin, and in the eastern half of the Upper Peninsula of Michigan were chosen for monitoring, with the work to be carried out by the University of Minnesota-Duluth cooperatively with EPA-Duluth. Sampling for this program was conducted in the fall of 1982 and the spring and summer of 1983. Subsequent reorientation of the Duluth program necessitated continuation of work beyond the summer of 1983 by a new contractor. Monitoring of 38 lakes was

assumed in fall 1983 by the University of Minnesota at Minneapolis, with contractual assistance from the Wisconsin Department of Natural Resources. The list of monitored waters was modified to eliminate stream sites because it was recognized that meaningful data could not be obtained for trend analysis on flowing systems in a monitoring program limited to three sampling dates per year. The list of lakes was further modified to eliminate some redundancy in lake characteristics, to reflect recent information on water quality changes in some Wisconsin lakes, to eliminate some insensitive lakes and lakes subject to watershed disturbance, and to provide a broader range of lake coverage in Minnesota.

In Maine, the U.S. Fish and Wildlife Service at the University of Maine had just recently completed an excellent survey of lakes of New England, and had undertaken fisheries-related research on effects of acidic deposition. It was logical to draw on their extensive expertise for the Northeast and to expand their existing program to include long-term montoring. Accordingly, monitoring of six lakes in the Tunk Lakes area of southeast Maine was begun in fall 1982. Included in this project is exploratory work on non-destructive fish sampling as well as chemical monitoring.

The State of Vermont had initiated lake monitoring on twenty lakes in 1981. Coverage was later expanded to 36 lakes with 24 sampled in alternate years. EPA initiated partial funding of the Vermont effort in 1982.

The need for monitoring low alkalinity reservoirs in the Southeast had been established. The Tennessee Valley Authority (TVA) possessed a large body of chemical and other data on reservoirs of the region, and arrangements were made for a survey by TVA of 54 reservoirs selected on the basis of the existing data. Based on the results of that survey, 12 reservoirs were chosen for long-term monitoring.

In the West, ongoing or planned long-term studies by the U.S. National Park Service and the U.S. Geological Survey provided monitoring coverage in Sequoia National Park, California, and Rocky Mountain National Park, Colorado. Proposed studies by the Geological Survey in the northern Cascade Mountains in Washington have been delayed, but work has been initiated by the National Park Service in the Olympic Mountains in that state. The most obvious omission in the West appeared to be the northern Rocky Mountains, and a cooperative agreement was implemented with Montana State University for a survey and subsequent monitoring of lakes in southwest Montana and northwestern Wyoming near Yellowstone National Park. From results of the survey, eleven lakes were chosen for monitoring. These are all high-elevation, low-alkalinity lakes.

Monitoring is more complex for streams than for lakes because of the influence of discharge coupled with season. Base flow tends to display uniform representative composition, but storm flow and snowmelt runoff may significantly alter stream chemistry. Proper stream monitoring, therefore, requires continuous recording of flow and sampling over a complete range of discharge, including during and following storm events and snowmelt.

Obviously, the high frequency of sampling required for streams presents a serious budgetary problem in a monitoring program. A reasonable solution was achieved through a cooperative approach with the U.S. Geological Survey. The Survey had initiated or was planning watershed studies on a number of low alkalinity streams in the East. A single stream in each watershed was gauged and instrumented for automatic sampling during storm or snowmelt events. Wet-dry deposition sampling was carried out at each site. EPA arranged to provide additional funding at three sites (the Catskills of southeastern New York, the Alleghenies of southwestern Pennsylvania, and the Sandhills of North Carolina) for sampling five or six additional streams on an approximately

monthly basis to provide more broadly based monitoring data. Event samples from the primary stream would provide indications of the effect of storms and snowmelt on stream chemistry, and monthly sampling would provide information on seasonal variation and long-term change.

Stream studies were also undertaken with TVA, in which five streams in the southern Appalachians have been instrumented for automatic storm event sampling. The project is funded jointly by Task Group E Objectives E-01 and E-02.

