PLANNING FOR THE VERMONT MONITORING COOPERATIVE

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VMC RESEARCH REPORT #2

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I. EXECUTIVE SUMMARY

Concerns about the future long-term health of Vermont's forests and projected local, regional and global changes in climate and pollutant exposures have led to the formation of the Vermont Monitoring Cooperative, a long-term, integrated, ecological monitoring program. The VMC is being planned as a cooperative effort among the University of Vermont (UVM), the Vermont Agency of Natural Resources (VT ANR), the US Forest Service (USFS) and other state agencies to conduct long-term environmental and biological monitoring in forested ecosystems in Vermont, and to facilitate long-term research on the response of these ecosystems to the changing physical and chemical climate.

Preliminary research was conducted to: (1) identify the important questions and objectives to be addressed by a long-term ecological monitoring program in Vermont, and (2) identify existing monitoring resources in Vermont. This report summarizes the results of discussions, interviews, and workshops conducted to address the first of these objectives. A second report, to be submitted in August, 1990, will summarize existing Vermont monitoring resources, and recommend specific future monitoring activities.

The conceptual structure of the VMC is envisioned as a core of activities involving environmental and ecological monitoring, and data integration. These activities interact with ecological research and management through a Technical Committee.

Priority planning issues addressed in this document are discussed under three main areas: program design, monitoring, and program management.

Program design priorities include developing specific questions to be answered by monitoring, developing methods for managing and evaluating the data, and getting the data and/or the knowledge derived from it into the hands of appropriate users.

Monitoring priorities include identifying short and long term monitoring objectives, assuring adequate funding, identifying specific monitoring tasks, identifying appropriate groups to implement these tasks, establishing long-term monitoring plots, implementing a QA/QC program, and identifying long-term support for equipment acquisition, field personnel, and laboratory services.

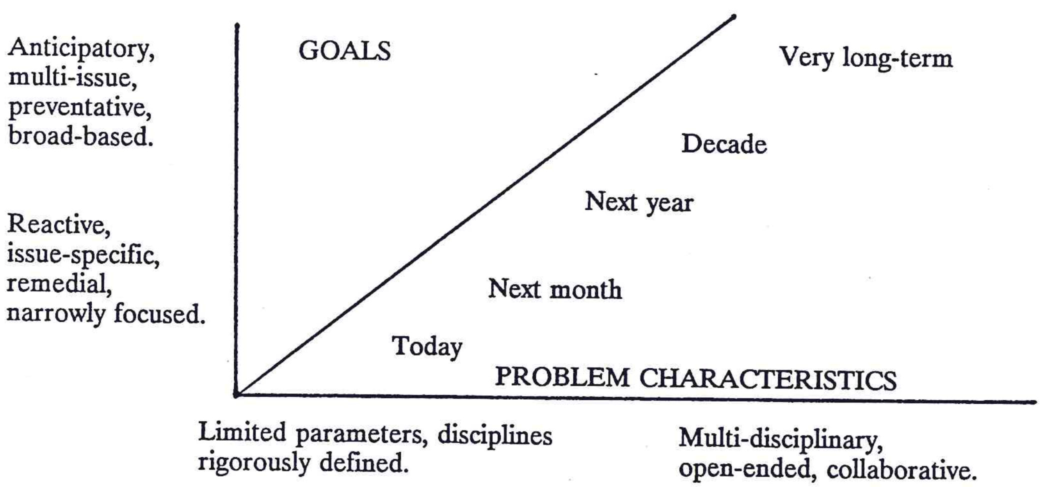
Program management priorities include assuring long-term program continuity, developing statistically sound and readily-accessible databases, and having a high degree of coordination internally and with other projects.

II. BACKGROUND

It is becoming increasingly clear that significant and complex changes are taking place in the physical environment around us. Regional stresses due to acid rain, toxic deposition, photochemical oxidants, increasing greenhouse gasses, decreasing stratospheric ozone, and population growth may be causing significant changes in ecosystem vitality and diversity. These ecosystem responses may, in turn, lead to reduced long-term forest productivity, altered pathways for forest pests and diseases, negative impacts on wildlife, reduced water quality, and degradation of recreational resources. Certain stresses (such as acid rain) may be reduced somewhat in the relatively near future, but others (such as climate change and stratospheric ozone depletion) are certain to worsen over the next century.

We currently have very limited information on the current health of Vermont's diverse ecosystems, and our ability to detect and address long-term change in ecosystem condition is minimal. We lack the ability to clearly perceive changes in ecosystem condition over time, to identify causal relationships, to recommend or undertake effective protective or remedial actions, or even to participate knowledgeably in regional, national or international discussions of pollution control strategies.

If we are to understand and protect the long-term health of our natural environment, we need to better understand the problems facing us, and adopt different strategies for addressing them. As the following figure (Foley, 1989) shows, there is a necessary relationship between our typically short-term, reactive approaches to environmental problems and the scope of the knowledge we derive from this approach. As the problems we are concerned with become more complex and interactive, we must develop longer-term, multi-issue goals. Or, to look at it another way, as we develop anticipatory, preventative goals, our work must become longer-term, more open-ended, and more multi-disciplinary.



Thus, if we desire to protect the long-term integrity of Vermont's natural ecosystems, we must develop new approaches to understanding them. We need (a) long-term, systems-oriented, ecological monitoring, and (b) coordinated environmental monitoring to provide information on the changing physical and chemical climate. Finally, we need to integrate these activities with basic research to identify the external stresses and internal processes which influence ecosystem condition. Meeting these objectives requires long-term monitoring in multiple environmental media, and a coordinated effort to integrate monitoring and research activities.

The Vermont Monitoring Cooperative (VMC) was formed to address these concerns in Vermont. Growing out of a series of discussions between scientists and planners in early 1989, a conceptual plan for a long-term environmental and biological monitoring program developed. This plan was circulated and discussed with scientists, planners, land managers, administrators, and governmental officials with encouraging results. In the autumn of 1989 Congress appropriated $250,000 for the establishment of a long-term integrated monitoring program in Vermont, these funds to be administered by the US Forest Service Northeast Forest Experiment Station.

From its conception, the VMC has promoted several goals. It will utilize resources of the Agency of Natural Resources (VT ANR) and the University of Vermont (UVM) in a coordinated manner to:

(1) Conduct long-term integrated biological, ecological, chemical and physical monitoring to characterize conditions and changes in forested ecosystems in Vermont;

(2) Provide monitoring data to support research on long-term ecosystem processes and responses to environmental change;

(3) Facilitate constructive interaction among regional monitoring and research activities;

(4) Provide information, technical expertise and recommendations about the status of forested ecosystems and the physical and chemical climate in Vermont for scientists, policy-makers, managers and the public.

