VERMONT AGENCY OF NATURAL RESOURCES AND UNIVERSITY OF VERMONT LONG-TERM INTEGRATED MONITORING AND RESEARCH COOPERATIVE

A proposal for a new cooperative initiative
to address long-term natural resource protection
in Vermont

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This proposal is being circulated for review and comment among interested individuals within the Vermont Agency of Natural Resources, the University of Vermont, and other groups concerned with the understanding and protection of Vermont's natural environment. Any opinions or recommendations expressed in this document are those of the authors, and do not necessarily reflect positions of the Agency or University.

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EXECUTIVE SUMMARY

The Vermont Integrated Monitoring and Research Cooperative is a developing partnership between and the Vermont Agency of Natural Resources and the University of Vermont (specifically, the School of Natural Resources and the College of Agriculture and Life Sciences). Its purpose is to monitor the condition of natural resources in Vermont's forested lands, support long-term research on the response of forest and associated aquatic ecosystems to changing environmental conditions, and communicate information about these efforts to scientists, policy-makers, and the public. This Cooperative will significantly enhance our ability in Vermont to perceive changes in ecosystem condition, to identify causal relationships between environmental stress and ecosystem condition, and to initiate timely protective or remedial actions. Recent changes in the ecological status of several indigenous Vermont species, concern about the long-term health of Vermont's forests, and projected local, regional and global changes in climate and pollutant exposures are among the factors which underscore the need for this Vermont Cooperative at this time.

Portions of routine Agency environmental monitoring activities and specialized University research activities will be coordinated in this program to take full advantage of the complementary strengths of the two organizations. This enhances the utility of individual monitoring and research efforts, increases access to federal and private sector grant monies, improves the University's ability to attract the highest caliber researchers and graduate students, and provides the Agency with timely information necessary to assure the wise management and protection of the State's natural resources.

Vermont already has in place several unique and successful programs of environmental research and monitoring, such as the extensive research on forest decline on Camel's Hump, intensive air quality monitoring and research at the Proctor Maple Research Center in Underhill, VT, and the Vermont Division of Water Quality Lake Monitoring Program, among others. What is still needed, however, is an integrated evaluation of whole-ecosystem conditions and responses to environmental change. This Cooperative provides such a coordinated, long-term, and multi-media program of biological, chemical and physical environmental monitoring. This monitoring will be conducted within a network of ecosystem research/monitoring sites throughout the State, and will provide coordinated support for long-term research on basic ecosystem processes, responses to environmental stress, and indicators of ecosystem condition.

A major initial activity of the Cooperative is the establishment of an intensive integrated monitoring and research site in the Mt. Mansfield area. This site builds upon the existing forest, climate and atmospheric monitoring and research activities at the Proctor Maple Research Center. State and University ownership of land in this area and on nearby Mt. Mansfield provides secure long-term access to a research area transecting lower elevation northern hardwood ecosystems, the undisturbed watershed of the upper Brown's River, high-elevation spruce-fir ecosystems, the summit

area of Mt. Mansfield, and the upper Ranch Brook watershed on the eastern slope of Mt. Mansfield.

In addition, a network of ecological monitoring sites is being developed in representative physiographic/ecological regions throughout Vermont. This system of extensive sites provides an early-warning system for detecting ecosystem changes, and provides data to evaluate the current and predicted status of the forest resources in the State.

Additional activities of the Cooperative include: developing a formal Memorandum of Understanding between the Agency and the University; establishing expert advisory groups, including an internal group of representatives from participating Agency and University Departments, and an external group of representatives from the US EPA, USDA Forest Service, Environment Canada, outside university groups and the private sector; developing a sophisticated integrated data management and reporting system; preparing annual state-of-the-ecosystem reports for the Governor, State Legislature, and others; and obtaining long-term funding support.

To initiate this cooperative project, a full-time position of Program Director is being created to plan, develop, and coordinate program activities. Partial support for this position is being shared jointly by the Agency and the University. Additional start-up funds (approximately $60,000) are needed for the balance of the Director's salary, office expenses, publication costs, travel, and computer expenses. These funds provide for initial program design research, implementing the data management system, and publication of initial reports. A small time commitment from key individuals in participating Agency and University Departments is also essential to the Cooperative's success. Long-term funding (approximately $125,000 per year) is being sought to support continued operations, equipment, and monitoring activities. Opportunities for external funding appear to be particularly timely given current plans for development of similar integrated monitoring/research programs by major federal agencies.

This program represents a unique cooperative effort between State government and a University, providing a model for innovative, efficient integration of scientific resources. It will provide much-needed information on the condition of our natural resources, and will put Vermont in a nationally prominent position in addressing the environmental challenges of the twenty-first century.

INTRODUCTION

Problem statement:

It is becoming increasingly clear that significant and complex changes are taking place in the physical environment around us. Regional stresses such as acid rain, toxic deposition, photochemical oxidants, increasing greenhouse gasses, decreasing stratospheric ozone and population growth may be causing significant changes in ecosystem diversity and vitality. In addition to direct effects from these changes, secondary ecological effects are likely, such as ecological compensation or cascading effects on trophic structures. Reduced genetic diversity and introduction of genetically-engineered organisms are factors which will increasingly affect ecosystems in the years ahead. Certain stresses (such as acid rain) may be reduced somewhat in the relatively near future, while others (such as climate change and stratospheric ozone depletion) are certain to worsen over the next century.

It is also obvious that the long-term health of Vermont's natural ecosystems is fundamental to the welfare and well-being of all of the State's citizens. Yet those of us charged with the responsibility for the evaluation or protection of the State's natural resources have limited information on the current health of these diverse ecosystems, and our ability to detect and address long-term change in ecosystem condition is minimal. We currently 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.