In practically all cases, lakes or streams are clustered to facilitate sampling and to minimize within-cluster variations in climate and deposition patterns.

Each group of monitored lakes or streams must be sufficiently represented by deposition chemistry monitoring sites to permit characterization of chemical loading. In most cases, one or more NADP sites are located in the monitoring area.

SUMMARY

Data Quality Objectives: Long-Term Surface Water Monitoring Program

Monitoring Objectives:

1. Detect and measure long-term trends in the chemistry of low-alkalinity surface waters that are related to atmospheric deposition.
2. Compare the response of low-alkalinity waters
   a. Over a geographic gradient of hydrogen ion and sulfate deposition
   b. In different major sensitive geographic areas that receive comparable deposition.
3. Monitoring data will be used to establish baselines with which future observations can be compared, to calculate time trends in significant chemical variables, and to determine the frequency and severity of chemical changes accompanying hydrologic events.

Data Collection Approach:

- Monitoring sites are located in sensitive (low alkalinity) regions receiving acidic deposition, as removed from disruptive anthropogenic influences as possible. (See site summary, Table 1).
- Sites are selected from a variety of locations exposed to various degrees of hydrogen ion and sulfate loading.
- Areas selected for monitoring include the northern Rocky Mountains, the Upper Midwest, the Adirondack Mountains, Maine and Vermont, the Catskill

Mountains (southeast New York), the Allegheny Mountains (southwest Pennsylvania), the southern Appalachians, and the south-central North Carolina Sandhills.

- Emphasis is on lakes in the glaciated Northeast, Upper Midwest, and mountainous West, and on reservoirs in the Southeast where natural lakes are virtually absent. Streams are monitored in New York, Pennsylvania, North Carolina, and the southern Appalachians.
- NADP/NTN or other precipitation monitoring stations are located in each area of surface water monitoring to provide characterization of atmospheric chemical wet loading.
- Lakes are sampled three times annually: following ice-out, during summer thermal stratification, and during fall overturn. The southeastern reservoirs do not freeze and are sampled quarterly.
- Lakes and reservoirs are sampled at a single location 0.5-1.0 m below the surface when not thermally stratified. When stratified, a second sample is obtained 1-2 meters from the lake bottom, providing representative samples of epilimnetic and hypolinmetic water.
- Streams are sampled seasonally over a range of flows, from base-flow to high runoff conditions.
- Lake and stream sampling are in accordance with EPA-prescribed protocols.

Data Quality Objectives:

1. Precision and accuracy

Determine whether long-term trends in the chemistry of low-alkalinity lakes, streams, and reservoirs are occurring. Trends are defined as sustained

year-to-year increases or decreases in the concentrations of any of the following variables at the stated confidence intervals:

pH ($\pm$ 0.1 units)

alkalinity ($\pm$ 10%)

Σ Ca, Mg, Na, K ($\pm$ 5%)

SO_4 ($\pm$ 5%)

NO_3^- ($\pm$ 10%)

Σ SO_4, NO_3, Cl ($\pm$ 10%)

Table 2 sets forth the required minimum analytical detection limits.

2. Representativeness

Collect data of sufficient quality to characterize individual lakes, streams, or reservoirs in terms of each characteristic measured and to generate distributions within lake, stream, or reservoir sets for each measured characteristic. Monitored sets of water bodies are located nationally to provide sampling coverage of low alkalinity (< 200 μeq/l) waters over the existing range of deposition of sulfate and hydrogen ions.

3. Completeness

The quantity and temporal distribution of data must assure adequate measurement of seasonal patterns of water chemistry to permit comparison of conditions from year to year.

4. Comparability

A standard sampling and analysis protocol prescribes the procedures used by each sampling team and analytical laboratory. Data will be calculated and

reported in the same units. Audit samples are analyzed three times each year to determine comparability of results among investigators.