In order to achieve these important but challenging goals and use our initial funding effectively, considerable effort has been put into long-range planning. A VMC Executive Committee was established in the winter of 1990, consisting of an administrator from the University of Vermont, the Vermont Department of Forests, Parks and Recreation, and the US Forest Service Northeastern Forest Experiment Station. In addition, a Technical Committee has been formed to assist in planning and coordinating VMC activities among participants. Appendix I provides the current makeup of these groups.

A portion of the initial funding for the Vermont Monitoring Cooperative has been designated for personnel to coordinate and plan the activities of the program. Some of these funds are being used to support a Forest Protection Specialist in the Forestry Division of the Vermont Department of Forest, Parks and Recreation. This position was newly defined principally to coordinate state and federal forest monitoring activities, and to help integrate VMC monitoring activities with these efforts.

In addition, some of these funds have been used to support long-term planning for the specific activities the Cooperative will undertake, and to conduct background research on existing monitoring resources and activities in Vermont. This report is a summary of the planning component of this process.

The remaining funds in the initial appropriation for the VMC are available for acquisition of new monitoring equipment, ongoing support services (e.g., site electricity), program coordination, and data integration and management.

III. OBJECTIVES OF THE PLANNING PROCESS

Monitoring in forested ecosystems is needed to describe environmental and biological conditions, variability, and trends, and to distinguish natural variation from changes due to external influences. Monitoring also provides data for modeling and predicting responses of forests to changing environmental conditions. Specific, problem-oriented objectives are needed to focus these monitoring efforts and to ensure their efficiency. Thus, the purpose of the initial planning process was to develop the foundation for a long-term monitoring plan. Specific planning objectives were to:

(1) identify questions to be addressed by monitoring and research;
(2) develop a structure for the VMC;
(3) identify information needs, target audiences, and data quality objectives;
(4) develop a list of possible specific monitoring tasks.

From its inception, the VMC has been seen as a science-management partnership. The complexity of the environmental and ecological problems facing us requires this approach (Risser, 1985; Harris et al., 1987). The VMC, therefore, should address specific management questions. At the same time, it should also support basic ecological research. A balanced involvement of both scientists and managers will insure that the activities and outputs of the VMC will provide comprehensive information about conditions and processes in Vermont's natural ecosystems.

To be most useful, long-term studies need to be able to respond to changing knowledge, and able to incorporate new questions as they arise. At the same time, however, these studies must maintain a strategic core of directed questions with enduring relevance, supported by a consistent management program (Strayer et al., 1986). Thus, part of this work is to develop the key questions that the monitoring effort will initially be designed to address, and to identify possible role for the VMC within the monitoring/research infrastructure of Vermont and the region.

Finally, the most visible work of the VMC - the monitoring tasks - must be carefully designed to address the key management and scientific questions, to reflect the current state-of-technology, to be compatible with regional monitoring and research needs, and to provide a long-term, sustainable monitoring program.

One part of this planning process involved convening workshops to discuss monitoring needs and objectives. Two workshops were held in the spring of 1990, and are summarized in Appendix II. In addition, continuing discussions with scientists, land managers, and planners in and outside of Vermont provided additional input to the planning process. Review of technical reports and planning documents has also provided important information for planning this long-term monitoring effort. What follows is a synthesis of information from these knowledge bases, providing a sense of what some of our long-term monitoring needs are, and recommendations for establishing a long-term monitoring program in Vermont.

IV. RECOMMENDATIONS

From the planning workshops (Appendix II) and assessment of other information about long-term monitoring and research, many ideas about the structure of a long-term monitoring program have been developed. This section summarizes this information and develops specific recommendations for the monitoring program.

Planning the VMC first requires attention to identifying the conceptual structure of the program and its relationship to other programs. Following this, recommendations for activities of the VMC are considered under three categories: program design and data evaluation, monitoring activities, and program management. These areas are addressed in turn below.

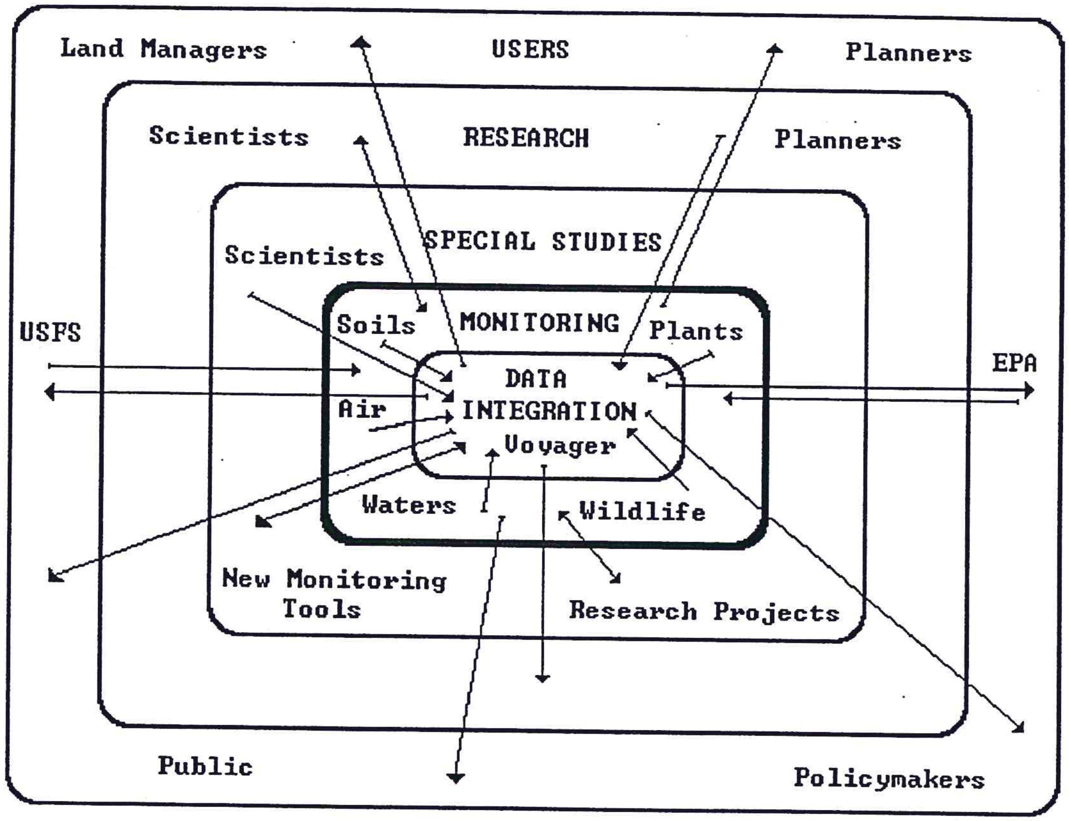
A. Conceptual Structure:

First and foremost, the VMC should be a vehicle for conducting long-term, basic environmental and ecological monitoring. Thus, one of the main roles of the VMC is to conduct monitoring. In this capacity, the VMC consists of equipment, sites, and people who make measurements and summarize, evaluate, maintain, and distribute data. Because there is a pressing need for data integration and coordination, this should be another central activity of the VMC. In this role, the VMC collects, interprets, and manages data. Special attention should be given to data integration, i.e., bringing together data from multiple sources and media to produce creative new views of ecosystem conditions and processes.

