United States
Environmental Protection
Agency

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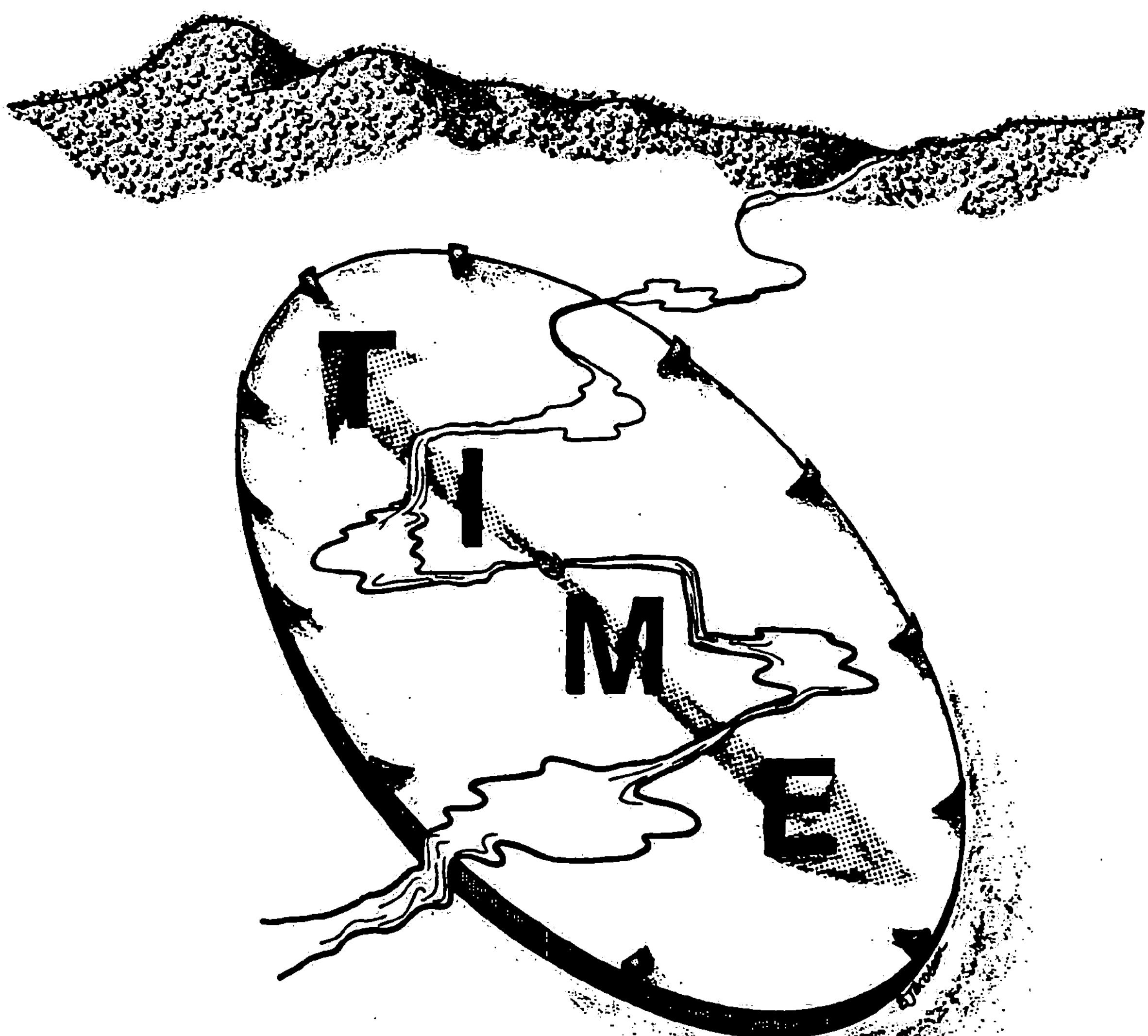
Corvallis, Oregon 97333

September 1988

THE CONCEPT OF TIME

Supplement



Aquatic Effects Research Program

THE CONCEPT OF TIME

TEMPORALLY INTEGRATED MONITORING OF ECOSYSTEMS (TIME)

Supplement

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12 September 1988

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1.0 INTRODUCTION

1.1 PURPOSE OF SUPPLEMENT

In August 1987, The Concept of TIME (Thornton et al. 1987), a conceptual plan for the Temporally Integrated Monitoring of Ecosystems (TIME) project, became available for review and comment. Since the production of The Concept of TIME, a redirection of priorities within the Environmental Protection Agency (EPA) has modified the scope and implementation schedule of TIME. The purpose of this document is to:

- o Describe the modifications in the TIME project.
- o Update the reader as to additional research efforts and workshops (since August 1987) that relate to development of the TIME Research Plan.

Much of the information in the original conceptual plan is still pertinent and will not be repeated in this supplement.

1.2 TIME

As was stated in The Concept of TIME (Thornton et al. 1987), the TIME project is a proposed long-term monitoring program designed to assess the effects of acidic deposition on aquatic ecosystems. The TIME project is intended to:

- o Provide early warning signals of surface water acidification or recovery in regions of interest.
- o Provide an ongoing assessment of regional patterns or trends in surface water acidification or recovery.
- o Assess the extent to which observed patterns and trends in surface water

chemistry correspond with model forecasts of surface water chemistry changes (e.g., from the EPA Direct/Delayed Response Project).

- o Assess the relationships between the observed patterns and trends in surface water chemistry, and patterns and trends in atmospheric deposition.

The TIME Project is currently scheduled for implementation in the spring of 1991.

2.0 THE CONCEPT OF TIME

2.1 CONCEPTUAL DESIGN

The original conceptual design of the TIME project was a hierarchical frame of four tiers (Section 3.4, Thornton et al. 1987). The purpose of Tier 1 (Regional Tier) was to describe broad regional patterns and trends in ecosystem attributes such as water chemistry. In Tier 2 (Seasonal Tier), a smaller number of ecosystems in each region were to be sampled seasonally in lakes or bimonthly in streams to identify seasonal patterns or trends in system attributes. The purpose of Tier 3 (Research Tier) was to integrate information from process oriented study sites or intensively monitored sites with the TIME sampling regime, and the purpose of Tier 4 (Special Studies Tier) was to investigate specific patterns of change within and among subregions or regions, and address issues raised in the ongoing work in the underlying tiers. This hierarchical design frame has been replaced by a "wheel and axle" design frame that emphasizes the early warning aspects of the program. This design, like the previous design, takes advantages of two of the elements of the existing Aquatic Effects Research Program (AERP), namely the National Surface Water Surveys (NSWS) (Brakke et al. 1988, Eilers et al. 1988a, Eilers et al. 1988b, Eilers et al. 1988c, Kaufmann et al. 1988, Landers et al. 1988a, Landers et al. 1988b, Messer et al. 1986, and Sale et al. 1988) and the temporally intensive Long Term Monitoring (LTM) project (Newell et al. 1987). Figure 2.1 illustrates the regions and subregions used to define the target populations for the National Surface Water Surveys.

2.2 WHEEL AND AXLE DESIGN

The wheel and axle design frame is presented schematically in Figures 2.2 through 2.5. The dashed axle and the wheels on the dashed axle represent existing AERP program elements on which the TIME project will be built. The axle represents the temporally intensive LTM project (Newell et al. 1987) and the wheels represent the regionally extensive Phase I Eastern (Linthurst et al. 1986, Brakke et al. 1988, Eilers et al., 1988a, Eilers et al., 1988b, Landers et al. 1988a, and Landers et al. 1988b), and