Table 1
FY84 EPA-Funded Long-Term Surface Water Monitoring Projects

Location	Principal Investigator	Agency	Sites	Type	Start
Montana-Wyoming	Gordon Pagenkopf	Montana State U.	11	lakes	Fall 1983
Upper Great Lakes Region(MN, WI, MI)	Patrick Brezonik	U. of Minnesota	38	lakes	Fall 1982
Maine	Terry Haines	USFWS, U. of ME	6	lakes	Fall 1982
Vermont	Wallace McLean	State of Vermont	36	lakes	Winter 1981
New York	Peter Murdoch	USGS, Albany, NY	7	streams	Summer 1983
New York	Charles Driscoll	Syracuse University	17	lakes	Spring 1985
Pennsylvania	James Barker	USGS, Harrisburg, PA	6	streams	Summer 1983
North Carolina	Kent Crawford	USGS, Raleigh, NC	5	streams	Summer 1983
Southern Blue Ridge Province (NC, TN, GA)	Harvey Olem	TVA, Chattanooga, TN	5 12	streams reservoirs	Fall 1983 Fall 1982

Table 2. Required Minimum Analytical Detection Limits, Expected Ranges, and Intralaboratory Relative Precision. (Adapted from National Surface Water Survey protocol).

Parameter (a)	Units	Required Detection Limit	Expected Range	Intralab Relative Precision Goal (%) (b)
Acidity	μeq/l	5	10-150	10
Alkalinity (ANC)	μeq/l	5	0-1000	10
Al, Extractable	mg/l	0.005	0.005-1.0	10(Al>0.01),20(Al<0.01)
Al, Total	mg/l	0.005	0.005-1.0	10(Al>0.01),20(Al<0.01)
Ca	μeq/l	0.01	0.5-20	5
Cl^-	μeq/l	0.01	0.2-10	5
Color	ALPH units	0	0-200	±5(c)
DIC	mg/l	0.05	0.1-15	10
DOC	mg/l	0.1	0.1-50	5(DOC>5),10(DOC<5)
F^-	μeq/l	0.005	0.01-0.2	5
Fe	μeq/l	0.01	0.01-5	10
K	μeq/l	0.01	0.1-1	5
Mg	μeq/l	0.01	0.1-7	5
Mn	μeq/l	0.01	0.01-5	10
Na	μeq/l	0.01	0.5-7	5
NH_4	μeq/l	0.01	0.01-2	5
NO_3	μeq/l	0.005	0.01-5	10
pH, field	pH units	-	4-7	±0.1(c)
pH, lab	pH units	-	4-7	±0.05(c)
Secchi Disk	meters	-	-	-
SiO_2	mg/l	0.05	2-25	5
SO_4^{2-}	μeq/l	0.05	1-20	5
Specific Conductance	μS/cm	(d)	1-1000	1
Total P	μeq/l	0.002	0.005-0.07	10(P>0.01),20(P<0.01)

(a) Dissolved ions and metals are being determined, except where noted.

(b) Unless otherwise noted, this is the relative precision at concentrations above about 10 times instrumental detection limits.

(c) Absolute precision goal in terms of applicable units.

(d) Blank must be <1.0 μS/cm.

Appendix IV. Working Protocol for Sampling, Sample Analysis, and QA/QC for the USEPA Long-Term Surface Water Monitoring Program.

3/15/85

WORKING PROTOCOL FOR SAMPLING, SAMPLE ANALYSIS, AND QA/QC FOR THE USEPA LONG-TERM SURFACE WATER MONITORING PROGRAM

Introduction

An EPA program for long-term monitoring of lakes and streams was initiated in 1982 within the NAPAP organizational framework. An ad hoc committee, with representation from USEPA, USGS, TVA, USDA-FS, USFWS, USNPS, and Brookhaven National Laboratory, developed a draft sampling and analysis protocol to standardize monitoring efforts among the member Task Group E agencies. This document, with periodic reviews and updates, has served as the standard protocol for the EPA surface water monitoring program since its inception.