Secondly, the VMC should provide desirable sites and useful environmental, biological, or ecological data to support research efforts on issues related to long-term environmental/ecological processes. While the VMC should not be primarily concerned with conducting this research, it should work closely with the research community in order to maintain appropriate research-monitoring linkages. These linkages include suggesting research directions to investigate aspects of monitoring and data integration outputs, and, where program flexibility permits, conduct monitoring to support the needs of important research priorities.

Administratively, the VMC should initially be a loose coalition of interested parties. Equipment should be owned and operated by cooperating participants. Costs of certain monitoring activities should be supported directly by cooperating agencies, while other activities should be supported externally. Funds for some common activities (data management, site electricity, equipment maintenance, etc.) should be administered centrally. In time, it may be advantageous to form an independent entity, such as a consortium, to manage and conduct VMC activities. The consortium structure has been adopted by several long-term research groups with multiple participants, including the Lake Champlain research community and the southern forest wetlands management and research communities.

This structure for the VMC can be diagrammed as follows on the next page:



Within this conceptual framework, monitoring and data integration are principal activities of the VMC. The Technical Committee plays a role in overseeing MONITORING and providing linkages between the VMC and SPECIAL STUDIES, RESEARCH, and USERS. SPECIAL STUDIES form an interface between MONITORING and traditional RESEARCH activities. Research results and information needs flow from the RESEARCH and SPECIAL STUDIES spheres to the INTEGRATION center, where data are managed, monitoring tasks are identified, and research directions are suggested. Data also flows from MONITORING both to the INTEGRATION center and to certain USERS. Integrated information flows from the INTEGRATION center to USERS. Many other connections exist in this scheme, but this brief discussion conveys the essential features of this conceptual structure for the VMC.

The VMC should provide data to address specific information needs of land managers, scientists, and policymakers. The following questions define the scope of possible monitoring and related research activities of the VMC.

(1) **What are the conditions and trends in the physical and chemical climate and the biological components and processes of Vermont's forested ecosystems?**

(2) **What are the relationships between changes in the physical/chemical environment and changes in forest communities?**

(3) **Can models be developed to predict responses of forested ecosystems or their components to possible future changes in environmental conditions?**

(4) **What management strategies are needed to maintain healthy forest ecosystems under changing environmental conditions?**

These four questions cover a continuum from basic information gathering to applied predictive modeling. Question 1 defines the activities of the VMC core, and to the extent it is desirable to develop new monitoring and data evaluation techniques, it also motivates special studies conducted by the VMC/research interface. Question 2 drives the integration work of the VMC, where in addition to developing tools for assessing causality, new relationships among parallel ecosystem components are identified.

Questions 3 and 4, as well as some aspects of question 2, are beyond the scope of the VMC. Detailed study of causal relationships, predictive modeling, and development of new management strategies are essential components of integrated environmental protection and long-term ecosystem study, but are generally under the purview of the research and user communities, not the VMC. On the other hand, since the VMC is ultimately concerned with identifying and measuring important environmental and ecological trends and processes, there will have to be close coordination with these research efforts.

In addressing these questions, and developing a work-plan, both short-term and long-term objectives should be set. Short-term objectives will insure frequent tangible results from the monitoring program, active involvement of people with the program, and program visibility. Long-term objectives will provide the necessary "vision" for the program to guarantee its continuity.

Specific prioritized planning recommendations are put forth below, organized under three headings: program design, monitoring activities, and program management.

Although there is some overlap among these categories, and other ways could be constructed to organize planning, this simple three-part construction seems to work well to keep track of critical issues and focus our effort. It is recognized that more recommendations are developed here than probably can be developed in the immediate future. Nonetheless, it is important to consider all the key issues and long-term objectives of this program as we plan implementation and funding strategies.

B. Program Design:

Data from the monitoring program should be used to help answer specific questions, as well as provide baseline information about conditions of the environment and ecosystems. Without these specific questions to focus on, monitoring may be poorly conceived, and monitoring data may have little value. In examining monitoring programs, Strayer et al. (1986) found that: (1) the initial design, variables, and methods must be carefully chosen, (2) continuous data interpretation by interested scientists should be used to update the design of the monitoring program, and (3) the program should be flexible, allowing for application of new knowledge as it develops. These are appropriate design objectives for the VMC.

In the planning process, a number of questions were identified which were of concern to natural resource managers. These are the "larger questions" about ecosystem responses to multiple and/or long-term environmental and feedback influences. They can be used to develop more specific questions which monitoring data can answer. Some of the questions seek to identify or develop:

- normal ranges of variability for variables
- guidelines for evaluation of multiple stress
- indices of historical impacts, changes, exposures
- relationships between site and tree status
- a practical set of monitoring variables
- critical triggering events
- an index of socio-political factors effecting ecosystem impacts
- societal goals, endpoints for management

A fundamental objective of the monitoring program, of course, is a quantitative description of "current conditions" and identification of temporal or spatial trends in the environment and ecosystems. In addition, the above items suggest several issues related to data evaluation which also need to be addressed by the VMC. One is the development of new multi-dimensional methods for data evaluation, to address concerns about interrelationships, multiple stresses, and development of indices. Another area involves development of models for describing systems or predicting impacts. A third need involves developing techniques to incorporate societal goals into planning, management, and systems models.

As we think about questions to be answered by monitoring and data evaluation, it is also useful to consider the central questions currently being posed by the US Forest Service in the national Global Change Research Program (USFS, 1988):

- **What processes in forested ecosystems are sensitive to physical and chemical changes in the atmosphere?**

- **How will future physical and chemical climatic changes influence the structure, function, and productivity of forests and related ecosystems?**

- **What are the implications for forest management and how must forest management activities be altered to sustain forest health and productivity?**

These questions are extremely broad, but they define the direction of the national forest monitoring/research program, as well as the regional monitoring/research efforts that the VMC will need to coordinate with. While keeping these questions in mind, the VMC should articulate a set of more narrowly focused questions to direct its local monitoring activities. In particular, the VMC should provide information about conditions and trends within Vermont, as well as the region.

There are three areas to be addressed in making recommendations for program design: (1) develop policy (management-oriented) and scientific (research-oriented) questions to be answered by monitoring and data evaluation, (2) develop the methods to be used for data evaluation, and (3) get the data and/or the knowledge derived from it into the hands of appropriate users. Priorities for this program element are listed below.