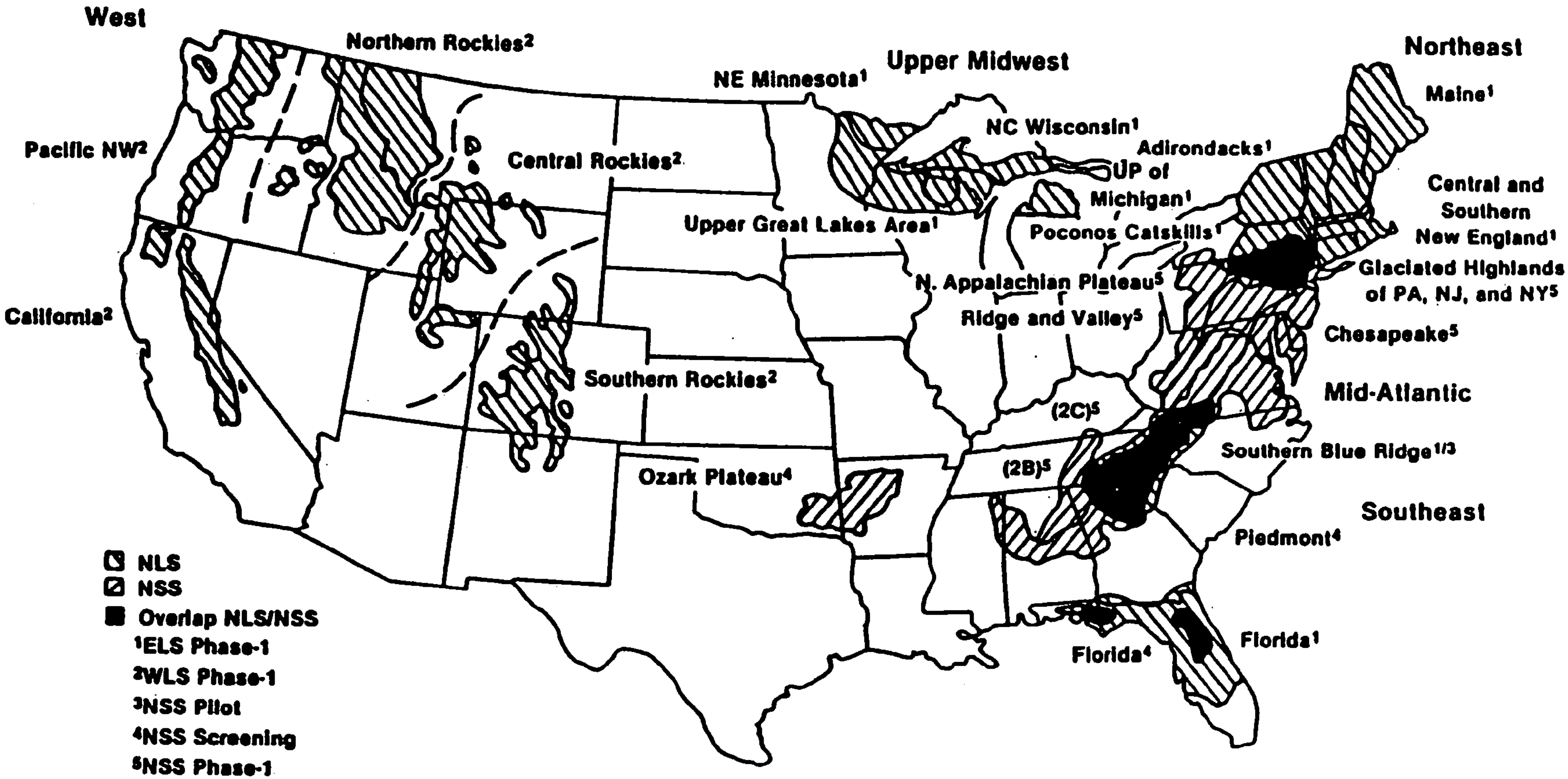

Figure 2.1. Regions and subregions of the United States used to define target populations for the National Surface Water Survey.

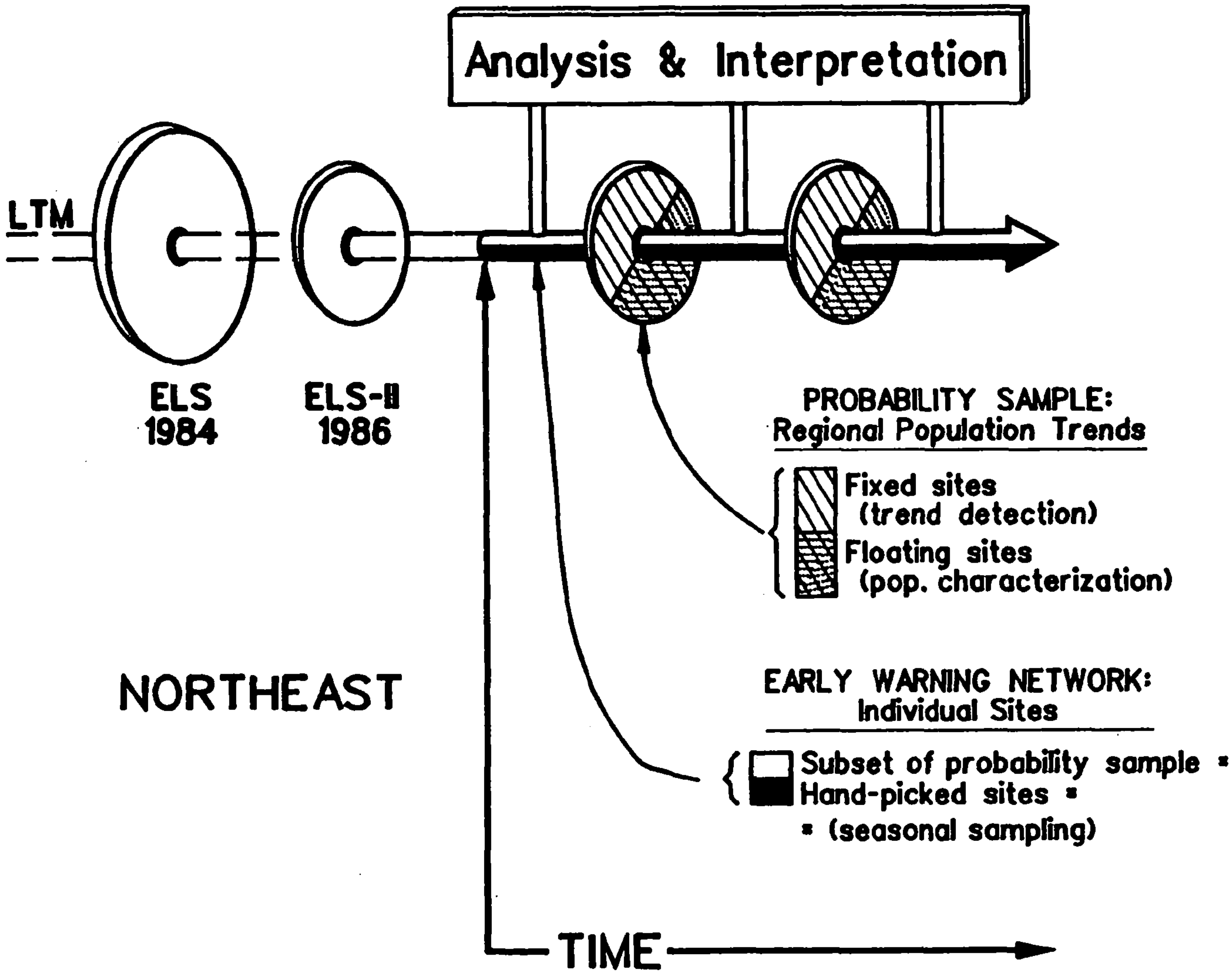

Figure 2.2. The conceptual "Wheel and Axle" design frame for the Northeast.