In 1984 EPA initiated the National Surface Water Survey (NSWS). This three-phase program is scheduled to culminate in the selection of geographically representative lakes for long-term monitoring in the east, upper midwest, and mountainous west. This third phase of NSWS is expected to subsume the existing long-term monitoring program. Most of the existing sites are probably compatible with Phase III owing to their location in low alkalinity regions and their positioning with respect to minimization of extraneous effects that could compromise interpretations of observed changes or trends.

The methods manual developed for NSWS (Hillman et al.) has been used, together with the Task Group E sampling and analysis protocol document, to produce the present "working protocol" for the long-term monitoring program. Laboratory analytical methodology, detection limits, and QA/QC procedures are more adequately and precisely specified; site selection criteria are not

included. The objective has been to align the long-term monitoring methodology with that of NSWS, without undue disruption of existing monitoring procedures. The present document replaces the Task Group E protocol (Aquatic Effects Task Group, March 1984 revised) as the procedural document for the EPA monitoring program. Participating agencies and institutions must be able to demonstrate their use of these or equivalent sampling, analysis, and QA/QC procedures. Audits will be conducted to determine compliances with these procedures.

This document recognizes that U.S. Geological Survey protocols used in their stream research and monitoring program are not necessarily identical with those set forth here. By prior agreement with the EPA project officer, USGS protocols are acceptable in the existing cooperative EPA-USGS stream studies. Differences are few, and are noted where appropriate in this document. The USGS laboratory at Denver, where samples from the cooperative studies are analyzed, is a participant in the NSWS. Therefore, there should be no differences in laboratory analytical methodology.

1.0 Collection of Samples in the Field

1.1 Lakes

Lakes should be sampled near their deepest points (at least 20 m from shore if possible). If the water column is not thermally stratified, one sample should be collected approximately one-half meter beneath the water surface. If the water body is stratified, one sample should be collected approximately one-half meter beneath the water surface and a second one or two meters above bottom. These two samples should not be mixed or composited. A plastic closing sampling device of the Van Dorn type should be used to obtain samples at depth; do not use a metal sampler. Samples should be collected

from the sampling device in plastic bottles that have been treated as described in 3.0. (See 6.1 regarding replicate samples.)

1.2 Streams

Samples are obtained by hand as near mid-stream as possible, using a properly cleaned and rinsed plastic container of appropriate size. (See 6.1 regarding replicate samples.) Keep hand away from mouth of container, and minimize the number of persons handling samples.

1.3 Carefully record any observed conditions that might affect analysis or interpretation of samples in field notes or sampling log.

1.4 Key project personnel who are responsible for sample integrity must be identified.

2.0 Measurements

A set of "core" measurements are specified for the EPA monitoring program. These measurements, which are considered to provide sufficient characterization of stream or lake water quality for assessment of sensitivity and changes related to acidification, are:

pH (field and laboratory air-equilibrated)

total alkalinity

specific conductance

temperature

Secchi disc transparency (lakes)

true color

major cations (Ca, Mg, Na, K)

major anions (SO_4, NO_3, Cl)

total aluminum (filtered).

Additional measurements, including titrated acidity, DIC, DOC, F^-, Fe, Mn, NH_4, SiO_2, and total P, are being made by NSWS; some of these analyses, while not required, are also being made by some cooperators in the monitoring program.

Care must be taken to assure that the highest quality deionized water is used throughout all stages of sampling and analysis. Specific conductance of such water should not exceed 1.0 µS/cm.

3.0 Sample Containers

3.1 Type

Containers should be composed of high density linear polyethylene, with polypropylene caps (do <u>not</u> use polyseal caps).

3.2 Cleaning of Plastic Containers

3.2.1 Containers to be used for pH, acidity, alkalinity, and anion determinations will be rinsed three times with deionized water, filled with deionized water and allowed to stand for 48 hours, then emptied and sealed in clean plastic bags until used in the field.

3.2.2 Sample containers for cations and metals will be rinsed three times with deionized water, rinsed three times with 3N HNO_3 (prepared from Baker Instra-Analyzed HNO_3 or equivalent), then rinsed six times with deionized water. They will then be filled with deionized water and allowed to stand for 48 hours.