Ecosystem complexity:

The ecosystem concept is an inherently complex one, as physical, chemical and biological ecosystem structures and processes are naturally integrated and continually interact with each other. Consideration of pollution stress further complicates understanding ecosystem processes, as pollutants continually interact with each other and with various ecosystem structures and processes. Thus, while effects of individual pollutants on individual plant or animal species are poorly understood, even less is known about effects of multiple stresses in natural ecosystems. An instructive example of this complexity is seen with red spruce, which is currently declining in certain high elevation Vermont forests. Some researchers have suggested that climate change may be a causal factor, while others believe that atmospheric deposition - which increases significantly with increasing elevation - is the primary cause of decline. But other potential causal or contributing stresses also increase significantly with increasing elevation. These include: UV-B radiation (which will continue to increase over time with reductions in stratospheric ozone); deposition of toxic metals (which can become increasingly soluble and available to plants as soils become acidified); concentrations of phytotoxic oxidants like tropospheric ozone and hydrogen peroxide (which are likely to increase as a result of increasing global temperatures and UV-B radiation, and which may

contribute, in turn, to increased formation of acids in precipitation and to further increases in global temperature). A variety of natural climatic stresses also increase with elevation, adding further difficulty to the process of identifying effects of individual pollutants or pollutant combinations. It is therefore not surprising that little is known about multiple pollutant effects on red spruce and other integral components of Vermont's high elevation forest ecosystems. Furthermore, little research has addressed interactions between ecosystem components, such as between terrestrial and aquatic processes. Certain pollutants, for example, are efficiently captured by high elevation forest systems, and may in turn be selectively processed and transferred to contaminate ground and surface waters. Here they may eventually accumulate in downstream sediments and/or become more concentrated in food chains of aquatic ecosystems, ultimately affecting the health of predatory fish, wildlife and human consumers.

Interactions between natural and pollution-related stresses complicate understanding ecosystem processes. For example, acid deposition and increasing UV-B radiation may act separately or in combination to reduce algal growth in certain Vermont surface waters. This may increase water clarity, allow deeper penetration of sunlight, and lead to changes in a lake's thermal characteristics and/or to increased growth of rooted aquatic plants. These changes may lead, in turn, to mobilization of toxic metals or organics from recently deposited lake sediments, and to an increased accumulation of these toxic pollutants in the aquatic food chain. In forest ecosystems, ozone exposure may reduce photosynthetic rates, deplete starch reserves, increase sensitivity of certain plants to frost damage, or increase susceptibility to insect or disease stresses. In other cases, natural moisture stress may decrease plant sensitivity to ozone and other gaseous pollutants, but increase the potential for damage from natural or pollution-induced nutrient deficiencies. Tree dieack creates openings in the forest canopy which increase exposures to natural climatic stresses. Thus, pollution stress may also cause damage by inducing additional natural stresses.

Environmental management and regulation:

Development and implementation of effective protective or remedial measures to address perceived effects of pollution stress is not always a straightforward process. First, it must be verified that some ecosystem component has changed. In some cases, we lack sufficient baseline information to define "natural" ecosystem conditions, and can only speculate on whether current conditions somehow differ from a natural state. Once this change has been perceived, it may be judged as adverse, benign or beneficial. When an adverse effect has been perceived, causal and contributing factors must be clearly identified (as indicated earlier, this is not necessarily the easiest of tasks). A next logical step is the development of strategies to control the primary stressor(s) or to otherwise remediate the adverse effect. Again, this can be an extremely difficult process, for which detailed advance knowledge of pollutant, ecosystem, and pollutant-ecosystem interactions is desirable.

An instructive example of the problems in this process can be seen in the recent proposal to lime Vermont's forests as a solution to the perceived adverse effects of acid rain on our forest

ecosystems. It is not clear, however, that the majority of the State's forests are in unnaturally poor health. For those locations where adverse forest conditions have been documented, it has not been clearly established that acid rain is a causal or contributing factor. Even if we were certain that acid rain was clearly causing adverse effects to the State's forests, it does not necessarily follow that liming would be an appropriate or effective solution. Costs would be exorbitant, and the long-term effects of indiscriminate lime applications are unknown. Sugar makers who attempt to treat their declining maple stands with lime may find that the physical damage to sensitive maple tree roots during the application process causes adverse effects which more than offset any benefit derived from the effort. Liming has also frequently been proposed as a solution to perceived adverse effects of acid rain on Vermont's critically acidified surface waters. In this case, adverse effects have been clearly documented, and causal relationships identified. Still, liming is not necessarily a practical or desirable treatment. Certain of Vermont's critically acidified lakes are predominantly influenced by naturally occurring organic acids. Liming these naturally acidic lakes would disrupt their natural condition and may well result in the irreplaceable loss of rare plant and animal species. Liming lakes acidified by human activities may also result in adverse side effects such as increases in concentrations of toxic metals or phosphorus, due to biological responses to the sudden change in water chemistry.

Control strategies to reduce concentrations and effects of different pollutants are not always mutually compatible. Reductions in SO_x emissions without carefully considered reductions in NO_x and Volatile Organic Compounds (VOCs) may not result in the desired reductions in sulfate deposition, and could result in increased concentrations of photochemical oxidants. Alternative reductions in either NO_x or VOC emissions may decrease oxidant concentrations in some locations, but increase these concentrations at other locations. Certain control technologies for SO_x and NO_x create solid waste disposal problems, and may also result in increased emissions of CO_2 and other greenhouse gasses. Landfill disposal of municipal and industrial wastes may eventually contaminate groundwater supplies, while incineration of these may increase air pollution and produce ash more toxic than the original waste.