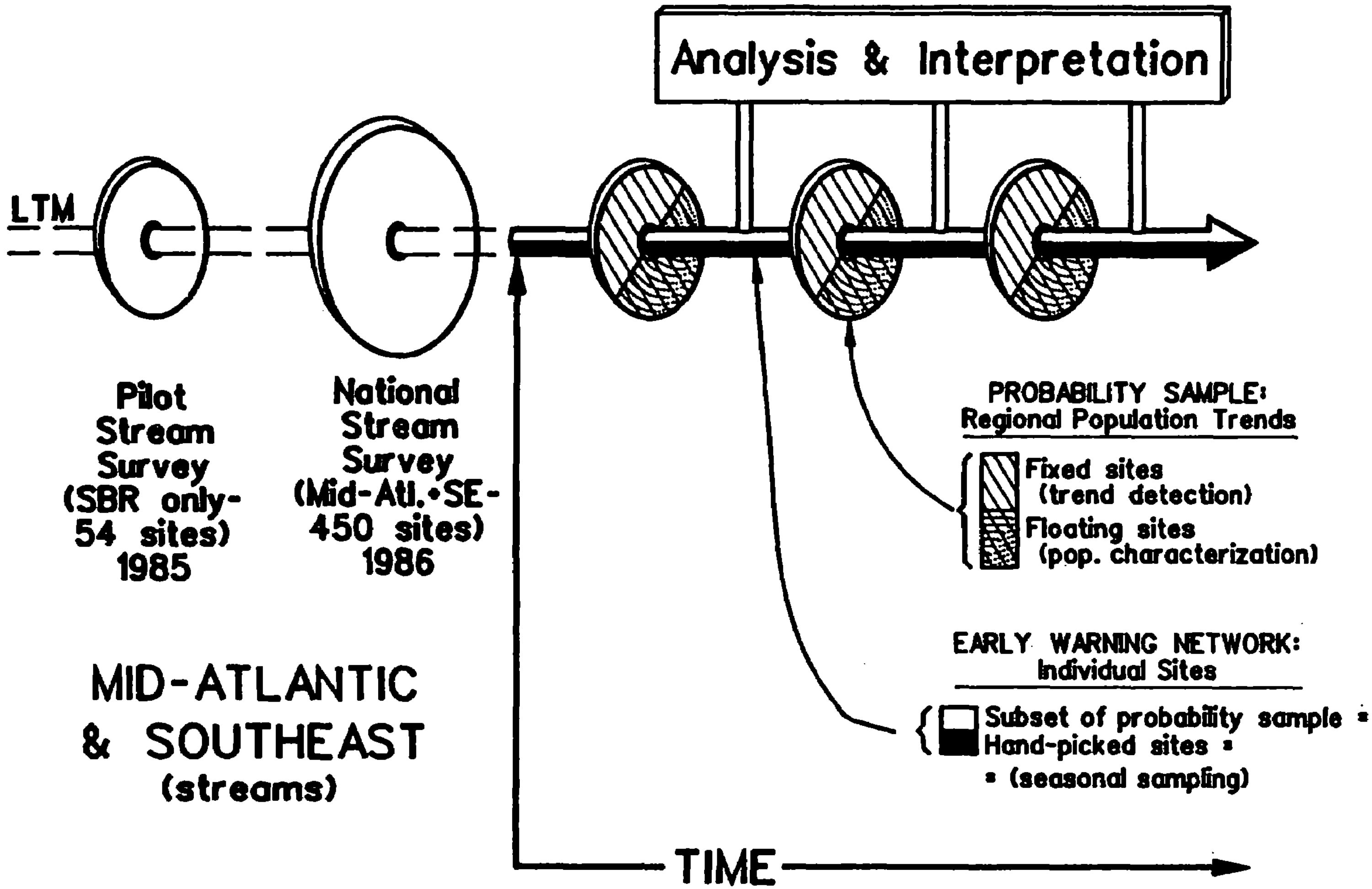

Figure 2.3. The conceptual "Wheel and Axle" design frame for the Mid-Atlantic and Southeast.

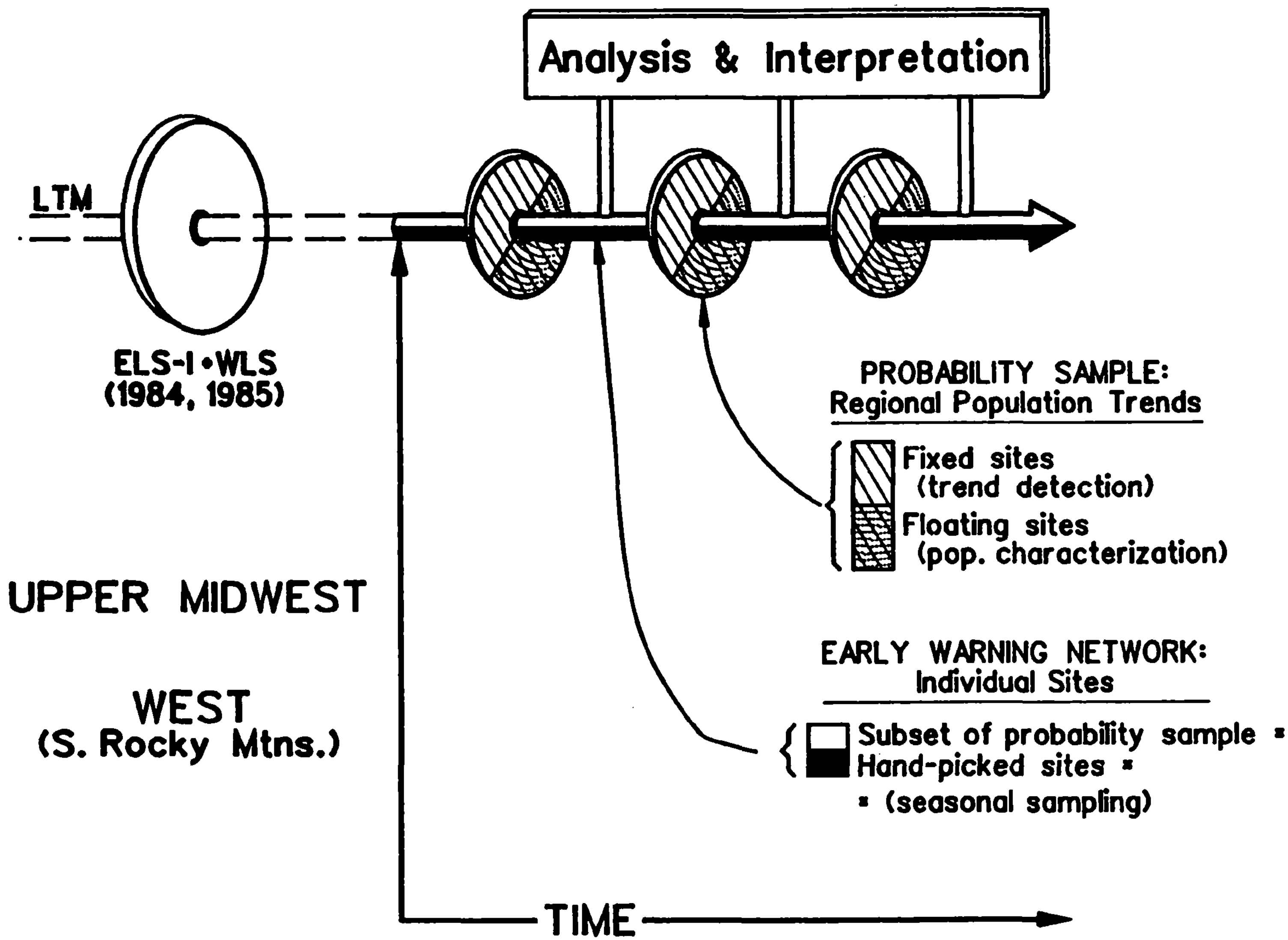

Figure 2.4. The conceptual "Wheel and Axle" design frame for the Upper Midwest and the Southern Rocky Mountains.

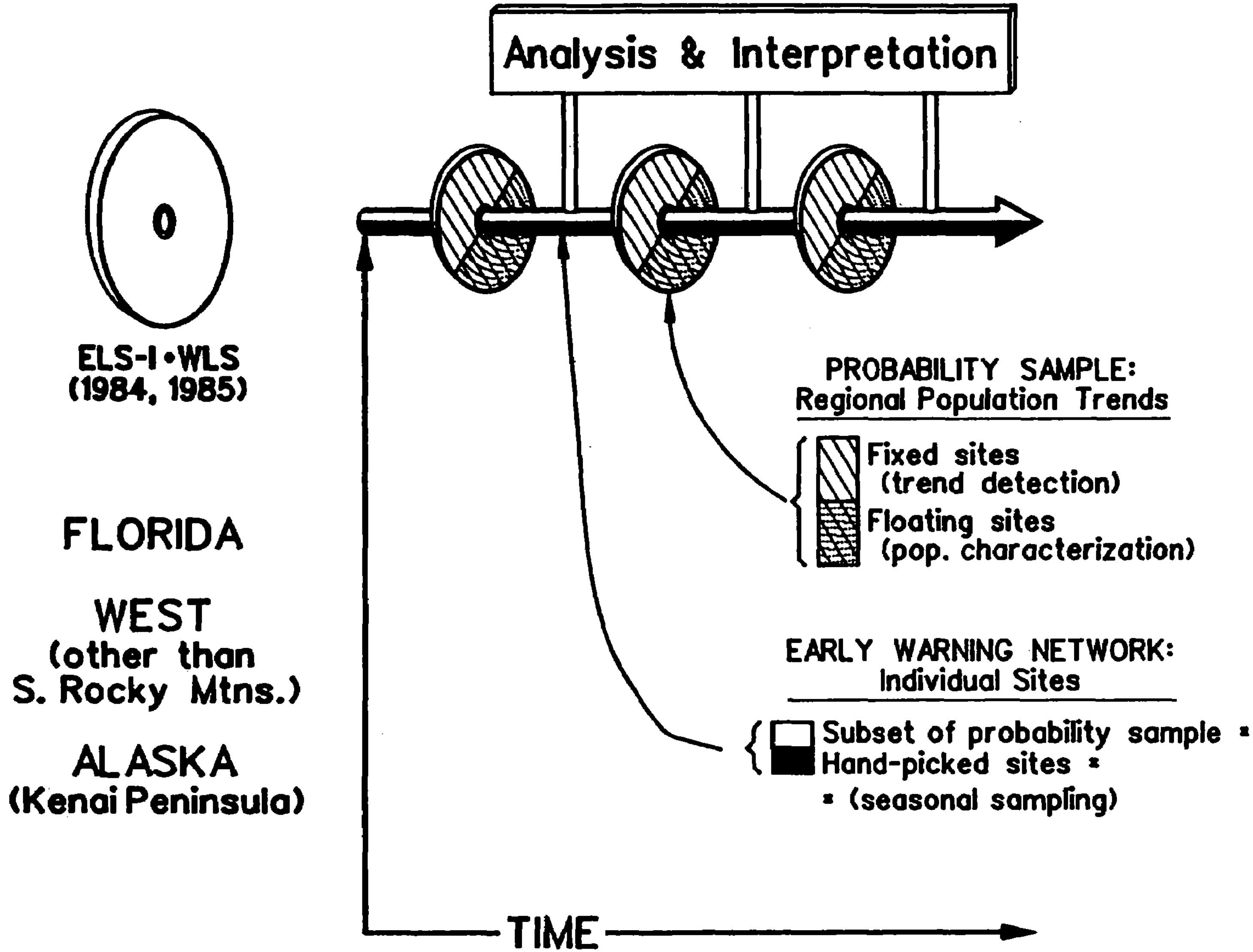

Figure 2.5. The conceptual "Wheel and Axle" design frame for Florida, in the West other than in the Southern Rocky Mountains, and Alaska (Kenai Peninsula).