They are then emptied, capped, and placed in clean plastic bags.

3.2.3 After the initial cleaning, 5 percent of the containers will be checked by filling with deionized water, capping, and slowly rotating the container so water touches all surfaces. Check conductivity; if greater than 1 μS/cm in any of the checked containers, rerinse all containers and retest 5 percent.

4.0 Sample Filtration

4.1 For anion analysis (including SO_4, NO_3, Cl): Rinse a cleaned 250 ml bottle three times with sample water which has been filtered directly into the sample bottle (discarding each rinse). Then fill to 250 ml with filtered sample. Use a 0.45 μm pore size membrane filter (e.g., Nucleopore polycarbonate). Ice or refrigerate. A good portable unit for filtering samples at field sites is described by Kennedy *et al.*, 1976.

4.2 For metals and cation analyses (including Ca, Mg, Na, K): Filter 100 ml of sample into an acid-washed bottle (see 3.2.2) after rinsing three times by passing 100 ml of sample through a 0.45 μm filter and discarding each rinse. Add a 1-ml ampoule of concentrated ultrapure nitric acid (Baker Ultrex or equivalent) to the sample. Ice or refrigerate.

4.2.1 U.S. Geological Survey presently uses 0.1 μm filters for Al, Fe, and Mn in their stream work. (They are conducting comparisons of various pore sizes.)

4.3 Samples for pH, alkalinity, specific conductance, and true color are not filtered.

5.0 Sample Preservation and Maximum Holding Times

5.1 Refrigeration at 4°C is the only recommended method of preservation for the following constituents. (Maximum allowable holding times appear in parentheses.) For present purposes, icing must be considered equivalent to 4°C refrigeration.

specific conductance (14 days)

color (48 hr)

pH (no approved holding time; field sample should be analyzed immediately, and air-equilibrated laboratory samples as soon as possible)

alkalinity (14 days, according to NSWS protocol)

sulfate (28 days)

chloride (28 days)

silica (28 days)

nitrate-nitrogen (7 days)

5.2 Refrigeration at 4°C plus acidification with nitric acid to pH < 2 is recommended for the following constituents:

calcium (6 months)

magnesium (6 months)

sodium (6 months)

potassium (6 months)

aluminum (6 months)

5.3 Labels on all containers should include sufficient information to permit tracing the sample back to point and time of collection.

6.0 QA/QC Samples: Lakes

Replicate samples, filtration blanks, and container blanks (total of four additional samples) are to be obtained one time for approximately every ten lakes sampled, as described below in Sections 6.1, 6.2, and 6.3. These are minimum requirements. For each project, this results in the following:

	No. of Rep/Blank Sets	
Project	Per Sampling Interval*	Per Year
Montana State University	1	3
University of Minnesota	3 (1/state)	9
University of Maine	1	3
Vermont	2	8
Syracuse University	2	8
TVA	1	4

* Sampling intervals are:

Minnesota, Maine -- spring, summer, fall

Montana -- July, August, September (approximately)

Vermont, TVA -- spring, summer, fall, winter

Syracuse -- quarterly (17 lakes are sampled monthly; 2 rep/blank sets per quarter)

6.1 Replicate Samples

Obtain a replicate sample by repeating step 1.1 or 1.2. These replicate samples are analyzed to determine the adequacy of the sampling process in obtaining a representative sample of the lake or stream at a particular point in time.

6.2 Filtration Blanks

Prepare two filtration blanks by filtration of deionized water into properly cleaned (1) anion container (3.2.1) and (2) cation container (3.2.2). Analysis of the filtrate for the appropriate ions determines the adequacy of the filtration process and the cleanliness of the sample containers.

6.3 Container Blanks

Prepare one unfiltered container blank by filling a properly cleaned container (see 3.2.1) with deionized water. Analysis of this sample for pH, alkalinity, specific conductance, and strong/weak acidity (if applicable) provides a check on the adequacy of the container.