1 - Policy Questions.

<u>P 1. How are Vermont's forestested ecosystems influenced by changes in the physical and chemical climate?</u>

- managers and planners need to have up-to-date information on current conditions and trends in various components of these ecosystems,
- managers and planners need to know relationships between environmental changes and ecosystem response.

<u>P 2. How can we identify "unnatural" perturbations in forested ecosystems?</u>

- managers need to distinguish between natural and human-induced changes, and need reliable tools for identifying perturbations.

P 3. How will changes in the physical and chemical climate influence management strategies?

- managers and planners need to design and implement appropriate management strategies for natural resource use.

2 - Scientific Questions.

S 1. What are the spatial and temporal trends in the health and productivity of Vermont forests, wildlife populations, and surface waters, and how are these influenced by changes in the physical and chemical climate?

- identify specific variables of interest in atmospheric, forest, surface water, and wildlife media for long-term monitoring,
- identify appropriate sites for conducting these measurements,
- identify possible indicator variables,
- develop a goal-oriented minimum set of monitoring variables.

S 2. What is the range of "normal" variability for certain variables?

- conduct long-term, continuous measurement of variables of interest,
- identify representative sites within a range of management strategies, ecosystem types, physiographic regions,
- develop multi-dimensional, multi-media assessments of influences on variability.

S 3. How do budgets for toxics, nutrients, energy, and water change with environmental conditions?

- develop ecosystem budgets and use as long-term monitoring parameters,
- integrate with measures of environmental and ecological condition,
- develop techniques for extrapolation from sites to regions.

S 4. What is the role of elevation, slope, and aspect in natural stresses and pollutant impacts?

- conduct environmental and ecological monitoring in a range of plots,
- identify impacting natural and pollution stresses,
- examine relationships between site and impact.

S 5. Are there historical patterns of environment-ecosystem interactions which are useful monitoring tools?

- monitor recording bioindicators (e.g., tree cores, sediments, fish scales),
- monitor bioindicator species (e.g., lichens, diatoms),
- develop multi-media indices of historical change.

S 6. What correlative and/or causal relationships exist between environmental and biological (ecosystem) conditions?

- identify known and possible linkages,
- examine relationships using traditional statistical and new exploratory data evaluation techniques,
- identify key events which are correlated with and may trigger episodes of ecosystem damage, productivity reduction, or habitat alteration,
- encourage research projects to examine relationships.

S 7. How do current and possible management strategies for forests, waters, and wildlife respond to changes in the physical and chemical climate?

- examine existing management on a range of sites,
- impose management procedures across a range of sites.

3 - Data Analysis.

3a. Develop new, multi-dimensional data management and evaluation systems.

- develop an integrated database management system with user-friendly access and easy import/export mechanisms,
- use the Voyager data exploration system as a tool for data integration and communication,
- identify other new technologies for data management.

3b. Build data from sites into site-specific, detailed GIS.

- develop complete Geographic Information System maps for the Proctor Maple Research Center site.
- identify other possible sites in Vermont for GIS application to long-term monitoring data.

4 - Information transfer.

4a. Develop electronic data transfer networks.

- between data-collection equipment and the data management system,
- among key users, including USFS and other cooperators.

4b. Identify data users and formats needed for them.

- to facilitate data transfer,
- as part of developing Data Quality Objectives.

4c. Provide regular data/information communications.
- to key users, including policymakers and public,
- develop objectives and formats for each user group.

4d. Provide special priority information announcements.
- about significant findings,
- about opportunities for cooperative work and support.

C. Monitoring Activities:

Specific tasks which might be valuable to a long-term monitoring effort could make a very long list, and identifying priorities will be difficult. Some tasks are simple and inexpensive, and others may be beyond our means. Some tasks are obvious, while others may not be identified for years. Development of specific questions (above) to be answered by the monitoring helps identify specific monitoring tasks. Because we don't always know what questions to ask about ecosystem processes or environmental change, however, it is important to design the monitoring program to be flexible, but at the same time oriented around a core of measurements we are certain will be of interest in the long run. Finding a cost-effective balance among these constraints is our challenge.

Forest health/air quality concerns have been a driving force in the development of the VMC to date. The VMC already has a strong position in atmospheric chemistry and forest monitoring at the PMRC, as the past decade has seen a variety of sophisticated measurements of maple tree physiology, meteorology, precipitation chemistry, aerosol, and gaseous measurements conducted by a dozen or more organizations with diverse objectives. However, development of an integrated monitoring program will require considerable effort. While the commitment to integrated, multi-disciplinary work is present, relatively little coordination and integration of monitoring activities or monitoring data has occurred to date, and we have little experience in this area to build on.

Over half of the specific issues discussed in the planning workshops (Appendix II) were specific recommendations for monitoring tasks. Generally, these dealt with measuring site characteristics, organism condition, and community structure. They included monitoring the following parameters.

Site characteristics:
- climate and weather
- water balance, energy balance, and nutrient/chemical cycling
- toxic contaminant budgets
- temporal and spatial ozone variability

- air flow patterns (synoptic weather)
- solar radiation, especially UV-B
- soil chemistry, organic matter percentage, soil organisms
- photochemical oxidants in forest canopy
- CO_2 levels in forest
- soil physical properties
- tree crown light factors
- foliar nutrients and other chemicals
- throughfall and precipitation chemistry
- groundwater chemistry
- net primary productivity

<u>Organism condition:</u>
- tree crown condition
- tree defoliation
- tree insect and disease impacts and tree recovery
- abundance, vigor, and quality of trees and herbaceous species
- tree phenology
- bioindicators of air quality, water quality, and soil conditions

<u>Community structure:</u>
- plant community composition
- forest age and growth pattern characteristics
- genetic diversity of trees
- wildlife habitat values and qualities
- animal species distributions
- forest invertebrate species distributions
- structure and function of aquatic communities
- mast and seed production
- crown closure
- impact of monitoring activity on site
- social/civil factors: land use, transfer, etc.

These monitoring variables encompass three broad areas: (1) basic physical properties of ecosystems, including climate, pollutant deposition, nutrient dynamics, and energy budgets; (2) conditions of trees, other plants, and aquatic organisms as integrating bio-monitors of change or stress in the ecosystem; and (3) community structure and function, covering plants, animals, habitat characteristics, and interactions among these. This "wish-list" is a useful start in identifying monitoring variables for implementation in the VMC. It is not complete, of course, nor does it reflect availability of current monitoring or financial resources. It does, however, demonstrate the broad diversity of ecosystem characteristics demanding attention, and the need for integrated approaches to ecosystem monitoring.

