NATURAL RESOURCE INVENTORY

AND

LONG-TERM ECOLOGICAL MONITORING PLAN

SHENANDOAH NATIONAL PARK

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I. OBJECTIVES

The objectives of the Inventory and Monitoring (I&M) program define what is to be achieved and assists in laying the foundation for establishing priorities. Continual changes in natural systems will require that inventories be updated at some interval and monitoring priorities be altered to meet new threats or changing conditions. The Shenandoah National Park (SNP) I&M Program objectives are to:

1) Obtain and maintain a scientifically-based understanding of the type, abundance, and distribution of natural resources.

2) Monitor resource condition and changes through time.

3) Monitor natural processes and anthropogenic influences that maintain or affect resource and ecosystem health.

The objectives of the 5-year strategic plan define the progress that will be made during the 5-year time period toward achieving the overall program objectives. These objectives are to:

1) Establish specific priorities for monitoring program accomplishment.

2) Establish a time sequence in which the priorities will be achieved.

3) Document funding and staffing levels required to accomplish specific program tasks.

4) Achieve program accountability by providing a mechanism to periodically evaluate program efficiency and achievement.

II. INTRODUCTION

Shenandoah National Park's (SNP) Natural Resource Inventory and Long-Term Ecological Monitoring (LTEM) Program is the backbone of the natural resources management function. It is designed to provide the fundamental understanding of natural resources and processes that is essential to the development of management and mitigating actions. Changing conditions in and around units the National Park System today have resulted in a situation where historically traditional National Park Service resource protection activities are no longer adequate to retain the natural character of the land. Aggressive management activities that go beyond Park boundaries and innovative mitigating actions are needed to protect threatened values or to restore impacted resources to a natural condition. It is now, more than ever before in U.S. National Park Service history, essential to be able to obtain scientifically credible information about the condition of resources and the general health of the critical ecosystem processes that sustain populations or environmental conditions.

The LTEM Program is a long-term continuing process that stresses the use of standardized measurements and protocols. While these measurements and protocols are standardized, they may be adjusted or refined as our knowledge and technical capabilities increase.

III. RELATIONSHIP OF INVENTORY, MONITORING, RESEARCH AND MANAGEMENT

The Park's inventory and monitoring program contains two elements: A program to inventory the current resource base, and the Long-Term Ecological Monitoring Program to evaluate resource conditions and natural processes. Inventory, monitoring, and research are all critical, yet different types of activities, each of which have specific roles in management, and ultimate protection, of the natural resources. It is important to have a thorough understanding of the underlying concepts of these three activities, especially that of monitoring. The terms monitoring and research are often used interchangeably, but their meanings are really quite different. Monitoring, in the context of ecology, is the systematic sampling and measurement over time of variables that describe the distribution and abundance of biological resources, the distribution and concentrations of physical, geological, and chemical properties, or the location and rates of important processes (O'Connor and Flemer 1987). It can be thought of as a descriptive status report on an integral of time and space. The purpose of monitoring is to obtain time series data sets that will detect significant changes in the environment and to provide timely warning and other important advice to managers (Segar et al. 1987).

Research can be defined as the systematic collection of data that produces new knowledge (O'Connor and Flemer 1987). The key word that distinguishes research from monitoring is "knowledge," which implies a greater understanding than can be obtained only by monitoring. The purpose of research in the context of ecology is to interpret facts, such as those obtained by monitoring, so that changes in the environment can be explained and the eventual consequences of those changes predicted. Research involves the experimental approach, in which the probable cause of an observation is determined by formulating an hypothesis and testing it in situations with and without the suspected cause. Research can be thought of simply as the use of the classical scientific method.

Unfortunately, a "scientific snobbery" has developed in ecology that dismisses "mere monitoring" as though it were unscientific (Taylor 1989). Ecological studies that are not conducted by means of specific questions, hypotheses, and the experimental approach are often regarded as "pedantic or pedestrian" (Likens 1983). A good example of this can be found in a review of the National Science Foundation's Long Term Ecological Research (LTER) program (Callahan 1984). He explains how the LTER program was developed through a series of workshops from 1977 to 1979 involving nearly 100 experts. During this time the title of the program wound up being "research," with "monitoring," "measurement," and "observation and study" having been considered and rejected. The evolution of this title documented the rejection by the participants of "collecting data for the sake of collecting data." It reflected the insistence of the workshop participants that the only way to expand ecological theory and to solve problems of environmental resource management is to organize research projects around ecological questions and hypotheses.