6.4 EPA-USGS Cooperative Stream Monitoring Projects

Replicate samples, filtration blanks, and container blanks will be taken at the primary (intensive) stream site each time that site is sampled. In addition, replicates will be obtained on two satellite streams three times yearly under low, intermediate, and high flow conditions.

7.0 Measurement Methods

7.1 pH

7.1.1 Field measurement. Measure as soon after collection as possible. pH should be measured to $\pm$ 0.02 units using a high quality pH meter with an expanded or digital scale. A good electrode is the Corning No. 476182 glass combination. The electrode should be calibrated in the field in pH 4 and 7 buffer solutions and checked with a sulfuric acid solution with a theoretical pH of 4 (5×10^{-5} molar H_2SO_4). Rinse probe copiously with sample or deionized water and immerse in sample. Do not stir. The electrode should remain in the sample until there is no discernable drift in the pH reading, but no longer than 15 minutes. At least 10 percent of samples must be measured in replicate. Upon completion of measurement of a sample batch, recheck pH of acid solution.

7.1.2 Laboratory (air-equilibrated) measurement. For normalization of pH values obtained by various participating investigators, air-equilibrated pH measurements should be obtained in the laboratory. Equilibration is achieved by bubbling samples with standard air containing 300 ppm CO_2 for 20 minutes while stirring on a magnetic stirrer. Use an acid-washed (see 3.2.2) fritted glass diffuser for dispersal of air in the sample. Measure pH immediately following equilibration, following procedure in Section 7.1.1. At least 10 percent of samples must be measured in replicate. (Ref: Hillman *et al.*)

7.2 Specific Conductance (µS/cm at 25°C). Measured in the laboratory using a wheatstone bridge type conductivity meter. See Section 8.2 for calibration and QA/QC instructions. (Ref: Hillman et al.)

7.3 True color. Comparison of centrifuged sample with platinum-cobalt color standards. (Ref: USEPA, 1979).

7.4 Total alkalinity. Titration with 0.020 N H_2SO_4 using Gran plot calculations. Fixed endpoint titration is not acceptable. (Ref: Gran, 1950, 1952; Golterman and Clymo, 1969; Zimmerman and Harvey, 1978-1979; Hillman et al.)

7.5 Calcium, magnesium, sodium, and potassium. Atomic absorption spectrometry, direct aspiration. (Ref: USEPA, 1979).

7.6 Sulfate, chloride, nitrate. Ion chromatography. (Ref: Hillman et al.)

7.7 Aluminum, total filtered. Graphite furnace atomic absorption (EPA Method 202.2). (Ref: Hillman et al; USEPA 1979).

7.8 Phosphorus, total. Colorimetric, automated, block digestor AAII (USEPA, 1979), or USGS colorimetric, phosphomolybdate, automated (Hillman et al.).

7.9 Ammonium. Colorimetric, automated phenate (USEPA, 1979).

7.10 Kjeldahl nitrogen. Colorimetric, automated phenate (USEPA, 1979).

7.11 Table 1 states desired minimum analytical detection limits and within-laboratory relative precision goals.

8.0 Quality Control Procedures

Procedures normally followed by participants in the long-term monitoring program should be continued. The intent of this section is to ensure the common use of standardized quality control procedures for

Table 1. Required minimum analytical detection limits and within-laboratory relative precision (note reporting units). (NOTE: Some listed measurements may not apply to the existing long-term montoring program. See 2.0.)