It is not appropriate to take a position that all pollution is harmful to the environment and must be eliminated. This is simply unrealistic. Moreover, the correct control decisions are neither obvious nor without associated economic costs. The environmental costs of prolonged indecision, or of making the wrong decisions, may be profound and irreversible. If we are to seriously protect the long-term health of our natural environment, we require more detailed knowledge of the current health status of Vermont's varied natural ecosystems, an efficient means to quickly and accurately perceive ecosystem changes over time, and a more comprehensive understanding of the internal processes and external stresses which influence ecosystem condition.

Recommendation:

Meeting these objectives will require a combination of long-term monitoring in multiple environmental media, and shorter-term applied research focusing on specific ecosystem processes

and stress mechanisms. This can be accomplished most efficiently through an integrated monitoring and research approach, and should include establishment of a formal mechanism for cooperation and coordination between the Vermont Agency of Natural Resources and the University of Vermont. This kind of cooperative effort would take advantage of the complementary strengths of the two organizations (Agency monitoring and University research), and would build upon the informal relationships which have already been established between various Agency and University departments. This would create special opportunities for timely information exchange, initiation of research and ameliorative programs, and would improve access of both organizations to federal and private sector funding support.

For numerous reasons this is an advantageous time for a Vermont effort of this nature. The International Joint Commission is currently developing recommendations for enhancement of integrated monitoring activities in the U.S.-Canada boundary region. Several federal and provincial agencies in Canada are now establishing integrated monitoring networks. The US EPA and USDA Forest Service are both in the process of establishing long term ecosystem monitoring and research programs. Congress has recently passed the Forest Ecosystems and Atmospheric Pollution Research Act of 1988 "to provide for (long-term) study and research on the decline in United States forest productivity and to determine the effects of atmospheric pollutants on forest environments." The US Senate is currently considering legislation which would provide funding support for a long-term study of ecosystem response to changing physical and chemical climatic conditions. If Vermont were to demonstrate initiative in this area, the State would be in an ideal position to take full advantage of these developing national and international programs.

WORK PLAN

Objectives:

The primary goal of the Vermont Integrated Monitoring and Research Cooperative is to provide reliable information about the status and trends of natural resources in Vermont for scientists, environmental policy-makers and planners, and the public, and to create a multi-disciplinary infrastructure to support long-term integrated ecosystem research in Vermont. The Cooperative utilizes the expertise of the Agency of Natural Resources and the University of Vermont in a coordinated manner to address several broad objectives:

(1) Conduct long-term integrated biological, chemical and physical monitoring to characterize conditions and changes in natural ecosystems in Vermont, with special emphasis on forested lands and associated aquatic systems.

(2) Provide environmental monitoring data to support research on basic ecosystem processes and responses to environmental change.

(3) Promote a more effective integration of regional monitoring and research resources.

(4) Provide information, technical expertise and recommendations in a timely fashion to the custodians and users of the State's natural resources.

Scope:

This program addresses these objectives for all forested ecosystems in the State. This refers to managed and unmanaged forest lands, and their associated streams and ponds, but tends to exclude larger rivers and lakes. There are several reasons for this limitation. First, there already exist well established monitoring programs for Vermont rivers and lakes, with excellent coordination between the Agency and University. Furthermore, new programs, such as the Vermont-New York-Quebec Joint Management Plan for Lake Champlain, will be focusing new efforts on these large aquatic ecosystems. Finally, for pragmatic reasons, it is not possible to adequately address the pressing monitoring and research needs of forested ecosystems and these large aquatic ecosystems. On the other hand, to the extent that all aquatic ecosystems receive inputs from both the atmosphere and upstream forested lands, some of the monitoring and research activities of the Cooperative will interact with the river and lake programs. Thus, the Cooperative will provide valuable monitoring data to these programs, and will engage in an ongoing, coordinated program of information and technology exchange.

The most unique feature of this Cooperative is the development of an integrated ecosystem monitoring program. This will encompass both biological monitoring (ecosystem "health", community productivity and composition, organism physiology, and other parameters related to the biotic environment) and environmental monitoring (air quality, precipitation, soil and water chemistry, climate, and other parameters related to the physical and chemical environment). These monitoring activities will be actively coordinated and inter-related to promote a more complete multi-media understanding of whole-ecosystem conditions and responses, in contrast to the perspective from single-medium measurements unrelated to other components of the ecosystem. This monitoring program will, in turn, provide coordinated support for research on basic ecosystem processes, ecosystem response to environmental stress, and identification of sensitive indicators of ecosystem condition.

Another important feature of this Cooperative is that it provides a context for linking Objectives 1 and 4 above (characterizing ecosystem conditions and providing recommendations for achieving desired endpoints). The process of linking ecosystem condition with socially-valued endpoints (such as productive sugarbushes, ample high-quality groundwater, healthy sportfish, etc.) requires development and distribution of summary information for scientists, planners, policy-makers, and the public. It is a high priority of this Cooperative to actively pursue this important process through interpretative reports and publications aimed at these clients.

Long-term ecosystem monitoring and research provides a number of important benefits, including providing useful data for resource use and planning, reducing the lag-time for response to perceived environmental problems, stimulating high-quality scientific research, and promoting the wise use of natural resources. This Cooperative is conceived, therefore, as a permanent addition to the environmental management responsibilities of the Agency of Natural Resources and the University of Vermont.

Tasks:

The specific tasks for implementing the Vermont Integrated Monitoring and Research Cooperative include the following:

1. Execute a Memorandum of Understanding between the Agency and University.

The purpose of the MOU is to formalize the intent of the two parties to cooperate to bring about the objectives of the Cooperative, to provide joint long-term support for a Director, and to formalize the organizational structure of the Cooperative. Administrative responsibility for the Cooperative will be vested in a small joint Agency/University management group.