While no one should argue that experiment has an important place in understanding ecology (and that the LTER program is making valuable contributions to ecology), the importance of monitoring has been greatly under-estimated (Likens 1983, Taylor 1989). Many of the environmental concerns that we have today, such as acid deposition, ozone depletion, toxic waste disposal, and changes in global climate, were unheard of 30 to 50 years ago when some of the effective monitoring programs were being established. While monitoring programs may not be directed at specific questions originally, the long-term records from monitoring programs eventually provide the opportunity to formulate hypotheses and to use the

experimental approach for determining cause and effect by using previous time series data sets as a comparison (Likens 1983). Taylor (1989) has taken this argument a step further and has suggested that the experimental approach often may not be appropriate for establishing ecological knowledge, particularly at the community and ecosystem levels. The philosophy of science, with its emphasis on hypothesis testing, had its origins in the physical sciences. There, scientists can presume that change is not likely to be occurring, so experiments can produce scientific knowledge by proceeding from hypotheses to theories to laws within a reasonably short period of time (certainly within the span of a professional career). Perhaps it is unreasonable to think that ecological knowledge can be established by the classical scientific method, because biological evolution and landscape geomorphology are ongoing processes. The complexity of interactions in communities and ecosystems also makes the design of effective experiments exceedingly difficult. Therefore, in ecology, observations and descriptions over long periods (monitoring) are necessary to formulate meaningful, testable hypotheses.

The Organic Act of 1916 established the National Park Service and gave it the challenging mandate to conserve and allow for public use. Although the term natural resource management did not appear in the original mandate, today this is the term that best describes the practice used by the Park Service to accomplish its fundamental purpose. Giles (1978) gave an excellent explanation of wildlife resource management, which is also applicable to the broader concept of natural resource management. A resource supplies specific benefits to people, and it is people who decide what is a resource. Natural aspects of the landscape, such as forests, mountains, streams, and wildlife, exist with or without people, but they only become natural resources because of human endeavors. These human endeavors do not have to be consumptive; simply enjoying the aesthetic qualities of a landscape unit can qualify it as a natural resource.

Natural resource management is the science and art of making decisions and taking actions to manipulate the structure, dynamics, and relations of populations, habitats, and people to achieve specific human objectives by means of the natural resources. Because, by definition, a natural resource is used to supply benefits to people, it would be impossible to maintain the availability of natural resources without their management. Management is a decision science. The object of this decision making is control. Unless change results that is significantly different from that which would occur without the presence of the manager, no management has occurred. There are two kinds of management: active and passive. Active management involves taking positive measures such as increasing, stabilizing, or decreasing a resource. Passive management is achieved by preventing certain actions from taking place or letting natural developments take their course. This is not to imply that passive management is the easier of the two roads to follow. It is increasingly more important and difficult for the NPS to "hold the line" on certain activities already allowed in the Parks that result in resource impacts and to actively oppose new activities that would compromise sensitive values than it is to carry out the above mentioned active management options.

There are feedback loops between monitoring, research, and management. It would not be possible for the NPS to accomplish its mandate without careful attention to all three components. As an example, data are being acquired on gypsy moth populations, components of stream ecosystems, and components of forest ecosystems throughout the Park. By reviewing the descriptive status reports generated from the monitoring program, changes might be detected in the macroinvertebrate communities of some streams that are suspected of being impacted by gypsy moth defoliation of the forest canopy over the streams. If

the changes were suspected to be a significant detriment to the streams and the important brook trout populations that reside in them, resource managers could immediately make the decision to take control of the situation and change the outcome by closing the affected streams to fishing. A more likely scenario would be for the monitoring program to generate a research program that would provide sufficient knowledge to explain the cause and effect and to predict the eventual outcome of gypsy moth infestation on stream ecosystems. The experimental approach could be used to answer questions such as: how does defoliation of the riparian forest cause a change in macroinvertebrate community structure and how will the changes in food and habitat affect brook trout populations? An hypothesis for the former question could be that the macroinvertebrate community will consist of fewer shredders because of less leaf input to the streams and more grazers because of the greater abundance of periphyton brought about by more sunlight reaching the stream. An hypothesis for the latter question could be that populations of brook trout will be reduced because of less macroinvertebrate food and increased water temperature. If this knowledge was acquired as a result of the research program, resource managers might decide to take firmer control of the situation and make more aggressive changes such as implementing integrated pest management to reduce gypsy moth populations.

If a management decision is made, either to take action or not to take action, the outcome of that decision must be monitored to determine if the decision was correct. For example, if a stream is closed to fishing to improve the success of brook trout, those populations should continue to be monitored to see if they do increase. Because of the complexity of communities and ecosystems and their dynamic nature, it is difficult to determine if ecological research results are accurate; therefore, monitoring is necessary for validation. If research results suggest that macroinvertebrate shredders are reduced by gypsy moths defoliating the forest canopy, the macroinvertebrates should continue to be monitored to determine if natural population cycles might have been the cause. If an active management option is pursued, such as the use of pesticides to reduce gypsy moth populations, then additional research should be implemented to determine the ecological effects of that decision.