Parameter (a)	Units	Required Detection Limit	Intralab Relative Precision Goal (%) (b)
Acidity	μeq/l	5	10
Alkalinity	μeq/l	5	10
Al, Total	mg/l	0.005	10 (Al>0.01), 20 (Al<0.01)
Ca	μeq/l	0.5	5
Cl^-	μeq/l	0.3	5
Color	ALPH units	0	± 5 (c)
DIC	mg/l	0.05	10
DOC	mg/l	0.1	5 (DOC>5), 10 (DOC<5)
F^-	μeq/l	0.3	5
Fe	mg/l	0.01	10
K	μeq/l	0.3	5
Mg	μeq/l	0.8	5
Mn	mg/l	0.01	10
Na	μeq/l	0.4	5
NH_4	μeq/l	0.6	5
NO_3	μeq/l	0.1	10
pH, field	pH units	-	± 0.1 (c)
pH, lab	pH units	-	± 0.05 (c)
SiO_2	mg/l	0.05	5
SO_4^{2-}	μeq/l	1.0	5
Specific Conductance	μS/cm	(d)	1
Total P	mg/l	0.002	10 (P>0.01), 20 (P<0.01)

(a) Dissolved ions and metals are determined, except where noted.

(b) Unless otherwise noted, this is the relative precision at concentrations above about 10 times instrumental detection limits.

(c) Absolute precision goal in terms of applicable units.

(d) Blank must be <1.0 μS/cm.

comparability of results. Any of the procedures given here that are not now being followed by cooperating agencies or institutions should be added to their QA/QC programs.

8.1 Precision and Accuracy

8.1.1 Precision

8.1.1.1 Definition: Precision is a measure of agreement among individual measurements of the same property, under prescribed similar conditions. In this program we recognize (1) intralaboratory and (2) sampling and analysis precision.

8.1.1.2 Intralaboratory Precision

Intralaboratory precision is determined by analyzing an individual sample in replicate. This should be done for at least one sample per batch for each variable being measured. The difference between the two resultant values is multiplied by 0.89 to approximate the standard deviation. The standard deviation divided by the mean of the duplicate values and multiplied by 100 yields the relative standard deviation (RSD) in percent. The RSD is an operational statistic (also called the coefficient of variation) indicating the dispersion of a set of replicate mesurements as a percentage of the mean value. In reporting precision for a given variable,

show the number of replicate analyses, range of RSD values, and average RSD.

8.1.1.3 Sampling and Analysis Precision

Sampling precision cannot be estimated directly. However, the precision in the combined sampling and analysis procedure can be estimated from the analysis of the replicate samples taken in the field (see 6.1). Then the sampling variance can be estimated by subtracting the analytical variance obtained in 8.1.1.2. The precision in the combined sampling and analysis operation is estimated by applying the same methodology described for intralaboratory precision (8.1.1.2).

8.1.2 Accuracy

8.1.2.1 Definition: Accuracy is a measure of the closeness of an individual measurement or an average of a number of measurements to the true value. Accuracy includes both precision and recovery and can be expressed as a percent recovery or percent bias interval.

8.1.2.2 Evaluation of Accuracy

Two approaches are specified:

8.1.2.2.1 Fortify an actual sample with a known amount of material, analyze the fortified (spiked) sample, and calculate the percent recovery. This should be done for at least one sample per batch for each variable being measured. In reporting accuracy for a given variable, show the number of spiked analyses, concentration of spike, range of bias (+ and - percent), and average bias (+ or - percent).

8.1.2.2.2 Audit samples are provided three times each year by an independent contractor. Analysis results are compared with the known concentrations to determine (1) intralaboratory bias and (2) comparability of measurements among the various monitoring projects.

8.2 Cautions Regarding Specific Conductance and Alkalinity

8.2.1 Specific Conductance

After calibration and prior to measuring the first sample, measure the conductance of a QC standard. The standard should have a theoretical or certified conductance of about 50 µS/cm (0.0005000 M KCl has a conductance of 73.90 µS/cm at 25°C). It must be prepared from a stock solution that is different from that from which the calibration standard is prepared. If

the measured conductivity is not within ± 1 percent of the certified value, then restandardize the meter and cell and repeat the measurement.

Remeasure the conductance of the QC standard at least once every 10 samples.

One sample per batch must be measured in duplicate.

8.2.2 Alkalinity

At least 10 percent of alkalinity titrations must be run in replicate. Agreement must be ± 10 percent or less. If not, run a third determination.

8.3 Further Procedural Checks

Once each variable in a sample has been determined, there are several procedures which must be followed to check the correctness of the analyses. These are outlined below.