This MOU will be implemented early in 1990.

2. Support a full-time Director for the Cooperative.

Significant progress toward the goals of the Cooperative could be made with minor redirection of existing Agency and University activities, provided a minimum of one full-time position is created to coordinate these activities and facilitate development of external funding sources. Thus, initiation of this program under the most limiting financial constraints requires hiring a Director. The Director's responsibilities will be to coordinate, manage, and focus the activities of the Cooperative, including identifying research and monitoring needs, implementing research and monitoring programs, preparing reports, applying for grants, chairing the local Expert Advisory Group, and having overall responsibility for program progress. Partial support for this position is being shared jointly by the Agency and the University. Additional start-up funds (approximately $60,000) are needed for the balance of the Director's salary, office expenses, publication costs, travel, and computer expenses. These funds provide for initial program design research, implementing the data management system, and publication of initial reports. A small time commitment from key individuals in participating Agency and University Departments is also essential. Additional support will provide for the necessary implementation, equipment, and long-term operations of the Cooperative's programs, and will be sought from a combination of Federal, State, Agency, University and private sector funding (see Task 7).

The Director will be hired as of September, 1989, a draft Procedure Plan prepared by April, 1990, and a final Procedure Plan submitted to the Management Group by July, 1990.

3. Establish Expert Advisory Groups.

A local group of experts will meet regularly to provide technical guidance and assist in planning, and will consist of personnel from the Agency (Water Resources, Air Pollution Control, and Forestry) and University (VT Water Resources Research Center, School of Natural Resources, Botany, and Biometry). Other personnel (regional monitoring or research program directors, industry representatives, government staff, etc.) will be brought in as needed.

An external group of experts will also be established, including members of government agencies such as the US EPA, USDA Forest Service, Environment Canada, other universities, and industry. These people will be chosen for their broad scientific view and political involvement in national environmental research programs. This group will not meet together on a regular basis, but will serve to provide guidance and integration on matters related to regional, national and international environmental monitoring and research programs.

The first meeting of the Expert Advisory Group will occur in January 1990.

4. Establish integrated monitoring/research sites.

A permanent site in the Underhill - Mt. Mansfield area will be established to conduct integrated ecological monitoring and research along east-west and elevational gradients. This site will support comprehensive air quality and climatic monitoring at the Proctor Maple Research Center, the summit of Mt. Mansfield, and the base of the eastern Ranch Brook watershed. Biological monitoring in the terrestrial and aquatic components of ecosystems along elevational transects will be carried out in this area. In addition, a number of mini-meteorological stations will be set up along elevational transects on the west and east slopes, and the Brown's River watershed will be gauged and instrumented for monitoring water quality and aquatic organisms. This site will be an intensive monitoring/research site, where a large array of both environmental and biological variables will be monitored, and coordinated long-term ecosystem research projects will be carried out. The functional goal of this type of site is to establish linkages between the biotic and abiotic components of the ecosystem. Field experience and research opportunities for students and interns will also be provided here.

A second integrated site will be developed as funds permit in southern Vermont. This will include a lower elevation forested ecosystem representative of a different physiographic/ecological region, and will include a secure undisturbed watershed where long-term monitoring and research can be conducted.

Environmental monitoring in these intensive integrated sites will include measurement and evaluation of all major ecosystem inputs including ozone, nitrogen oxides and nitric acid vapor, hydrogen peroxide, PAN, speciated hydrocarbons, size-fractionated aerosol elemental analysis, wet deposition amount and chemistry, cloud liquid water content, temperature, wind direction and speed, relative humidity, etc. Dissolved-phase ecosystem outputs (stream-water volume and chemistry) will also be measured to evaluate the status of ecosystem nutrient budgets and weathering. Biological monitoring will be conducted in and around permanent study plots (0.05 ha rectangular and point) in hardwood, conifer, and stream systems. Probable measurements will include productivity, reproductive capacity and regeneration, community structure, growth and yield, insect/pathogen status, foliage duration and condition, foliar chemistry, and soil chemistry. In addition, pilot programs will be developed and tested here for monitoring toxic pollutant deposition, the survival and effects of genetically engineered organisms, and new environmental or biological parameters of interest. Ecological research at these sites will include long-term research on ecosystem processes, identification of sensitive life-stages and other responsive ecosystem parameters, and reduction of uncertainty in the reliability of these parameters as markers of ecosystem condition.

Implementation of the Mt. Mansfield site will begin in 1990 with the establishment of forest monitoring plots, with the goal of being fully operational by the fall of 1991 when environmental monitoring equipment in high elevation areas will be in place. Support for additional equipment and long-term operation ($150,000 initially, $50,000 annually) will be sought through grant proposals

prepared in 1990. Grant proposals to support the second site will be developed in 1991, with the goal of beginning to implement the site by 1992.

5. Develop a regional long-term monitoring/research network.

A network of monitoring sites will be developed with appropriate spatial and physiographic resolution to provide a State-wide assessment of ecosystem conditions. This network will provide an early-warning system for detecting ecosystem changes, and will provide data to evaluate the current and predicted status of the natural resources of the State. This network will be implemented in several stages, with Phase I being the identification and utilization of existing monitoring programs and data, and publication of annual data and program reports. Procedures will be developed for utilizing remote sensing data with field data from this network, and a combined Geographic Information System (GIS) and Data Exploration System will be developed to compile and integrate existing and new databases. Phase II will establish a network of new sites at which identified ecosystem variables will be monitored and ongoing research related to the goals of the program will be conducted. Issues to be resolved for Phase II include identifying key physiographic regions and possible sites within them, implementing a statistical sampling framework, selecting and updating appropriate variables to monitor for climate and ecosystem condition, and ensuring long-term site security. Efforts will be made to establish long-term research covenants for private lands where necessary.