Several steps must be taken to implement monitoring tasks under the VMC, including (1) identifying short and long term objectives to address the central questions listed earlier, (2) implementing a quality assurance program, (3) establishing long-term monitoring plots, (4) identifying monitoring tasks, and (5) acquiring equipment and supporting field activities. Priorities for a monitoring program are listed below. Monitoring priorities are further subdivided into three categories: site characteristics, organism condition, and community structure.

1 - Objectives.

1a. Identify long-term funding mechanisms:
- support long-term monitoring tasks and data management,
- insure central program coordination and continuity.

1b. Measure selected environmental and ecological parameters:
- establish baselines, and identify trends and differences,
- address policy and scientific questions,
- continue previous and current monitoring in key areas.

1c. Develop an integrated suite of environmental and ecological variables:
- use and develop multi-media evaluation techniques,
- develop a holistic view of ecosystem conditions and processes.

1d. Develop data dissemination mechanisms:
- reach appropriate audiences in a timely fashion.

1e. Maintain close linkages with research community:
- provide useful monitoring services,
- develop new monitoring technologies and approaches,
- participate in modeling and other special research.

2 - Quality Assurance.

2a. Develop Data Quality Objectives:
- identify intended use of data: answering scientific questions, reaching target user audiences, statistical use, etc.

2b. Establish QA/QC work group to assist in this area:
- from the Technical Committee and others as needed.

2c. Coordinate with USFS, EPA, and other QA/QC protocols:
- utilize existing protocols,
- maximize data compatibility.

3 - Plots.

3a. Identify permanent plots for long-term studies at PMRC, adjacent private lands, and State and UVM lands on Mount Mansfield:
- identify land use histroy for plots,
- measure baseline soil characteristics,
- include unmanaged and managed forests and stream systems,
- conduct experimental manipulations,
- coordinate with regional and national permanent plot networks, and locally with Mount Mansfield River Watch.

3b. Establish a Lands Use Advisory Committee:
- coordinate monitoring and research planning on lands and in plots at PMRC and adjacent sites,
- identify suitable sites and permissible activities,
- pursue acquisition of research covenants on private land near PMRC.

3c. Coordinate VMC plot system with USFS, EPA, and others in region:
- provide data compatibility and support data exchange,
- coordinate field activities and personnel,
- develop other VMC permanent forest monitoring plots in Vermont.

4 - Monitoring. (4.1 - site characteristics)

4.1a. Meteorology, climate, and weather in open and in forested plots:
- an important component of integrated data evaluation,
- correlate with other variables,
- track basic climate changes.

4.1b. Precipitation chemistry:
- continue and expand chemical deposition data at site,
- track precipitation amount and chemistry changes.

4.1c. Ozone temporal and spatial characteristics:

- correlate with vegetation and climate patterns,
- track regional and local distributions.

4.1d. Toxic contaminant deposition:

- quantify deposition of known toxics (metals, PCBs, etc.),
- identify new toxic contaminants of importance,
- include fine particulate and visibility monitoring,
- develop ecosystem input/output budgets for selected toxics.

4.1e. Soil characteristics:

- characterize baseline conditions in permanent plots,
- track long-term changes in structure, chemistry, and biota,
- relate to climate, chemistry, vegetation and watershed data.

4.1f. Surface water physical characteristics:

- measure short term fluctuations in water quality,
- track long-term changes in hydrological patterns,
- relate to plant and animal population characteristics,
- track long-term changes in water quality and hydrology.

4.1g. Gases in forest canopy (other oxidants, CO_2, N-compounds, etc.).

- identify new contributors to pollutant mixture,
- characterize exposures and trends.

4.1h. Solar radiation, especially UV-B:

- quantify local dosage to ecosystem components,
- track long-term patterns of exposure.

4.1i. Water balance, energy balance, and nutrient/chemical cycling:

- develop data for whole-system input/output studies,
- measure local short-term and long-term changes in patterns,
- facilitate modeling of regional (state, biosphere) energy budgets.

4.1j. Tree canopy light factors:

- correlate with vegetation patterns and physiological studies.

4.1k. Social/civil factors, such as land use patterns, land transfer:

- track long-term patterns and relationships with ecosystem conditions,
- integrate with ecological and environmental data.

4.1l. Impacts of monitoring activities on plots:
- recognize artifacts in measurements,
- improve experimental designs for long-term studies.

4 - Monitoring. (4.2 - organism condition)

4.2a. Tree crown conditions:
- compatible with other studies,
- measure extent of short-term and long-term defoliations,
- relate to land use history,
- correlate with physiological studies on foliar conditions.

4.2b. Tree insect and disease impacts and tree recovery:
- maintain long-term records of patterns in permanent plots,
- characterize variability,
- correlate with vegetation and environmental data.

4.2c. Abundance, vigor, and quality of trees and herbaceous species:
- maintain long-term records of patterns in permanent plots,
- correlate with ecological and environmental data.

4.2d. Toxic contaminants in terrestrial and aquatic plants and animals:
- identify potential stressors and their location,
- identify patterns of transport and sequestering,
- track changes in long-term patterns of transport and sequestering.

4.2e. Tree phenology:
- characterize phenological patterns, variability, and changes,
- correlate with ecological and environmental data.

4.2f. Native species as bioindicators of air quality and soil conditions:
- identify useful bioindicators,
- track changes in long-term patterns of bioindicator response,
- correlate with ecological and environmental data.

4 - Monitoring. (4.3 - community structure)

4.3a. Species community composition:
- characterize ecosystem plant or animal community structure,
- track changes in community composition,

- develop indices of community composition to correlate with ecological and environmental data.

4.3b. Forest stand age and growth pattern characteristics:
- provide local information on long-term patterns of forest growth,
- correlate with land use histroy.

4.3c. Genetic diversity of trees:
- provide baseline information and long-term data on changes in genetics of mapped individuals in permanent plots,
- examine relationships between genetics, vigor, and survival.

4.3d. Wildlife habitat values and qualities:
- develop integrated forest/wildlife measures,
- relate to animal distributions and population trends,
- correlate with ecological and environmental data.

4.3e. Animal species distributions:
- develop integrated forest/wildlife measures,
- track long-term changes in populations,
- relate to habitat characteristics.

4.3f. Forest insect species distributions:
- provide sites and data to support existing programs,
- characterize ecology of non-pest species,
- correlate with physiological, ecological and environmental data,
- develop integrated forest/insect measures.

4.3g. Forest disease distributions:
- provide sites and data to support existing programs,
- correlate with physiological, ecological and environmental data,
- develop integrated forest/disease measures.

4.3h. Aquatic macroinvertebrate distributions:
- develop baseline data on population characteristics,
- correlate with environmental and ecological data,
- describe macroinvertebrate population variability.

4.3i. Structure and function of aquatic communities:
- develop baseline data on community characteristics,
- correlate with environmental and ecological data,
- describe variability in certain aquatic community variables.

5 - Field support.