8.3.1 Cation-Anion Balance

Theoretically, the sum of equivalents of anions equals the sum of equivalents of cations in a sample. In practice, this rarely occurs due to analytical variability and ions which are present but not measured. For each sample, the sums of the measured anion and cation equivalents, total ion strength, and ion percent difference are calculated as follows:

$$\Sigma \text{ anions} = [Cl^-] + [F^-] + [NO_3^-] + [SO_4^{2-}] + [HCO_3^-] + [CO_3^{2-}]$$

$$\Sigma \text{ cations} = [Na^+] + [K^+] + [Ca^{2+}] + [Mg^{2+}] + [NH_4^+] + [H^+]$$

$$\% \text{ Ion Difference} = \frac{\Sigma \text{ anions} - \Sigma \text{ cations}}{\Sigma \text{ anions} + \Sigma \text{ cations}} \times 100$$

Total ion strength = Σ anions + Σ cations

[Omission of F^-, CO_3^{2-}, and NH_4^+ will not significantly affect results. Alkalinity plus H^+ (calculated from pH) may be used for HCO_3^-.]

All concentrations are expressed as microequivalents/liter (μeq/l). Table 2 lists factors for converting mg/l to μeq/l for each of the parameters.

Samples which have a poor ion balance may have to be reanalyzed. Table 3 lists the reanalysis criteria.

8.3.2 Specific Conductance Balance

An estimate of the specific conductance of a sample can be calculated by summing the equivalent conductance values for each measured ion at infinite dilution.

The calculated conductance is determined by multiplying the concentration of each ion (in μeq/l) by the appropriate factor (F) in Table 4.

The calculated conductance for the entire sample is obtained from the relationship,

$$\text{Calculated Conductance} = \frac{\Sigma\ (F \times \text{Conc. in } \mu eq/l)}{1000}$$

The percent difference between measured conductance and calculated conductance is given by

$$\%\ \text{Conductance Difference} = \frac{\text{Calculated} - \text{Measured}}{\text{Measured}} \times 100$$

Samples which have percent conductance differences exceeding the limits listed in Table 3 may have to be reanalyzed.

Table 2. Factors to convert mg/l to μeq/l.

Ion	Factor (μeq/l per mg/l)
Ca^{2+}	49.9
Cl^-	28.2
CO_3^{2-}	33.3
F^-	52.6
K^+	25.6
Mg^{2+}	82.3
Na^+	43.5
NH_4^+	55.4
NO_3^-	16.1
SO_4^{2-}	20.8
Alkalinity (as $CaCO_3$)	20.0

Table 3. Chemical reanalysis criteria.

A. Cation-Anion Balance

Total Ion Strength (μeq/l)	% Ion Difference*
< 50	> ± 60
≥ 50 < 100	> ± 30
≥ 100	> ± 15

B. Calculated vs. Measured Conductance

Measured Conductance (μS/cm)	% Conductance Difference*
< 5	> 50
≥ 5 < 30	> 30
≥ 30	> 20

* If the percent difference exceeds these values, the sample is reanalyzed. When reanalysis is indicated, the data for each parameter are examined for possible analytical error. Any suspect parameters are then reanalyzed and the above percent differences recalculated.

Table 4. Conductance factors (F) of ions.[a]

Ion[b]	Conductance (μS/cm at 25°C) per $\frac{\mu eq/l}{1000}$	Ion[b]	Conductance (μS/cm at 25°C) per $\frac{\mu eq/l}{1000}$
Ca^{2+}	59.5	NO_3^-	71.4
Mg^{2+}	53.1	Cl^-	76.3
Na^+	50.1	SO_4^{2-}	79.8
K^+	73.5	HCO_3^-	44.5
H^+	350.0	OH^-	198.0
NH_4^+	73.4		

[a] From McInnes, 1961.

[b] H^+ and OH^- calculated as: $[H^+] = 10^{-pH} \times 10^6$ μeq/l.

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