This extensive network of sites will be designed primarily to characterize ecosystem condition and to provide a regional early warning system. Some of these sites will be probability samples from a larger population distribution, while others will utilize sites already supporting certain monitoring activities. Together they will provide representative data for the major physiographic and ecological regions in the State. There will be a large number of sites (15-20, or more if separate forest and aquatic sites are identified), and they will involve less detailed measurements than the integrated intensive sites. At the network sites mainly biological monitoring will be conducted, along with basic climatic data. Because of the difficulty of selecting useful and enduring ecological variables to monitor, this network will tend to utilize relatively simple, inexpensive and proven measurements, and will be adaptable to new developments in this field. Types of measurements in these sites will include annual surveys of insect populations, foliage condition and duration, crown condition, understory vegetation and regeneration, surface water chemistry, and less frequent surveys for radial and height tree growth, soil and foliar chemistry, aquatic bioassays, and detailed surface and ground water chemistry.

Phase I, summarizing existing research and monitoring activities, will be accomplished by September, 1990. Phase II, implementing the network of sites will begin in 1991, with the goal of being operational in 1992. Much of the routine network monitoring will be conducted through existing ecosystem monitoring programs in the Agency and University, requiring only coordinated redirection of portions of these programs into the sites.

6. Implement an integrated data management program.

This is a critical component of the Cooperative, providing a central mechanism for coordinating the monitoring and research results, and for providing information to users. The first task of this program will be to identify existing monitoring and research activities operating in the State, and to incorporate an inventory of these programs into an integrated central database. In addition, all future monitoring and research data will be incorporated into this database. Through this program, program integration and data exchange will be coordinated with other regional monitoring and research programs, as well as with federal programs such as the US EPA EMAP and USDA Forest Service FAI-PRP. The centerpiece of this system will be a state-of-the-science computerized expert system linking the Vermont ecosystem database, a regional GIS, and/or the new Voyager data exploration software. On-line data extraction capabilities will be available, seasonal data summaries will be maintained on-line, and annual data summaries will be published.

The first Annual Data Summary will be published in December, 1990.

7. Prepare annual reports to the Governor and State Legislature.

Annual reports reviewing the Cooperative's activities and summarizing monitoring and research results will be prepared and presented to the Governor and to the Natural Resources Committees of the State Senate and House of Representatives. In addition, State-of-Science Reports will be prepared every two years. These reports will synthesize past monitoring and research results to provide the best available information on the current state of Vermont ecosystems and recommendations of key directions for future research. More frequent briefings will occur in the event of particularly significant monitoring or research results, opportunities to secure outside funding support, etc. Continual communication with, and feedback from, the Executive and Legislative branches of State Government will be essential to the effective long-term operation of the Cooperative, and will keep State Law-makers and the public appraised of the status of Vermont's natural ecosystems under changing environmental conditions.

In addition, scientific research publications will be prepared by scientists working in the Cooperative, presenting new research findings and also describing new initiatives in integrated monitoring/research efforts which have come out of this program.

The first annual Report will be submitted in September, 1990, and the initial State-of-Science Report in January, 1991.

8. Initiate long-term funding and personnel exchange programs.

External funds will be sought to support the continued development and long-term operation of the intensive integrated sites, the extensive network of sites, and other activities of the Cooperative. The unique collaborative nature of this Cooperative will permit access to external funding sources which have not previously been available to either the Agency or the University acting alone. The planned commitment to long-term ecosystem monitoring and research efforts by several federal agencies (USDA Forest Service, US EPA) provides a most timely opportunity for Vermont to attract funding and expert technical support, provided the State and University can demonstrate some initiative in this area. At this time, the most likely sources for funding include the National Science Foundation and new initiatives for long-term ecosystem monitoring from the USDA Forest Service and US EPA. It is also anticipated that certain private industries will be interested in providing technical or financial support to an effort of this nature. The objective of using the best possible scientific information in making environmental management and regulatory decisions is generally well supported by both industry and environmental groups. Vermont industry clearly benefits from the current high quality of the State's natural environment, and may have a vested interest in assuring that this quality is maintained or enhanced.

By its nature, the Cooperative will provide more ready exchange of expert information between the Agency and University, and also between in-State and out-of-State groups with similar interests. A number of opportunities for personnel exchange will be pursued, including student internships and visiting research sabbaticals within the Agency, visiting lecturers at the University, team-taught courses in environmental management or related subjects at the University, and a joint Agency/University seminar program.

The first grant proposals will be submitted in 1990 for implementation and long-term support of the Mt. Mansfield integrated site. Proposals to support the second integrated site will be initiated in 1991. Proposals for long-term support for data management and for maintenance of the network sites will also be sought in 1991. The joint seminar program will begin in the spring of 1990. The first placement of a student intern in the Agency will take place in the fall of 1990.

AGENCY PERSPECTIVE

Mission and responsibilities:

Recent passage of Vermont's Act 200 (Growth Bill) requires that "the quality of air, water, wildlife and land resources shall be maintained or enhanced." Vermont's Act 250 (Land Use Planning and Development Law) requires comprehensive review of projects by the Agency of Natural Resources to assure that proposed development will not adversely affect air or water quality, wildlife habitat, endangered species, agricultural or forest soils, or scenic resources. Furthermore, the statutory creation of the Agency of Natural Resources conveys responsibility to the Agency for the "proper development, management and preservation of Vermont's natural resources." The Agency's mission is premised on a stated philosophy that "the State's natural resources - plants animals, soils, minerals, air and water - are functioning parts of complex and delicate natural systems" and that "for the benefit of this and future generations, the integrity, diversity and vitality of Vermont's natural systems must be sustained and enhanced."