Western (Landers et al., 1987, and Eilers et al., 1988c) Lake Survey, the Phase II Eastern Lake Survey (Thornton et al. 1986), the Pilot Stream Survey (Messer et al. 1986), and the National Stream Survey (Kaufmann et al. 1988 and Sale et al. 1988). The array of wheels varies from region to region and some subregions lack the temporally intensive LTM sites.

TIME is currently scheduled for implementation in 1991 when the "axle" sites will come on-line. The hand-picked sites in the "axle" will form the core of the early warning system. The "axle" also includes a subset of the probability sites that comprise the regionally extensive "wheels". This subset of probability samples will be tracked seasonally to provide an ongoing assessment of seasonal and annual variability in order to assist in the interpretation of regional patterns and trends made from the "wheels" or periodic resurveys.

Hand-picked sites will be chosen from a pool of low acid neutralizing capacity (ANC) candidate sites that meet one or more of the following criteria:

- o Previous monitoring information.
- o Ancillary watershed studies relevant to tracking acidic deposition effects.
- o Ancillary sites to meet particular information needs for an early warning network (e.g., position along a deposition gradient).

This pool includes, but is not limited to, existing LTM sites. Other potential sites include those currently under study by other federal or state agencies or university researchers. Some higher ANC reference sites may be included in this set in order to separate out the potential influence of other factors (e.g., short-term hydrologic fluctuations).

The "wheels" represent periodic resurveys and the sites in this group will be composed of probability samples in each region. The sites that make up the wheels will be of two types: fixed and floating probability samples. Fixed sites for repetitive sampling are necessary in order to specifically evaluate regional trends. Floating sites, which will change from survey to survey, will ensure an ongoing characterization of populations within each region.

The spacing of wheels in Figures 2.2 through 2.5 does not necessarily imply sampling at regular intervals. Spacing will vary depending on results from the early warning (axle) sites, regional needs, and budgetary constraints.

The areas of interest and the focus of the TIME program are low ANC regions, as in the NSWS. These areas include the Northeast, the Mid-Atlantic and Southeast, Florida, the Upper Midwest, and the West. The types of systems targeted for monitoring in each region are primarily:

- Northeast: Drainage lakes and (possibly) streams
- Mid-Atlantic/Southeast: Streams
- Florida: Precipitation dominated seepage lakes
- Upper Midwest: Precipitation dominated seepage lakes
- West: Drainage lakes and (possibly) streams

3.0 STATUS OF STUDIES AND WORKSHOPS

3.1 AVAILABLE REPORTS AND REPORTS IN DEVELOPMENT

Reports and workshops that have been completed since the publication of the conceptual plan include:

- Loftis et al. (1988) - Detecting trends in time series data.
- Newell (1987) - Summary of the exploratory TIME cluster analysis workshop, October 1987, Corvallis, Oregon.
- Pollard et al. (1987) - Workshop on quality assurance for Temporally Integrated Monitoring of Ecosystems (TIME) Project, held in Las Vegas, Nevada, November 18-20, 1987: Preliminary Summary.
- Pollard et al. (1988) - Expanded summary of the workshop on quality assurance for Temporally Integrated Monitoring of Ecosystems, Las Vegas, Nevada, November 18-20, 1987.

In addition, several reports and summaries are being developed. These reports and summaries include:

- Marmorek et al. (In Preparation) - Biological monitoring for acidification effects: U.S. - Canadian Workshop, March 21-23, 1988, Burlington, Ontario.
- Report on multivariate trend detection in time series data.
- Report on regional trend assessment and model-based approach.
- Individual manuscripts from the Biomonitoring Workshop to be published in a journal or special publication.
- Evaluation of deposition networks.
- TIME Research Plan.
- TIME QA Plan.

- TIME Data Analysis Plan.

These recent contributions will be summarized in the following sections.

3.2 TREND DETECTION IN TIME SERIES DATA

In Section 4.7 of The Concept of TIME, two progress reports that examined trend detection procedures were summarized (Loftis and Ward 1987a; Loftis et al. 1987b). The final draft report for that project is now complete (Loftis et al. 1988).

Loftis et al. (1988) tested various methods for detecting water quality trends in individual and groups of lakes impacted by acidic deposition. Data sources used in the study included the LTM data set, data from Environment Canada for Clearwater Lake, Ontario, and data from the U. S. Bureau of Reclamation for Twin Lakes, Colorado. These data were used to make generalizations regarding the level of seasonal behavior, serial correlation, and non-normality anticipated from TIME data.

Several candidate tests for trend detection were selected by Loftis et al. (1988) for evaluation. These candidate tests included:

- Analysis of covariance
- Analysis of covariance on ranks
- "Modified t"
- "Modified t" on ranks
- Kendall tau following removal of seasonal means
- Seasonal Kendall with serial correlation correction
- Seasonal Kendall

Monte Carlo simulation studies, designed to reproduce data characteristics observed in existing data sets and anticipated for TIME sites, were used to compare the performance of the candidate tests. The performance indices were actual significance level and power of trend detection. The significance level of a test, in a Monte Carlo evaluation, is determined by generating a large number (e.g., 500) of sequences of data with known characteristics and no trend. The trend detection method is applied to each sequence, and the significance level is computed as the fraction of trials in which a trend is falsely detected.

The power of a given test is estimated in the same manner, except that a trend of known magnitude is added to each sequence of data. Power is the fraction of sequences in which the trend is correctly detected. The upper bound on the trend magnitude used by Loftis et al. (1988) was similar to that observed at Clearwater Lake, Ontario, an acidic lake in the Sudbury region that is undergoing rapid chemical recovery following dramatic decreases in deposition from Sudbury stacks. The magnitude of the trend for ANC recovery at that site is currently 2.8 ueq/L per year or 0.7 standard deviations per year.

To adequately represent the range of characteristics anticipated from TIME data and to compare alternative tests, a very large number of simulations were performed in each experiment. Parameters varied by Loftis et al. (1988) include:

- Seasonal patterns in mean
- Seasonal patterns in standard deviation
- Ratios of largest to smallest quarterly standard deviation
- Ratio of largest to smallest quarterly mean
- Trend magnitude
- Length of record
- Underlying distribution
- Lag-one autocorrelation coefficient
- Nominal significance level

There were 3456 combinations of parameters evaluated, and for each combination at least 500 sequences were generated to empirically determine the power or significance level of the candidate test.

For annual data (in which no prior removal of seasonal means is necessary), the Kendall tau test is recommended. For seasonal (quarterly) sampling, either the analysis of covariance on ranks or the Seasonal Kendall test is recommended. Both tests performed well on the Monte Carlo simulations under conditions of seasonal variation and both non-normal and log-normal noise. Loftis et al. (1988) recommended that if a choice must be made between the two methods, the Seasonal Kendall should be used, especially for large data records. However, neither test performed well when observations were serially correlated. Loftis et al. (1988) noted that the Seasonal Kendall test with corrections for correlation is sufficient for large data records and small correlation.

Ongoing work extends these approaches from univariate to multivariate analyses. These approaches will also permit evaluation of the relationships between changes in surface water quality and changes in atmospheric deposition.