5a. Financial support of operations at monitoring site:

- electricity, communications, site maintenance,
- materials for plot establishment and maintenance,
- supplies for monitoring equipment.

5b. Financial support for equipment acquisition and maintenance:

- identified monitoring equipment,
- repairs and maintenance.

5c. Financial support of field technician:

- to maintain and conduct monitoring studies,
- carry out field data management.

5d. Coordinate with other regional programs:

- Share field resources for some monitoring tasks,
- develop common protocols.

D. Program Management:

Good program management may well be the most important aspect of a long-term monitoring program. All participants in the planning process have stressed their concern that careful planning, coordination, non-duplication of effort, program continuity, and data quality and security have a high priority in the VMC. In the IES report "Long-term ecological studies," Strayer et al. (1986) found that the most important contributors to successful long-term projects were dedicated guidance by a single project leader and good program management.

Prior to the formation of the VMC, plans for future monitoring activities have not been developed in a coordinated manner among university, state, private, regional, and federal organizations. Current and historical monitoring results conducted by separate organizations have not been synthesized into a common database. Absence of a strong central management program has been one important reason for this failure in coordination. An equally important obstacle has been (and remains) the lack of stable, dedicated, long-term funding and personnel resources.

In general, there is widespread agreement that monitoring and research programs in Vermont need better coordination, data management, data dissemination, and financial support. Important issues which have been raised related to management of a long-term monitoring program include:

- good documentation of data
- development of an integrated data library and database
- an active data management program
- coordination with other databases
- high statistical quality and clear data quality objectives (DQO's)
- long-term data preservation, including time-capsuling data and samples
- coordinated funding
- development of new, multi-dimensional data evaluation techniques
- an active information exchange and distribution program
- coordination with regional and federal programs
- coordination of program needs and resources (people, equipment, labs)

These concerns suggest that the VMC should pay attention to both program coordination and data management and use. Priorities for program coordination should address: staffing, funding, planning, and coordination. Data management priorities should address data quality, long-term data integrity and storage, developing new technologies for data management and interpretation, and information exchange systems.

Because of the multi-agency nature of the VMC, special attention to cooperative management will be required. The following priorities are suggested for implementation by the VMC. Key areas include (1) personnel, (2) data management systems, (3) clear objectives, and (4) good internal and external coordination.

1 - Personnel.

<u>1a. Support a program coordinator:</u>

- to oversee and coordinate monitoring and data integration activities,
- provide liaison among cooperating agencies,
- conduct data integration and research,
- provide long-term guidance, and continuity
- develop new funding sources.

<u>1b. Develop an active Technical Committee:</u>

- to provide technical advice and oversight,
- help implement and coordinate monitoring tasks,
- assist in annual program review,
- include high-visibility and federal agency people in adjunct capacity.

1c. Support a data manager:

- to develop and maintain central information and data databases,
- develop new multi-dimensional data management tools.

1d. Develop personnel exchange programs:

- encourage cooperation and technology transfer,
- provide educational opportunities.

2 - Data.

2a. Develop computerized, integrated databases:

- containing information about monitoring and research projects, and data from core monitoring activities,
- examine other database systems: AIRS, Border, LTERS, Source of the Brook,
- develop electronic data transfer systems among key users: VT ANR, USFS, EDEX (Ecological Data Exchange), and NESCAUM (Northeast States for Coordinated Air Use Management),
- coordinate with local research and monitoring groups to consolidate data.

2b. Insure good data documentation and preservation:

- for long-term data security and storage, and timely information access.

2c. Develop Geographic Information System of data at PMRC site:

- develop a model system of GIS/data linkages,
- provide useful integrated data/site information.

2d. Develop information dissemination systems:

- for timely information transfer to target audiences,
- annual reports and special briefings.

3 - Objectives.

3a. Execute a Memorandum of Understanding (MOU):

- between UVM and VT ANR,
- to codify objectives and mechanisms of collaboration.

3b. Identify Data Quality Objectives:

- including target audiences, information needs of each, and data characteristics required by each.

4 - Coordination.

4a. Coordinate efforts with other programs:

- among UVM, VT ANR, and USFS,
- within VT ANR,
- with local lay monitoring groups (e.g., Mount Mansfield River Watch),
- with other regional groups (Forestry Canada, adjacent states, Hubbard Brook Experimental Forest, NESCAUM, etc.).

4b. Coordinate funding:

- identify spending priorities,
- seek short-term and long-term funding from a variety of sources,
- coordinate funds, resources, and needs.

4c. Develop self-evaluation procedures for the program:

- using the Technical Committee,
- annually.

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APPENDIX I
MANAGEMENT STRUCTURE OF THE VERMONT MONITORING COOPERATIVE:

EXECUTIVE COMMITTEE

Responsible for management coordination among the University of Vermont, the Vermont Department of Forests, Parks and Recreation, the Northeast Forest Experiment Station, and other agencies participating in the VMC.

- Denver Burns, Director, USFS Northeast Forest Experiment Station.
- Larry Forcier, Dean, UVM School of Natural Resources.
- Conrad Motyka, Director, Forestry Division, Vermont Department of Forests, Parks and Recreation.

TECHNICAL COMMITTEE

Responsible for providing technical oversight in development and implementation of the program, assisting in developing scientific priorities, planning monitoring activities, and identifying appropriate monitoring techniques. They will also take an active role within their respective organizations to implement and coordinate monitoring activities. It will assist in the annual program review process, and in providing technical information transfer to researchers, managers, planners, and the public. At this time, the following members have been identified, representing a broad range of expertise and covering potential monitoring activities of the program. This committee may be modified as needed.

- Bill Bress, VT Dept. of Health: Human Health.
- Bob Brooks (<u>ad hoc</u>), USFS Northeastern Forest Experiment Station, Amherst, MA: New England Forest Health Program, Wildlife Ecology.
- Doug Burnham, VT Dept. of Environmental Conservation: Surface Waters.
- Nancy Burt, Green Mountain National Forest, Rutland, VT: Soils, Forest Monitoring.
- Deane Wang, UVM School of Natural Resources: Forest Ecology, Lanscape Ecology.
- Chris Eagar (<u>ad hoc</u>), Northeastern Forest Experiment Station, Radnor, PA: Forest Ecology.
- Larry Garland, VT Dept. of Fish and Wildlife: Wildlife.
- Dave Marvin, VT Governor's Task Force on Forest Health: Forestry, Maple Industry.
- Rich Poirot, VT Dept. of Environmental Conservation: Atmospheric Processes and Modeling.
- Brent Teillon, VT Dept. of Forests, Parks and Recreation: Forest Health.
- Jon Turmel, VT Dept. of Agriculture: Agriculture, Entomology.
- Mel Tyree, UVM Botany Dept.: Proctor Maple Research Center, Tree Physiology.