Thus, the Agency has both a legislative mandate and a philosophical mission to protect or even enhance the condition of the State's natural ecosystems. In practice, however, it is virtually impossible for the Agency to operate with a long-term, multidisciplinary view of the State's natural environment. A large measure of Agency funds and personnel resources are necessarily directed in response to relatively immediate threats to the short-term quality of one-dimensional environmental media (engineering, review, permitting, inspection, compliance, enforcement of air and water standards and regulations, response to emergency contamination, fish kills, outbreaks of forest insects, disease, aquatic weeds, etc.). Monitoring within separate Departments and Divisions is usually conducted within strictly defined disciplinary boundaries, limited to the media (air, water, forest, soil, etc.) of each Division's jurisdictional responsibility. Furthermore, monitoring is frequently constrained by specific regulatory requirements and associated non- discretionary funding. Consequently, aquatic chemistry and biology are measured at one set of locations; wet deposition, air quality and meteorology are measured at other sites; forest tree health, soil chemistry, wildlife and fish populations are monitored at other sets of locations; while intensive University research of specific ecosystem processes and stress mechanisms is conducted at yet other sites.

The Agency, therefore, has very limited ability to integrate this information to provide meaningful process-level models of ecosystem function and response to natural and manmade stresses. Without this integrated understanding of ecosystem response to stressors, it is difficult to design or implement ameliorative programs. This is not a result of poor Agency planning, but rather, a consequence of the separate funding and regulatory structures under which the separate Agency Departments and Divisions have been created. In addition, the increasing involvement of the public in environmental management and protection issues demands an increasing Agency focus on local backyard issues of most immediate public concern. Scarce monitoring resources are

increasingly directed toward quantification of perceived short-term changes in environmental conditions, while long-term monitoring efforts to detect trends over space and time are neglected.

Given these constraints, the Agency's responsibilities to protect and enhance the quality of the State's natural ecosystems must be carried out with limited understanding of the complex biogeochemical processes and multimedia environmental stresses which influence ecosystem condition. Increasingly, the Agency is forced to make difficult management and regulatory decisions with little advance information about the full consequences of these decisions. How, for example, can the Agency Forester advise the concerned landowner whose sugarbush is declining for unknown reasons? Should he thin his stand, spray for pear thrips, apply lime or fertilizer, or reduce tapping for a year or two? Or perhaps the stand will die anyway, and he should cut his losses by tapping as heavily as possible and/or harvesting the trees while they still have some value as saw logs or firewood. How does an Agency Air Pollution Control official evaluate the relative environmental merit of a proposed new local source (or a proposed National emission control program) which will achieve state-of-the-art reductions of sulfur or nitrogen oxides using control technology that will increase emissions of ammonia, toxic metals or CO_2?

This is not to suggest that the Agency's short-term, single-media monitoring, management and regulatory activities are unimportant or should be curtailed. But it is important to recognize that the Agency also has a broader responsibility to preserve and enhance the long-term health of the State's natural environment, a responsibility which is not currently receiving adequate attention.

Needs:

Although the Agency is reasonably well equipped to conduct routine monitoring activities, it lacks the financial resources and personnel to carry out long-term integrated environmental monitoring, or to support specialized research on ecosystem impacts. Individual Agency monitoring efforts need to be better coordinated, and long-term funding commitments need to be secured, in order to provide a comprehensive long-term record of multiple pollutant exposures, natural stresses, and ecosystem condition. Applied research is also needed to provide a better understanding of the manner in which complex ecosystem structures and processes respond to changing natural and pollution-related stresses. Thus, the Agency would benefit greatly if specialized University research activities could be encouraged in specific multidisciplinary subject areas or at specific multi-media monitoring sites where long-term Agency monitoring activities are focused. The resultant integrated Agency/University sites will become "centers of excellence" in environmental monitoring and research (much like the Hubbard Brook Experimental Forest). This program will attract the highest caliber environmental scientists to the State, increase access to financial support from outside funding sources, and create unique opportunities for development and exchange of information vital to the wise management and protection of the State's natural resources under what are virtually guaranteed to be increasingly unfavorable future climatic conditions.

Resources:

The Agency is in a particularly good position to benefit from a cooperative effort of this nature at this time. Because of its relatively small size and strong central leadership in recent years, there is already a degree of inter-department and inter-division coordination which exceeds that of most other states. Excellent informal relationships also exist between Agency Divisions of Forestry, Water Quality, Air Quality, Fisheries Management and Wildlife Management and their University of Vermont counterparts in the School of Natural Resources, College of Agriculture and Life Sciences, Water Resources Research Center, and Environmental Program. Agency Divisions have also established exceptionally good working relationships with their counterparts in various federal agencies, and are currently involved in cooperative projects with the USDA Forest Service, U.S. Fish and Wildlife Service, U.S. Environmental Protection Agency, National Park Service, and National Acid Precipitation Assessment Program. The Agency is also actively involved with a variety of regional and international organizations such as the New England Interstate Water Pollution Control Commission, Northeast States for Coordinated Air Use Management, Environment Committee and Forest Productivity Work Group of the New England Governors and Eastern Canadian Premiers Conference, International Air Quality Board and International Joint Commission.