Loftis et al. (1988) also considered the expected performance of monitoring (i.e., the power of trend detection) for various numbers of sites and levels of spatial correlations, assuming linear trend. Figure 3.1 illustrates the level of detectable trend for $\alpha = 0.10$ and $\beta = 0.10$ (where α is the probability of rejecting the null hypothesis of no trend when it is true and β is the probability of accepting the null hypothesis when a real trend exists). Five configurations of number of lakes and spatial correlation are presented. These configurations are:

- Curve a - 1 lake (no spatial correlation, by definition)
- Curve b - 4 lakes with no spatial correlation
- Curve c - 16 lakes with no spatial correlation
- Curve d - 4 lakes with spatial correlation = 0.2
- Curve e - 16 lakes with spatial correlation = 0.2

As an example of how to use Figure 3.1, assume that the "average" temporal standard deviation of a constituent in individual lakes is 10 ueq/L. Also assume that sampling is annual and that a total change of two standard deviations is the desired level of detectability. It would take approximately 28 years to detect a change in a constituent at a single lake of 10(2)=20 ueq/L (curve a). Suppose that one desired to see a change of this magnitude in a shorter time span (e.g., 5 years). Figure 3.1 indicates a 90% probability that a trend in the means of this magnitude could be seen in 5 years using 16 sites that exhibited no spatial correlation (curve c). (In this case, the

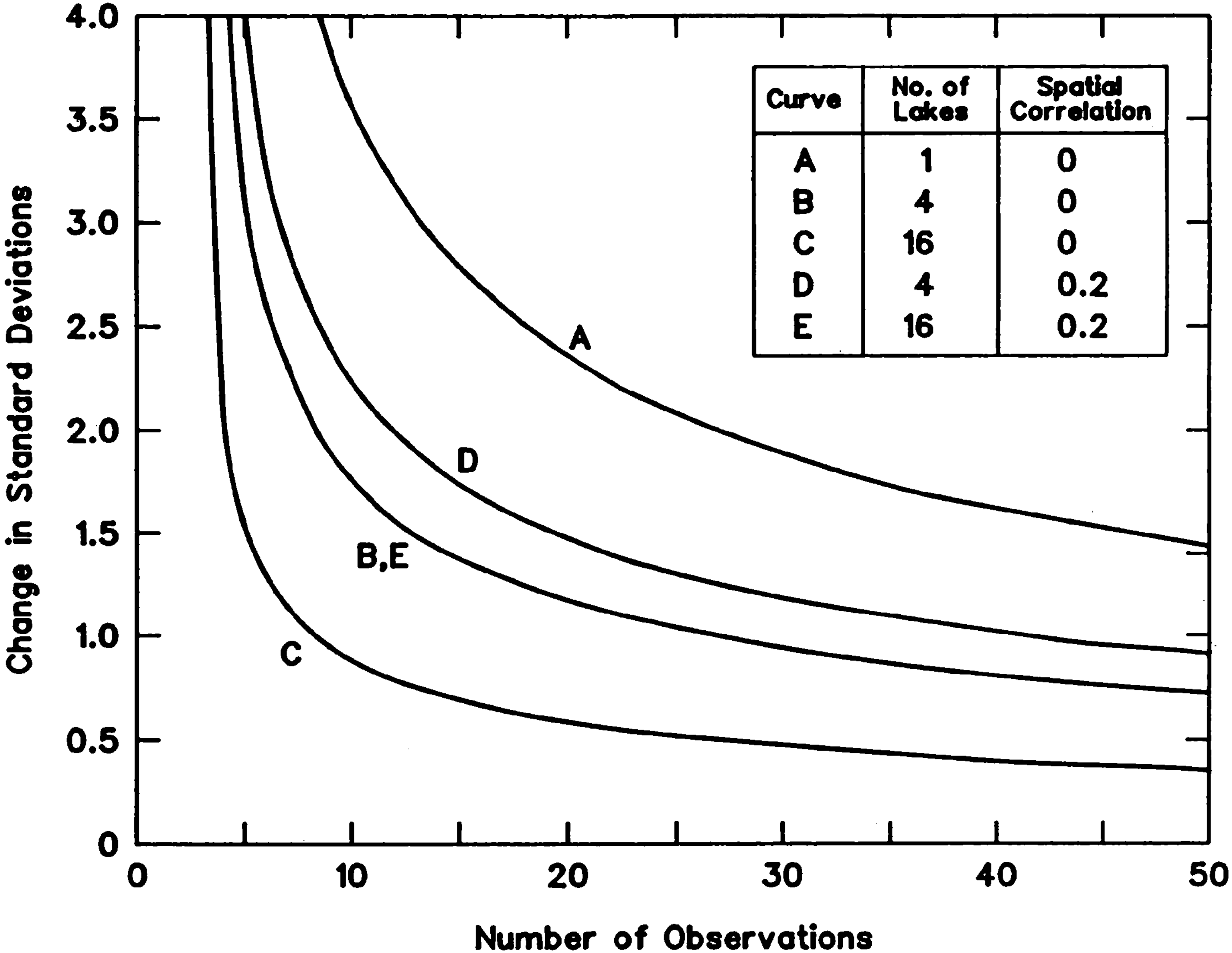

Figure 3.1. Level of detectable trend for α = 0.10 and β = 0.10 for five configurations of number of lakes and spatial correlation = 0.0 and 0.2 (Loftis et al. 1988).

probability of falsely detecting a trend also is only 10%.) However, because inter-lake correlation has an impact on the power of detecting trends in a group of lakes, spatial correlation needs to be taken into account. Figure 3.1 indicates that for a mean spatial correlation of 0.2 among 16 lakes, it would take about 9 years to detect the 2 standard deviation change (curve e). Analysis of the best (based on length and completeness of record) 11 records from the Adirondack lakes indicates that pairwise spatial correlations generally fall in the range of 0.2 - 0.4 for this subregion (Loftis et al. 1988). This type of analysis specifically applies to trends in the mean when multiple sites are considered, and only linear trends are considered. Despite these constraints, however, the analysis is useful as a scoping activity to indicate the trade-offs between numbers of sites and length of records for realistic values of temporal variance and spatial correlation.

3.3 EXPLORATORY ANALYSES

Cluster analyses were used to identify subpopulations of lakes and their characteristics during the ELS-Phase II design (Section 4.9, Thornton et al. 1987). A similar exercise was performed for TIME using exclusion criteria developed specifically for TIME.

On October 26-28, 1987, a small workshop was held at the Environmental Research Laboratory in Corvallis, Oregon (ERL-C), to interpret cluster analyses on the National Lake Survey (NLS) data. These exploratory cluster analyses were used to describe the types of lakes in regional populations and to aid in the site selection design for the TIME project.

The analyses on the NLS data set stratified various combinations of factors, including:

- ANC.
- Atmospheric SO4 deposition levels.
- Hydrologic type and retention time.
- Silica, to separate precipitation dominated seepage lakes from groundwater dominated seepage lakes in the Upper Midwest.
- Potassium, to separate precipitation dominated seepage lakes from

groundwater dominated seepage lakes in Florida.

The workshop helped identify issues of potential importance for TIME site selection, and additional analyses are currently being conducted by ERL-C. Principal component analysis/factor analysis is being used to explore meaningful combinations of chemical and physical variables that will help identify populations of interest in the various subregions.

3.4 QA/QC INTERPRETATION

The QA/QC workshop referred to in Section 4.11 of The Concept of TIME was held on November 18-20, 1987 at the Environmental Monitoring Systems Laboratory in Las Vegas, Nevada (EMSL-LV). The purpose of the workshop was to provide a forum to discuss QA/QC issues relevant to the TIME project (Pollard et al. 1987) and to initiate discussions on optimizing TIME's QA plan based on experience with the strengths and weaknesses of the QA plan for the various surveys.

Major topics discussed at the workshop included precision, bias, detectability, and characterization of system error. Numerous issues were raised during the workshops, many of which were not resolved. Recommendations from the workshop were as follows:

1. It was resolved to focus effort on benchtop and field QC throughout the project rather than on post-hoc QA analyses. This effort will include providing known QC standards to the analytical laboratories so the analysts will know if the system is achieving desired precision and accuracy. In addition, rapid analysis and feedback of QA/QC data to field and laboratory personnel is a priority item, in order to achieve the best possible analyses on an ongoing basis.
2. Bias estimation should be evaluated using measurements of absolute bias rather than relative bias. A method for accomplishing this was not formally established during the workshop. However, in order to use absolute bias, any audit should have a defined reference value that is

highly defensible (i.e., measured confidence bounds of the reference should be at least 3 times, and preferably 10 times, better than the desired accuracy of the analytical laboratories receiving the samples).