PROGRAM COORDINATORS

Responsible for ongoing direction of the program, coordination of operations, budget management, grant applications, etc. Ideally, these activities should be shared between the University of Vermont and the Vermont Department of Forests, Parks and Recreation.

- Tim Scherbatskoy, Research Assistant Professor, UVM School of Natural Resources: Forest Physiological Ecology, Plant Physiology.
- Sandy Wilmot, Forest Protection Specialist, Forestry Division, VT Dept. of Forests, Parks and Recreation: Forest Health, Entomology.

APPENDIX II
RESULTS OF THE WORKSHOPS

On May 1 and 3, 1990, two meetings were held in Waterbury and Burlington to discuss the question below. The purpose of these meetings was to involve people directly in the planning for implementation of monitoring activities under the Vermont Monitoring Cooperative. The focusing question was:

> "In your opinion, what are the most important data or research/monitoring approaches needed to determine impacts of environmental change on forested ecosystems in Vermont?"

To pursue this question, these workshops used Nominal Group Technique (round-robin generation of ideas followed by discussion and ranking). In ranking, participants were asked to prioritize their top five items. Priorities were then converted to weighted ranks in order to identify the relative importance of topics. Listing of all items from each meeting and results of ranking are given after the following discussion of general results below.

General characteristics of the data:

The information collected in these meetings tended to fall into five main subject areas. These are listed below in order of the percentage of items in each area (given in brackets). These overall percentages change by only 0-2% if calculated using only items in the top-five group. Where several categories are listed under each main area, percentage distribution within that area is given in parentheses.

1. Site characteristics. [37%]
   - soils, geology (7%)
   - land use and management (18%)
   - chemical and energy budgets (36%)
   - general ecosystem properties (39%)

2. Program and data management. [25%]

3. Organism condition. [17%]
   - plants (85%)
   - animals (15%)

4. Community structure. [11%]
   - plants (75%)
   - animals (25%)

5. Evaluation and modeling. [11%]

Data from the meetings:

All items, in the order raised in the meetings, are listed below. For each item receiving votes, calculations of ranks are shown in brackets. Participant's priorities were converted to points (priorities 1, 2, 3, 4 and 5 were assigned values of 5, 4, 3, 2 and 1, respectively), summed, and divided by the number of participants to generate a weighted rank. Thus, [124 > 542 > 11/12 = 0.92] refers to: [individual priority ranks > individual value points > ratio > overall weighted rank]. This example shows that three people ranked this item in the top five giving it priorities of 1, 2, and 4; overall its weighted rank is 0.92. Items without these calculations did not receive top-five recognition. A separate listing of the top-ranked items, in order of priority, follows after the data from the two meetings.

<u>Waterbury meeting, 1 May, 1990, 12 participants, 26 items (out of 49) identified in top 5, 50 votes cast:</u>

1. Monitor tree crown condition, including internodal length, apical bud vigor, and all other aspects. [3111 > 3555 > 18/12 = 1.50]

2. Monitor tree species composition and stand structure. [14 > 52 > 7/12 = 0.58]

3. Develop toxic contaminant budgets: identify current sources, processes, sinks, and effects of potentially toxic organics and metals. [124 > 542 > 11/12 = 0.92]

4. Develop thorough site histories, including past harvesting, weather events, insect and disease outbreaks, etc. [4 > 2 > 2/12 = 0.17]

5. A goal should be to establish data on background tree mortality and patterns of stand change (to identify what is "normal" and what current conditions are).
6. Compare unmanaged sites with managed ones (both current management practices and past management).

7. Monitor changes in abundance, vigor, and quality of trees and herbaceous species at the established sites. [334 > 332 > 8/12 = 0.67]

8. Monitor water balance, energy balance, and nutrient/chemical cycling. [114 > 552 > 12/12 = 1.00]

9. Monitor structure, function of aquatic communities. [34 > 32 > 5/12 = 0.42]

10. Monitor degree, frequency, susceptibility, and recovery of trees from insect and disease problems. [333 > 333 > 9/12 = 0.75]

11. Monitor climate and weather in forested stands. [22223 > 44443 > 15/12 = 1.25]

12. Monitor foliar nutrients and other chemicals.

13. Monitor forest age characteristics.

14. Monitor solar radiation, especially UV-B. [4 > 2 > 2/12 = 0.17]

15. Monitor soil chemistry, organic matter percentage, and organisms. [45 > 21 > 3/12 = 0.25]

16. A goal should be to create a practical model or set of guidelines to evaluate impacts of multiple stresses.

17. Monitor past and present changes in tree growth rates and patterns.

18. Monitor changes in groundwater chemistry in forested sites.

19. Evaluate how elevation, slope, and aspect affect pollutant deposition loading, and relate to tree response. [35 > 31 > 4/12 = 0.33]

20. Carefully develop database management system, with attention to relationships among databases. [12 > 54 > 9/12 = 0.75]

21. Incorporate state-of-the-art technologies in data evaluation and integration methods. [2 > 4 > 4/12 = 0.33]

22. Monitor tree defoliation (insect, disease, weather, unexplained, etc.) annually. [4 > 2 > 2/12 = 0.17]

23. Monitor mast (seed providing food for wildlife) and seed production.

24. Monitor photochemical oxidants in forest canopy and evaluate interactions with canopy foliage. [5 > 1 > 1/12 = 0.08]

25. Monitor air flow patterns (synoptic weather) at sites. [2 > 4 > 4/12 = 0.33]

26. A goal should be to have close coordination with the New England Forest Health Monitoring Program.

27. Evaluate current and past land use patterns at site.

28. Monitor native plants which serve as bioindicators of air quality of soil conditions. [4 > 2 > 2/12 = 0.17]

29. Monitor animal species. [3 > 3 > 3/12 = 0.25]

30. Monitor wildlife habitat values and qualities. [2 > 4 > 4/12 = 0.33]

31. Monitor plant communities for shifts in community composition over time. [2 > 4 > 4/12 = 0.33]

32. Monitor temporal and spatial ozone variability in state. [145 > 521 > 8/12 = 0.67]

33. Monitor throughfall and precipitation chemistry.

34. Monitor crown closure in softwood stands.

35. Monitor genetic diversity of trees.

36. Monitor potential sources (emitters) of airborne pollutants. [1 > 5 > 5/12 = 0.42]

37. Monitor changes in tree phenology. [4 > 2 > 2/12 = 0.17]

38. Monitor impact of monitoring activity on site. [5 > 1 > 1/12 = 0.08]

39. Monitor CO2 levels in forested sites.

40. A goal should be to use this program to develop improved monitoring techniques and approaches.

41. Monitor soil temperature, moisture, depth, and physical structure.

42. Develop indices of historical impacts, exposures, changes, etc. in various disciplines.

43. Monitor species distributions of invertebrates in various forest types.

44. Evaluate relationships between elevation, exposure, slope (i.e., site conditions) and tree status.

45. Establish clear data quality objectives.

46. Characterize site geology.

47. Identify biomonitoring plants and animals to indicate exposure to pollutants. [45 > 21 > 3/12 = 0.25]

48. Develop methods for information exchange and coordination with other groups. [5 > 1 > 1/12 = 0.08]

49. Make photographic records of sites.

<u>Burlington meeting, 3 May, 1990, 12 participants, 14 items (out of 27) identified in top 5, 44 votes cast:</u>

1. Identify site-specific range of "normal" variability, using historical information if possible. [1112234 > 5554432 > 28/12 = 2.33]

2. A goal should be to develop compatibility with Forest Service and other regional monitoring efforts.

3. Need to define "stress," "health," "status" by user group.

4. Characterize monitoring sites as to their place in the range of ecosystem types; select representative sites, and include representative management strategies. [155 > 511 > 7/12 = 0.58]

5. Determine if identifying causality is a goal, and if so, couple monitoring with research to determine nature of causal relationships.