Opportunities and benefits:

If a small portion of current and planned Agency monitoring activities could be coordinated at a few common sites and sustained over a prolonged period of time, the value of measurements in separate environmental media would be greatly enhanced. Measurements of meteorology and deposition chemistry could add considerably to our understanding of measured changes in surface water chemistry. Surface water chemistry measurements in a calibrated watershed can contribute to a better understanding of wet and dry deposition rates and of selective retention, processing and release of pollutants by the ecosystem. Air quality and climatological measurements can promote a better understanding of measured changes in forest health, and so on. An additional benefit of long-term integrated monitoring and research is that the whole exceeds the sum of the parts. This benefit is difficult to quantify in advance, but it characterizes similar efforts at sites like Hubbard Brook, New Hampshire and Kejimkujik, Nova Scotia. Comparisons of long-term trends in presumably unrelated variables often reveal unexpected spatial and temporal patterns which promote a new understanding of causal relationships. A second intangible benefit derives from the cross-fertilization of ideas that inevitably results when scientists from different disciplines are drawn together at a common site. From a financial perspective, as additional variables are measured at common sites, additional opportunities are created to secure supplemental funding support from various federal and private organizations.

The US EPA is in the process of implementing a long-term "Environmental Monitoring and Assessment Program" (EMAP) and a related program for the "Temporally Integrated Monitoring of Ecosystems" (TIME). The USDA Forest Service has recently initiated the Forest - Atmosphere

Interaction Priority Research Program "to determine how anticipated changes in the earth's atmosphere and climate will affect forest and related ecosystems worldwide." The International Joint Commission is currently developing recommendations for long-term integrated monitoring activities in the US-Canada boundary region. The recent New York-Vermont-Quebec Memorandum Of Understanding on Environmental Cooperation on Management of Lake Champlain and the pending designation of a Lake Champlain-Adirondack Biosphere Reserve under the UNESCO "Man and the Biosphere" program should both encourage additional monitoring and research coordination within Vermont, as well as within the region.

A Vermont Integrated Monitoring and Research Cooperative will be particularly timely in light of these developing regional, national and international programs. A small Vermont investment could result in significant future coordination with, and funding support from, these developing programs.

UNIVERSITY PERSPECTIVE

Mission and responsibilities:

The University of Vermont has a mission to engage in education, research and public service. One of the many goals of the University with respect to this mission is to provide a framework for understanding and protecting the natural environment. This is becoming an increasingly important objective for many reasons, particularly because of the increasing pressure on natural resources in the region from air pollution, global climate change and land development.

The University has a unique set of resources which aid it in realizing this objective. This includes educators, scientists, existing research programs, research and natural areas, the Extension Service, access to certain funding sources, and a reputation for academic and research excellence. Recognizing its obligation to work for understanding and protecting the natural environment, the University should use its resources fully to promote long-term ecosystem research within Vermont, as well as within wider regions. This could best be accomplished by developing an integrated cooperative program which combines the unique resources of the University and the Agency of Natural Resources to facilitate long-term environmental monitoring and research. For many reasons the University of Vermont is in a unique position to enter into a cooperative effort such as this. Among these are the University's geographic location, its excellent reputation for environmental research, and its existing involvement in cooperative research efforts.

Needs:

There is currently little integrated forest-oriented atmospheric monitoring in Vermont, yet this type of information is sorely needed by research scientists, policy makers, and planners. Process-level ecosystem research at the University is currently limited by this lack of monitoring data, as it is often too expensive and/or difficult for a small ecosystem research project both to conduct research and to monitor the environment. Furthermore, out-of-State integrated monitoring programs (such as Whiteface Mtn. or Hubbard Brook Experimental Forest) do not provide data characteristic of the Vermont chemical, climatic, geologic, or ecological environment. Ironically, as these integrated sites have grown and (limited) funds have been directed at their enhancement, it has become more difficult for Vermont researchers to obtain certain types of research funding. Yet there is a recognized need for environmental monitoring data here, partly because of Vermont's important location (witness the locating of the EPRI OEN and EPA Acid Modes programs in Underhill, VT). Furthermore, data from these out-of-State sites is of little direct value to local ecosystem problems, due to considerable site-specific variability. Consequently, local integrated ecosystem monitoring will be a great asset to environmental research in Vermont.

Resources:

The physiographic features of northwestern Vermont make this an important area for conducting long-term integrated ecosystem research. This region, as well as much of New England, is already known to be subject to the long-range transport of air pollutants. It is likely that regional deposition of known and as yet unknown pollutants and toxic substances from both long-range and local sources will increase in the future. This region encompasses a wide range of ecosystem types, from the islands of Lake Champlain to the alpine tundra of Mt. Mansfield, occurring within a 40 km distance and 1300 m elevation. It appears highly probable that the Lake Champlain Basin will be designated a UNESCO Global Biosphere Reserve. This pending designation underscores the unique nature and ecological importance of this region, and is likely to encourage an increased focus on environmental research in the basin and surrounding mountain areas. Finally, the key elements for integrated ecosystem monitoring occur here, relatively close to the University. These include protected research forests and natural areas at high and low elevations, undisturbed watersheds, Lake Champlain, and already existing research and monitoring programs.

The University has access to a number of tangible resources such as research facilities and natural lands which provide unique assets for establishing a cooperative research/monitoring program. The Proctor Maple Research Center (PMRC), in Underhill, VT, is a 50 ha research forest and sugarbush owned by the University and operated by the Department of Botany. This is a particularly good site for field research, as it is convenient to the University (30 km), relatively remote from urban pollution sources, and thoroughly characterized as to climate, agricultural practices, and atmospheric deposition. A new state-of-the-art laboratory building is being developed at the site, providing laboratory space and all necessary support equipment for integrated field research. This site has recently been recommended for federal support by a Select Congressional Feasibility Committee established to evaluate the research/monitoring value of the site. Reasons for this favorable report include existence of sophisticated multi-agency monitoring and research programs already in place there, (including programs operated by the Agency of Natural Resources) and the site's uniquely important location. It is envisioned that the PMRC will form the cornerstone of an intensive integrated monitoring/research site. The University also owns the Mt. Mansfield summit area, recently designated a National Natural Landmark. In addition to its qualities as a prized natural area, the summit provides unique and important atmospheric research and monitoring opportunities. Between University and Vermont State land ownership, there is nearly unbroken control of lands between the PMRC and the eastern slopes of Mt. Mansfield in the Ranch Brook watershed.