3. Bias information needs to be quantified and reported, but the data should not be corrected in the data base. This was viewed as necessary for the data user to be able to interpret the patterns in the data sets. No resolution was reached on how data corrections might be performed, or on how to interpret interlaboratory bias.
4. While the data generator needs estimates of precision, bias, and accuracy to maintain the system within the control bounds established by the data quality objectives, the data user needs estimates of precision, bias, and accuracy to evaluate the effect of the measurement error on data interpretation, and to assess the extent to which the quality control procedures kept the system in control. Therefore, there is still a need for QA assessment with blind QA audits, even though benchtop QC is a priority concern.
5. If the measurement error is small in comparison to the overall error (population sampling or within-site error), it may not be necessary to know the components of the measurement error. On the other hand, if the measurement error is large in comparison to the overall error, it will be important to know all the components of the sources of error.
6. Detectability issues (detection limits, decision limits) should not pose major problems. Detection limits become important for variables at low concentration levels. Variables on a regional basis, for which detectability is important, need to be identified and a method for measuring detection or decision limits needs to be developed.

Several important QA/QC elements identified at the workshop that need to be accomplished include:

1. Developing the number and types of audits to be used in the TIME

project, and determining what information will be provided.

2. Evaluating QA/QC data from the NSWS to develop "system goals" for the TIME project. It is important to determine which variables should be evaluated for system contamination levels, and if the levels observed in the NSWS are within the ranges tolerable for the TIME project.
3. Defining protocols for determination of both system and method detection and decision limits.
4. Developing detailed protocols for control chart use for both method-level and system-level considerations. These control goals should be based on data quality objectives for precision, accuracy, bias, and detectability.
5. Building a variance component experimental design that will demonstrate how the components of variance of measurement error could be partitioned. The example should include a cost estimate based on real analytical cost per sample and use realistic assumptions about the number of laboratories and number of crews sending samples to each laboratory.
6. Comparing the overall error with the total measurement error in the NSWS data to determine the relative magnitude of measurement versus population sampling error. This will be based upon various stratification schemes, beginning with the clustering scheme provided by ERL-C.

3.5 MULTIVARIATE TREND DETECTION IN TIME SERIES DATA

Although substantial work has been done on identifying appropriate statistical techniques to apply to trend detection, these explorations have concerned only univariate data. Multivariate approaches potentially give better power for trend detection and allow the detection of trends in a vector of variables. It is likely that trends in a vector of variables will be more meaningful than examining variables one by one.

The ongoing multivariate trend detection work is focused on:

1. Identifying all multivariate techniques potentially applicable to issues of trend detection and drawing statistical inferences about the relationships

between changes in acid deposition and changes in surface water chemistry.

2. Identifying characteristics of the data base necessary to satisfy the requirements of each technique. Examples of characteristics might include specific water quality and deposition variables of interest, length of records, number and spatial density of stations, sampling frequency, and completeness of records.
3. Proposing procedures for evaluating the statistical tests and data sets.
4. Exploring the sensitivity to assumptions and power against specified hypotheses of each candidate procedure on at least four real long-term data sets.
5. Exploring the sensitivity and power of each of the candidate procedures on simulated data.

3.6 ASSESSMENT OF REGIONAL TRENDS AND MODEL-BASED APPROACH

The surface waters in any region can be conceptualized as an assemblage of specific types of lakes or streams with different characteristics. One way to survey a specific type of lake or stream within a given region and be able to extrapolate results to the larger population of all lakes or streams of that type in the region is to define a population identity (i.e., population of interest) and devise a statistical sampling frame. Because populations will vary in terms of characteristics that affect the rate, timing, and magnitude of acidification and recovery, each population should be considered independently. The issue of regional trends therefore becomes an issue of defining the populations of interest within the region, and picking the appropriate size/probability sample from each population to ensure accurate population expansions.

Once the populations of interest are defined, population trends can be studied. Several approaches to determining population trends are being considered. For example, population distributions can be described at successive points in time and representation of trends in the distributions can be made using simple distribution-free tests of trends in moments (e.g., mean and variance); quantiles (median and percentile);

or reference proportions (e.g., pc). Other methods might include parametric representations of these trends (i.e., fitting an explicit distribution, and characterizing the trend in the parameters of the distribution). A different approach is to describe trends in individual systems (e.g., Loftis et al. 1988; Section 3.2 of this report) and characterize the population as a distribution of trend characteristics. The rigor with which these latter results can be associated with populations of interest depends critically on the relationship of the individual systems to the larger sampling frame.

The most straightforward way to relate population trends back to a statistical sampling frame (e.g., the Phase I National Surface Water Survey (NSWS)) is to choose the sites composing the population as a probability sample from the larger sampling frame. However, in some cases it may be desirable to analyze records from handpicked sites that are not part of the larger sampling frame (e.g., LTM sites). To put such sites into a regional population context, model-based extrapolation procedures must be developed.

Model-based extrapolation procedures will allow the implications of observed changes in hand-picked sites that are not part of the original NSWS sample to be extrapolated to the larger regional surface water resource. The model-based extrapolation procedure is still under development, although some of the groundwork has been conducted during analysis of data from the Phase II of the Eastern Lake Survey (ELS-II) (as summarized in the TIME Conceptual Plan, Section 4.3, Thornton et al. 1987). The use of sites included in the statistical frame of the NSWS will probably involve some form of calibration. One simple way to do this is to identify homogeneous clusters or populations of interest within the larger sampling frame and associate hand-picked sites with clusters as appropriate (Overton 1988a). It is important to recognize, however, that hand-picked sites do not constitute a probability sample of a cluster, and that assignment of sites to clusters involves some degree of informed judgement, even when objective techniques such as discriminant analysis are applied. Therefore, the extrapolation from patterns and trends in one or several hand-picked sites to population patterns or trends is necessarily based on the assumption of representativeness (Overton 1988a). Careful description of the populations and their associated hand-picked sites will provide the information necessary to assess the validity of the population expansions.

Work on both regional population trends and the model-based approach is ongoing (Overton 1988b), and will be summarized in the TIME Data Analysis Plan. Techniques developed in this project will also be applied to extrapolating the implications of observed patterns and trends in the existing LTM data set to populations of interest within the various regions. The utility of this approach will be compared to that of a probability double sample that can lead to more rigorous inferences.

3.7 ROLE OF BIOMONITORING

In The Concept of TIME (Thornton et al. 1987), Sections 4.4 and 4.5 considered the role of biological data and biologically relevant chemistry. After these sections had been written, a joint United States/Canada Biological Monitoring Workshop was held on March 21-23, 1988 in Burlington, Ontario, at the Canada Center for Inland Waters. The goal of the workshop was to answer two questions:

1. What is gained (relative to chemical measurements alone) by incorporating biological measurements into a regionally extensive monitoring program focused on surface water acidification and recovery?
2. If biological measurements are worthwhile, what is the most informative and cost effective sampling strategy for each ecoregion of concern?

Prior to the convening of the workshop, eight background papers were prepared discussing the use of phytoplankton (diatoms (Smol 1987), chrysophytes (Siver 1987), dinoflagellates (Holt 1987), and bluegreen/greens (Baker 1987)), periphyton (Stokes and Howell 1987), benthic invertebrates (Singer and Smith 1987), zooplankton (Marmorek and Bernard 1987), and fish (Baker 1987) as early warning indicators. Five overview papers, one for each organismal group, were presented at the workshop. After the summary presentations, the participants broke into groups of seven to nine in each area to discuss topics such as:

- o Best response variables to use as early warning indicators (indicator species, species composition, community indices such as species richness or diversity, biomass, interorganismal group indicators, etc).

- o Regional differences in response variables and sampling methodologies.
- o Inferences obtainable at different levels of monitoring frequency (e.g., annual, seasonal, etc.), and sampling and data analysis methods required.
- o Estimated total costs of data collection.
- o Types of analyses that can be done using existing data sets to improve sampling design.

In addition to the specialists in each work group, statisticians and generalists were spread among the groups. The consensus of the participants (Marmorek et al., in preparation) was that:

- o Biomonitoring greatly improves our knowledge of the actual response of aquatic ecosystems, as distinguished from the inferred response obtained by linking chemical monitoring data with laboratory or field bioassays.
- o Biomonitoring provides a sound mechanism for integrating and evaluating the aquatic effects of seasonally varying surface water chemistry.
- o To obtain the maximum value per dollar invested in biomonitoring, biomonitoring programs should provide data and insight into both incipient biological changes (i.e., early warning indicators) and "biologically important" changes, where "biologically important" changes are taken to mean those significant changes that are important to either (1) ecosystem functioning, or (2) human ecosystem utilization, particularly, fishing and other water based recreation.

A series of specific technical recommendations for TIME biomonitoring design was made. These are summarized in Marmorek et al. (in preparation).