6. Develop information dissemination methods: timely; identify target audiences; include public and policymakers. [55 > 11 > 2/12 = 0.17]

7. Monitor tree crown condition and light factors.

8. Monitor social factors: land use, urbanization, land transfer, etc. [124 > 542 > 11/12 = 0.92]

9. Include managed and unmanaged sites to identify impacts/benefits of management.

10. Incorporate civil data into site selection process.

11. Develop 4-dimensional matrix of pollutant exposure, sensitive species, sensitive ecosystem processes, using currently available information for first cut. [24 > 42 > 6/12 = 0.50]

12. Coordinate efforts with past and existing information bases and monitoring efforts. [223455 > 443211 > 15/12 = 1.25]

13. Identify a practical set of monitoring variables, based on clearly identified needs. [4 > 2 > 2/12 = 0.17]

14. Assure statistical relevance through identification of data quality objectives, consistency of methods, frequency, equipment, etc. [11 > 55 > 10/12 = 0.83]

15. Determine in advance how to match program needs with available personnel and their interests.

16. Use photography (with ground-truthing) as a monitoring tool; include remote sensing and GIS linkages. [245 > 421 > 7/12 = 0.58]

17. Identify triggering variables. [3 > 3 > 3/12 = 0.25]

18. Incorporate economic and political factors into an index for impact measurement.

19. Time-capsule data and samples.

20. Ensure long-term data integrity. [1334 > 5332 > 13/12 = 1.08]

21. Identify indicator species.

22. Identify and coordinate funding to encourage use of sites. [3445 > 3221 > 8/12 = 0.67]

23. Contribute to predictive mathematical modeling of ecosystem processes. [2 > 4 > 4/12 = 0.33]

24. Determine if analytical capabilities match needs.

25. Develop integrated data base; with good documentation; managed by data specialist; both for catalog of projects and for raw data. [12333 > 54333 > 18/12 = 1.50]

26. Use decision-theory to focus monitoring on stewardship goals, endpoints.

27. Monitor recreation impacts in forests, wetlands, lakes, etc.

Top-five ranking in order of importance:

Following are the top-five items, in order of importance. Values in brackets are their calculated ranking. Leading numbers (e.g., 1w, 25b) refer to item numbers from the Waterbury ("w") and Burlington ("b) meetings listed above.

1b. Identify site-specific range of "normal" variability, using historical information if possible. [2.33]

1w. Monitor tree crown condition, including internodal length, apical bud vigor, and all other aspects. [1.50]

25b. Develop integrated data base; with good documentation; managed by data specialist; both for catalog of projects and for raw data. 1.50]

11w. Monitor climate and weather in forested stands. [1.25]

12b. Coordinate efforts with past and existing information bases and monitoring efforts. [1.25]

20b. Ensure long-term data integrity. [1.08]

8w. Monitor water balance, energy balance, and nutrient/chemical cycling. [1.00]

3w. Develop toxic contaminant budgets: identify current sources, processes, sinks, and effects of potentially toxic organics and metals. [0.92]

8b. Monitor social factors: land use, urbanization, land transfer, etc. [0.92]

14b. Assure statistical relevance through identification of data quality objectives, consistency of methods, frequency, equipment, etc. [0.83]

10w. Monitor degree, frequency, susceptibility, and recovery of trees from insect and disease problems. [0.75]

20w. Carefully develop database management system, with attention to relationships among databases. [0.75]

7w. Monitor changes in abundance, vigor, and quality of trees and herbaceous species at the established sites. [0.67]

32w. Monitor temporal and spatial ozone variability in state. [0.67]

22b. Identify and coordinate funding to encourage use of sites. [0.67]

2w. Monitor tree species composition and stand structure. [0.58]

4b. Characterize monitoring sites as to their place in the range of ecosystem types; select representative sites, and include representative management strategies. [0.58]

16b. Use photography (with ground truthing) as a monitoring tool; include remote sensing and GIS linkages. [0.58]

11b. Develop 4-dimensional matrix of pollutant exposure, sensitive species, sensitive ecosystem processes, using currently available information for first cut. [0.50]

9w. Monitor structure and function of aquatic communities. [0.42]

36w. Monitor potential sources (emitters) of airborne pollutants. [0.42]

19w. Evaluate how elevation, slope, and aspect affect pollutant deposition loading, and relate to tree response. [0.33]

21w. Incorporate state-of-the-art technologies in data evaluation and integration methods. [0.33]

25w. Monitor air flow patterns (synoptic weather) at sites. [0.33]
30w. Monitor wildlife habitat values and qualities. [0.33]

31w. Monitor plant communities for shifts in community composition over time. [0.33]

23b. Contribute to predictive mathematical modeling of ecosystem processes. [0.33]

15w. Monitor soil chemistry, organic matter percentage, and organisms. [0.25]

29w. Monitor animal species. [0.25]

47w. Identify biomonitoring plants and animals to indicate exposure to pollutants. [0.25]

17b. Identify triggering variables. [0.25]

4w. Develop thorough site histories, including past harvesting, weather events, insect and disease outbreaks, etc. [0.17]

14w. Monitor solar radiation, especially UV-B. [0.17]

22w. Monitor tree defoliation (insect, disease, weather, unexplained, etc.) annually. [0.17]

28w. Monitor native plants which serve as bioindicators of air quality of soil conditions. [0.17]

37w. Monitor changes in tree phenology. [0.17]

6b. Develop information dissemination methods: timely; identify target audiences; include public and policymakers. [0.17]

13b. Identify a practical set of monitoring variables, based on clearly identified needs. [0.17]

24w. Monitor photochemical oxidants in forest canopy and evaluate interactions with canopy foliage. [0.08]

38w. Monitor impact of monitoring activity on site. [0.08]

48w. Develop methods for information exchange and coordination with other groups. [0.08]