The University also has conducted ecological research and monitoring for over 20 years in the Camel's Hump Research Area, a portion of Camel's Hump State Park. The database on ecological processes from this site is unparalleled, and represents an invaluable University resource. Other important University assets include the Jericho Research Forest, the Manchester Research Forest, Concord Woods Natural Area, and numerous other large and small protected natural areas throughout Vermont. In addition, other notable assets include a state-of-the-art Geographic

Information Systems (GIS) facility in the School of Natural Resources (funded by the State and using State-approved software), the MV Melosira, a 14 m research vessel on Lake Champlain, and the University's research laboratories and facilities themselves.

The University is well known for its active environmental research programs. In forest ecosystem research, for example, national reputations exist for the Camel's Hump Research Program (investigating causes and consequences of forest decline) and the Forest Entomology Program (investigating forest pest ecology). Furthermore, there are currently over 14 forest-ecosystem-related research projects underway in several departments at the University, operating with approximately 1.1 million dollars in annual grant monies. Several of these research projects operate with formal or informal cooperation with Agency of Natural Resources Departments. In addition, the University houses the Vermont Water Resources Research Center, a State-Federal program which conducts research, disseminates information, and implements water research programs of the U.S. Dept. of Interior and the State of Vermont. The Center actively supports interdisciplinary water resources research and monitoring in a variety of ecosystems, utilizing the expertise of personnel from both the University and the State. The University also collaborates closely with the USDA Forest Service Northeast Forest Experiment Station through formal contracts and informal research cooperation. This has proven to be a particularly beneficial relationship, resulting in a cooperative program on tree stress physiology between the Departments of Botany and Forestry and the USDA Forest Service. The Department of Botany is also home to the innovative Field Naturalist Program, a Masters Degree program providing multi-disciplinary field training in environmental science. This program will directly benefit from, and provide limited support to, the integrated ecosystem research and monitoring of the Cooperative. Finally, the University Extension Service provides ongoing programs of education and technical information exchange between the research community and the custodians and users of natural resources in Vermont. The Service has identified "improving environmental quality" and "increasing forest profitability" as two of its high-priority issues for the next four years. Thus, the Extension Service has vested interest in environmental research and monitoring, and is in a position to serve as a valuable asset to the Cooperative in the area of information dissemination.

In order for the Cooperative to be maximally effective and efficient, coordination with research efforts outside of Vermont will be necessary. A good start in this area already exists, as the University is already involved in a number of successful cooperative research or monitoring programs. For example, cooperative pollutant deposition and air quality monitoring is being carried out at the Proctor Maple Research Center. This site supports intensive atmospheric chemistry monitoring conducted by NADP, EPRI, US EPA, and UAPSP. In addition, a cooperative project between the Vermont Air Pollution Control Division and the University of Rhode Island School of Oceanography has developed a valuable multi-year database on atmospheric deposition at the site. The site has been recently instrumented with co-located monitoring equipment from the EPRI OEN and EPA Acid Modes networks, providing comprehensive air quality, dry deposition, and meteorological data. The continuation of this high-quality monitoring will be assured through the Cooperative. For several years the University has also cooperated with NASA and the Jet

Propulsion Laboratory in remote sensing of forest decline, and this work is continuing through cooperation with the EOS Institute in Durham, NH. Discussions about cooperative monitoring and research efforts are currently underway with representatives of the Hubbard Brook Experimental Forest, the Institute of Ecosystem Studies, Dartmouth College Dept. of Environmental Studies, Cornell Dept. of Natural Resources, Yale School of Forestry, Massachusetts Dept. of Environmental Management, Atmospheric Sciences Research Center at Whiteface Mtn. (SUNY-Albany), the US Geological Service, the US Corps of Engineers, and the Canadian Forest Service. These contacts, their willingness to work with us in this effort, and this regional concentration of research activity represent key strengths of the Cooperative.

Opportunities and benefits:

Through the Cooperative, new opportunities for funding research and monitoring programs will arise. Many granting agencies view favorably innovative cooperative efforts between private and government institutions. For example, both the National Science Foundation and the US Environmental Protection Agency provide support for innovative interdisciplinary Research Centers, through programs which will be appropriate for the Cooperative. Furthermore, an integrated, multi-disciplinary research/monitoring program will allow increased research efficiency and will attract additional research activities. Examples of this process have been seen in the Camel's Hump research programs, the Hubbard Brook Experimental Forest, and the Atmospheric Sciences Research Center at Whiteface Mountain.

The Cooperative will also provide new educational opportunities and programs of information and technology exchange. Student internships in the Agency of Natural Resources will be offered through easily implemented short-term contracts, providing summer or semester work experiences. Hands-on field experience in environmental monitoring and research will also be available through the involvement of University personnel in the Cooperative. A seminar program utilizing University, Agency and outside professionals will provide additional information exchange among the participants in the Cooperative. Finally, professional educational opportunities such as sabbaticals could be arranged for personnel to spend time working within the Agency of Natural Resources or teaching at the University.

Through the Cooperative the University will achieve a national reputation as a center of excellence in ecological and natural resource research and monitoring. The Cooperative will attract new and visiting scientists, graduate students and environmental professionals. This program will be a unique cooperative effort between State government and a University, providing a model for innovative, efficient integration of scientific resources. Furthermore, the Cooperative will provide tangible evidence of positive cooperation between State government and the University of Vermont. Finally, it will serve to propel the State and University of Vermont into a nationally prominent position in addressing the environmental challenges of the changing global climate in the twenty-first century.