There was a consensus among the 39 workshop participants that many of the common perceptions about biological monitoring are erroneous (e.g., it is unmanageably complicated, is not amenable to QA/QC, and is unreasonably costly). Participants felt that although the issues raised in biological monitoring design are complex, they are no more intractable for biologists than are similar issues in chemical monitoring design for chemists. The primary response variable of interest identified by most of the work groups was species composition. Biomonitoring need not be more expensive than chemical monitoring, nor are biological data base management problems unique. For example, the large biological data base collected by the Electric Power Research Institute (EPRI) - funded Paleoecological Investigations of Recent Lake Acidification (PIRLA) Project (Charles et al., 1986) demonstrated that compositional data are both amenable to QA/QC and can be adequately managed. Although in some instances biological results are not straightforward, this generally occurs because the questions to be answered are not adequately defined. Clearly defined questions obviate this problem. In short, the consensus of the 39 participants was that biological monitoring can be as cost effective as chemical monitoring if the program is well-defined, and can supplement chemical monitoring with respect to important short-term transient phenomena such as episodes of low pH and ANC and high Al. Finally, biological monitoring can provide a context within which the significance of subtle chemical changes can be evaluated.

Statistical aspects of the biomonitoring program also were considered. Three main areas of statistical research were identified to serve this program:

- o Multivariate methods for monitoring
- o Definition of the detection threshold for species presence/absence
- o Time series analysis on proportional (relative abundance) data

Marmorek et al. (in preparation) are summarizing the results of the biological workshop. The eight various literature reviews prepared as background papers for the workshop will be published as an EPA report and/or as a set of papers in the peer reviewed literature.

3.8 DEPOSITION NETWORK EVALUATION

One of the questions the TIME project is intended to address is, "What are the relationships between the observed patterns and trends in surface water chemistry and regional patterns and trends in atmospheric deposition?" This question was briefly addressed in Section 4.13 of The Concept of TIME (Thornton et al. 1987).

Regional trend detection in deposition is being addressed by the U.S. Geological Survey (USGS), the EPA Atmospheric Sciences Research Laboratory in Research Triangle Park, North Carolina (ASRL-RTP), and the statistical group at Battelle's Pacific Northwest Laboratory in Richland, Washington (PNL). Close coordination among the above mentioned laboratories and agencies and the TIME project will be necessary to minimize duplication of effort and to provide the linkages required for achieving the TIME objective of assessing the relationships between patterns and trend in surface water chemistry and patterns and trends in depositions.

The adequacy of existing deposition networks for TIME's purposes will be evaluated. In addition, work has been initiated to evaluate the most appropriate statistical techniques for assessing relationships between changes in surface water quality and changes in atmospheric deposition. Finally, the issue of how to analyze temporal trends in spatially complex data is also currently under study.

4.0 SITE SELECTION

In The Concept of TIME (Thornton et al. 1987), site selection was discussed in Section 7.0. The site selection model in Section 7.0 of that document is still current, with only slight modifications. In particular, Figure 7.1 has been replaced by Figure 4.1 of this supplement.

Step A identifies the desired target populations for each class (i.e., probability samples, rapid response sites, and special interest sites), and may apply to any level of the classification process. The cluster analyses and factor analyses discussed in Section 3.3 of this document are major components of step B.

In step C the desired number of sites in each category will be determined. Then, all the potential sites in the candidate pool will be listed (step D), and exclusion criteria applied to these sites (step E). If there are not enough sites, the exclusion criteria will be re-evaluated, and if there are too many sites, some will be eliminated based on ancillary inclusion criteria. The process sketched here is discussed in greater detail in Section 7.0 (Thornton et al. 1988).

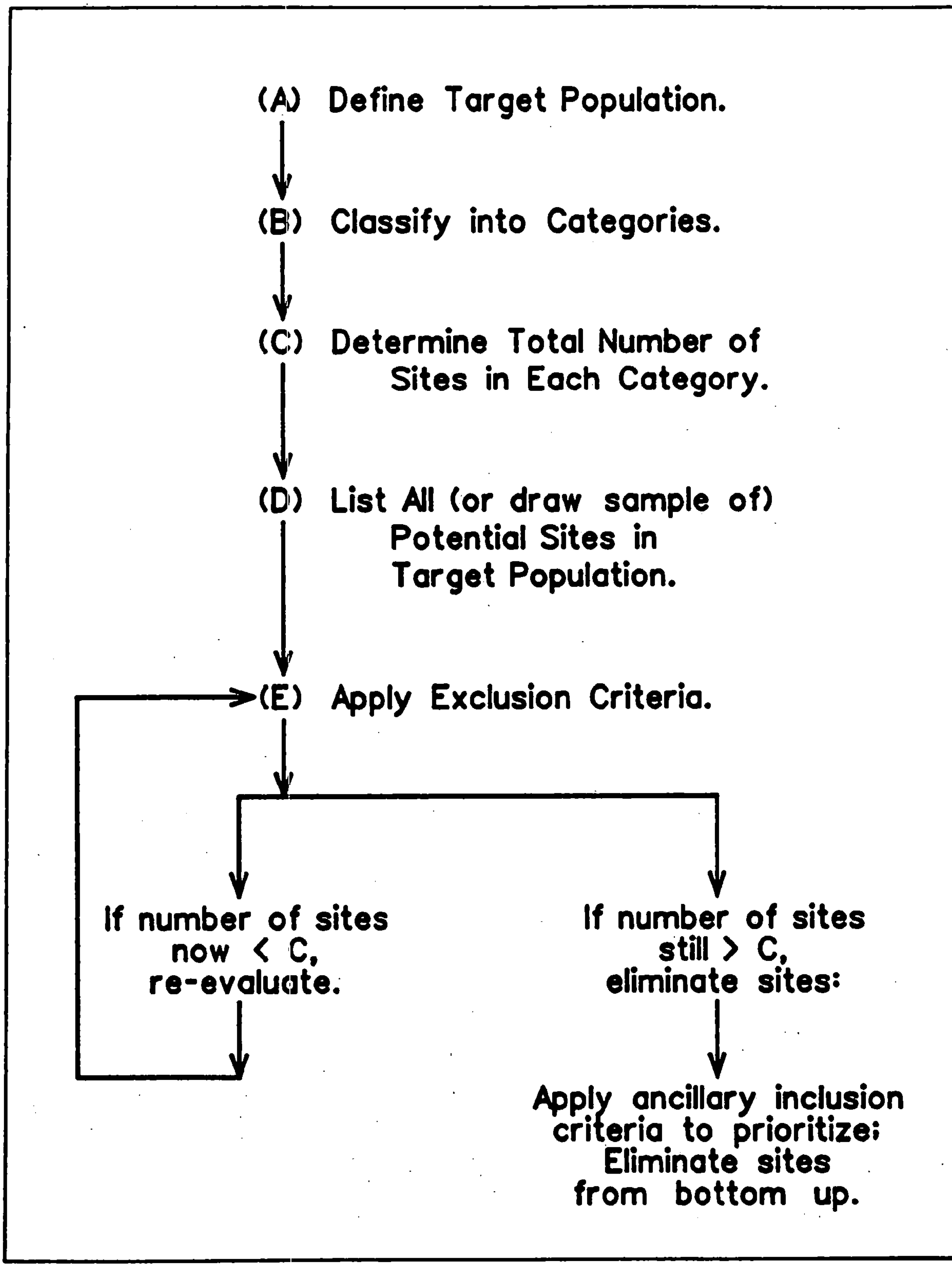

Figure 4.1. Overview of site selection process.

5.0 LITERATURE CITED

Baker, J. P. 1987. The use of fish in long-term monitoring programs for lake and stream acidification (and recovery). Report prepared for the U.S. Environmental Protection Agency, Corvallis Environmental Research Laboratory, Corvallis, OR. 99 pp.

Baker, K. K. 1987. A literature review on the usefulness of bluegreen and green algae to detect chronic or episodic acidification and/or recovery in the context of a long-term monitoring program. Report prepared for the U.S. Environmental Protection Agency, Corvallis Environmental Research Laboratory, Corvallis, OR. 77 pp.

Brakke, D. F., D. H. Landers, and J. M. Eilers. 1988. Chemical and physical characteristics of lakes in the Northeastern United States. Environ. Sci. and Tech. 22:155-163.

Charles, D. F., D. R. Whitehead, D. S. Anderson, R. Bienert, K. E. Camburn, R. B. Cook, T. L. Crisman, R. B. Davis, J. Ford, B. D. Fry, R. A. Hites, J. S. Kahl, J. C. Kingston, R. G. Kreis, Jr., M. J. Mitchell, S. A. Norton, L. A. Roll, J. P. Smol, P. R. Sweets, A. J. Uutala, J. R. White, M. C. Whiting, and R. J. Wise. 1986. The PIRLA Project (Paleoecological Investigation of Recent Lake Acidification): Preliminary results for the Adirondacks, New England, N. Great Lakes States, and N. Florida. Water, Air, and Soil Pollut. 30:355-365.

Eilers, J. M., D. F. Brakke, and D. H. Landers. 1988a. Chemical and physical characteristics of lakes in the Upper Midwest. Environ. Sci. and Tech. 22:164-172.

Eilers, J. M., D. H. Landers, and D. F. Brakke. 1988b. Chemical and physical characteristics of lakes in the Southeastern United States. Environ. Sci. and Tech. 22:172-177.

Eilers, J. M., D. F. Brakke, D. H. Landers, and P. E. Kellar. 1988c. Characteristics of lakes in mountainous areas of the Western United States. Verh. Internat. Verein. Limnol. 23:144-151.

Holt, J. R. 1987. The use of four common armored dinoflagellates as indicators of the early stages of acidification. Report prepared for the U.S. Environmental Protection Agency, Corvallis Environmental Research Laboratory, Corvallis, OR. 35pp.

Kaufmann, P. R., A. T. Herlihy, J. M. Elwood, M. E. Mitch, W. S. Overton, M. J. Sale, J. J. Messer, K. A. Cougan, D. V. Peck, K. H. Reckhow, A. J. Kinney, S. J. Christie, D. D. Brown, C. A. Hagley, and H. I. Iager. 1988. Chemical characteristics of streams in the Mid-Atlantic and Southeastern United States. Volume I. Population descriptions and physico-chemical relationships. EPA/600/3-88/0021a. United States Environmental Protection Agency, Washington, DC.

Landers, D. H., J. M. Eilers, D. F. Brakke, W. S. Overton, P. E. Kellar, M. E. Silverstein, R. D. Schonbrod, R. E. Crowe, R. A. Linthurst, J.M. Omernik, S.A. Teague, and E. P. Meier. 1987. Characteristics of lakes in the Western United States. Volume I. Population descriptions and physico-chemical relationships. EPA-600/3-86/054a. United States Environmental Protection Agency, Washington, DC.

Landers, D. H., J. M. Eilers, D. F. Brakke, and P. E. Kellar. 1988a. Characteristics of acidic lakes in the Eastern United States. Verh. Internat. Verein. Limnol. 23:152-162.

Landers, D. H., W. S. Overton, R. A. Linthurst, and D. F. Brakke. 1988b. Eastern Lake Survey, regional estimate of lake chemistry. Environ. Sci. and Tech. 22:128-135.

Linthurst, R. A., D. H. Landers, J. M. Eilers, D. F. Brakke, W. S. Overton, E. P. Meier, and R. E. Crowe. 1986. Characteristics of lakes in the Eastern United States. Volume I. Population descriptions and physico-chemical relationships. EPA-600/4-86/007a. United States Environmental Protection Agency, Washington, DC.

Loftis, J. C. and R. C. Ward. 1987a. Progress Report. Long-term monitoring project: Statistical tests for trend analysis. Dept. of Agri. and Chem. Engr. Colorado State University. 14 pp.

Loftis, J. C., R. C. Ward, R. D. Phillips, and C. H. Taylor. 1987b. Progress report No. 2 TIME Project: Statistical tests for trend analysis. Dept. of Agri. and Chem. Engr. Colorado State University. 48 pp.

Loftis, J. C., R. C. Ward, R. D. Phillips, and C. H. Taylor. 1988. Detecting trends in time data series. Dept. of Agri. and Chem. Engr. Colorado State University. 162 pp.

Marmorek, D. R., D. P. Bernard. 1987. The use of zooplankton to detect lake acidification and recovery. Report prepared for the U.S. Environmental Protection Agency, Corvallis Environmental Research Laboratory, Corvallis, OR. 61 pp.

Marmorek, D. R., D. P. Bernard, and J. Ford. (In Preparation). Biological monitoring for acidification effects: U.S. Canadian. Workshop, 21-23 March 1988 in Burlington Ontario. U.S. Environmental Protection Agency, Corvallis-Environmental Research Laboratory (Draft).

Messer, J. J., C. W. Ariss, R. Baker, S. K. Drouse , K. N. Eshleman, P. R. Kaufmann, R. A. Linthurst, J. M. Omernik, W. S. Overton, M. J. Sale, R. D. Schonbrod, S. M. Stambaugh, and J. R. Tuschall, Jr. 1986. National Surface Water Survey: National Stream Survey Phase I - Pilot Study. EPA/600/4-86/026. United States Environmental Protection Agency, Washington, DC. 179 pp.

Newell, A. D., C. F. Powers, and S. J. Christie. 1987. Analysis of data from long-term monitoring of lakes. EPA/600/4-87/014. United States Environmental Protection Agency, Office of Acid Deposition, Environmental Monitoring and Quality Assurance, Washington, DC, 150 pp.

Overton, W. S. 1988a. Outline of topics - study of regional trends (memo).

Overton, W. S. 1988b. Cooperative Agreement 1989-1990 between the U.S. Environmental Protection Agency and Oregon State University.

Pollard, J. E., K. Howe, and D. T. Haggen. 1987. Workshop on quality assurance for the Temporally Integrated Monitoring of Ecosystems (TIME) Project held in Las Vegas, Nevada, November 18-20, 1987: Preliminary Summary, United States Environmental Protection Agency, Office of Acid Deposition, Environmental Monitoring and Quality Assurance, Washington, DC, 55 pp.

Pollard, J. E., K. Howe, and D. T. Haggen. 1988. Expanded summary of workshop on quality assurance for the Temporally Integrated Monitoring of Ecosystems (TIME) Project. Las Vegas, Nevada. November 18-20, 1987. United States Environmental Protection Agency, Office of Acid Deposition, Environmental Monitoring and Quality Assurance, Washington, DC, 74 pp. (Draft).

Sale, M. J., P. R. Kaufmann, H. I. Jager, J. M. Coe, K. A. Cougan, A. J. Kinney, M. E. Mitch, and W. S. Overton. 1988. Chemical characteristics of streams in the Mid-Atlantic and Southeastern United States. Volume II. Streams sampled, descriptive statistics, and compendium of physical chemical data. EPA/600/3-88/0021b. United States Environmental Protection Agency, Washington, DC.

Singer, R., D. Smith. 1987. The use of benthic macroinvertebrates as indicators of acidification. Report prepared for the U.S. Environmental Protection Agency, Corvallis Environmental Research Laboratory, Corvallis, OR. 47 pp.

Siver, P. A. 1987. A critical literature review on the usefulness of chrysophytes to detect lake chronic or episodic acidification and/or recovery in the context of a long-term monitoring program. Report submitted to U.S. Environmental Protection Agency, Corvallis Environmental Research Laboratory, Corvallis, OR. 112 pp.

Smol, J. P. 1987. Usefulness of diatoms in detecting acidification and/or recovery in a long-term monitoring program. Report prepared for the U.S. Environmental Protection Agency, Corvallis Environmental Research Laboratory, Corvallis, OR. 124pp.

Stokes, P. M., E. T. Howell. 1987. The usefulness of periphyton to detect lake chronic or episodic acidification and/or recovery in the context of a long-term monitoring program. Report prepared for the U.S. Environmental Protection Agency, Corvallis Environmental Research Laboratory, Corvallis, OR. 88 pp.

Thornton, K. W., J. P. Baker, K. H. Reckhow, D. H. Landers, and P. J. Wigington, Jr. 1986. National Surface Water Survey - Eastern Lake Survey - Phase II Research Plan. U.S. Environmental Protection Agency, Corvallis Environmental Research Laboratory, Corvallis, OR.

Thornton, K. W., F. E. Payne, J. Ford, and D. H. Landers. 1987. The Concept of TIME. U.S. Environmental Protection Agency, Environmental Research Laboratory - Corvallis, Corvallis, OR.

GLOSSARY

AERP	-	Aquatic Effects Research Program
ANC	-	Acid Neutralizing Capacity
ASRL-RTP	-	U.S. Environmental Protection Agency, Atmospheric Sciences Research Laboratory, Research Triangle Park, North Carolina.
ELS	-	Eastern Lake Survey - Phase I
ELS-II	-	Eastern Lake Survey - Phase II
EMSL-LV	-	U.S. Environmental Protection Agency, Environmental Monitoring Systems Laboratory, Las Vegas, Nevada
EPA	-	Environmental Protection Agency
EPRI	-	Electric Power Research Institute
ERL-C	-	U.S. Environmental Protection Agency, Environmental Research Laboratory, Corvallis, Oregon
LTM	-	Long Term Monitoring Project
NLS	-	National Lake Survey
NSS	-	National Stream Survey
NSWS	-	National Surface Water Survey
PIRLA	-	Paleoecological Investigations of Recent Lake Acidification
PNL	-	Batelle's Pacific Northwest Laboratory, Richland, Washington.
QA/QC	-	Quality Assurance and Quality Control
TIME	-	Temporally Integrated Monitoring of Ecosystems
USGS	-	United States Geological Survey
WLS	-	Western Lake Survey - Phase II