IV. REVIEW OF LONG-TERM STUDIES

There are numerous examples that document the importance of long-term studies (monitoring and research) in ecology (see Likens 1983, Callahan 1984, Franklin 1989, Taylor 1989 for reviews and discussion). The explanation that is common to all long-term studies is that natural systems are complex, so it takes longer in ecology than other disciplines to build up enough useful background information for developing meaningful hypotheses (Likens 1983). Franklin (1989) specified four classes of ecological phenomena for which long-term studies are essential: slow processes, rare events or episodic phenomena, processes with high annual variability, and complex phenomena. Forest succession, population dynamics of long-lived organisms, soil development, and wood decay are examples of important slow ecological processes. Any ecological phenomena that require more than a few years to occur fall into the category of rare or episodic. Many long-lived species are episodic reproducers. Disturbances, such as fires, floods, and extreme weather conditions, are important because they reset ecosystems, but they occur occasionally and irregularly.

Biological phenomena linked to highly variable physical phenomena will also be highly variable (e.g., plant productivity and precipitation).

Patterns of complex phenomena, such as nutrient dynamics, are often difficult to distinguish from the larger number of small variations frequently found within ecosystems.

There have been many success stories relative to long-term monitoring and studies. The Long-Term Ecological Research (LTER) program of the National Science Foundation is a recent effort that probably has the broadest scope of any long-term study (see Callahan 1984 for an overview). It was developed from 1977 to 1979, and funding began in 1980. Fifteen sites have been established out of a planned total of 20 (Franklin 1989). These represent a diverse sample of ecosystems in the United States: coniferous forest, oak savannah, deciduous forest, salt marsh/estuary, desert, tall-grass prairie, short-grass prairie, large rivers, alpine tundra/lakes, lakes, and swamp. Comparability of data among sites is a high priority. At most sites, previous data were available. The LTER program is strongly oriented toward the experimental approach. The five core areas, which all funded programs are required to address, are: pattern and control of primary production, spatial and temporal distribution of populations selected to represent trophic structure, pattern and control of organic matter accumulation, patterns of inorganic input and movements, and patterns and frequency of disturbance.

From the LTER program and others, certain basic requirements and principles have been derived. They are:

1) Continuous records must be maintained and constantly updated, scrutinized for errors, and rigorously analyzed. It is important to standardize methods and procedures. Careful attention must be given to what is the best frequency for samples in a time series.

2) Plots and other study sites should be permanently identified and marked, with records kept in more than one place.

3) There must be an appropriate administrative structure to guarantee stability and continuity. Dedication to a study should be rewarded appropriately so that the same talented persons will remain at work for as long as possible. Because of the duration of long-term studies, it is inevitable that there will be changes in personnel, so there should be plans for making smooth transitions. Provisions should be made for long-term storage of some samples, which could be useful for analyses that were overlooked initially or for which new techniques might become available. Voucher specimens of the biota should be placed in museums where they will be guaranteed to receive permanent curatorial care.

4) Funding must be sustained and reliable. Responsible agencies and institutions must be willing and able to make long-term commitments.

V. HISTORY OF INVENTORY AND MONITORING BY THE NATIONAL PARK SERVICE

The National Park Service (NPS) has only recently made an effort to develop a sustained, comprehensive monitoring program. The monitoring that has been done in the past largely reflects the changing priorities and philosophies for managing natural resources in national parks. The following review is based upon publications by the Commission on Research and Resource Management Policy in

the National Park System (1989), Stottlemyer (1987), Franklin (1989), and Sellars (1989).

Scenic preservation was the major factor behind the establishment of the system of national parks that began with Yellowstone in 1872. The aspects of the scenery that appealed to the public were spectacular topography and conspicuous biological components such as trees, wildflowers, large mammals, and attractive birds. The Organic Act of 1916 established the NPS and gave it dual responsibilities of preserving natural resources and providing for public enjoyment in national parks. During the first 20 years of its existence, the Park Service placed top priority on the latter responsibility. Most activities were aimed at promoting and developing the parks to accommodate visitors. Any preservation activities were primarily for protecting scenery. Forest fires were suppressed, predators of large mammals were eradicated, and forests were sprayed to prevent defoliation by insects.

There were no monitoring programs during this period. Because the accepted practice of protecting scenery, which has been termed facade management, had no foundation in science there was no need for ecological information. It was believed that as long as development activities did not change the scenery, the parks were being preserved. In fairness to the NPS, ecological science was not well understood at that time and did not contribute information that would have been useful for managing natural resources.

In the 1930s, the NPS first began to give consideration to scientific information for managing natural resources. Ecology and other natural sciences had advanced to the point where it was possible to understand that the natural resources in parks were interrelated components of ecosystems. The leader of this effort was George Wright, an independently wealthy NPS biologist who personally funded the first biological survey of parks in the early 1930s. Wright believed that science based management was essential to the success of the NPS. The first monitoring programs were begun in this period. He and his colleagues began inventories and prepared management strategies based on their findings (Wright et al. 1933, Wright and Thompson 1935). Unfortunately, the scientific movement within the NPS was set back with Wright's death in an automobile accident in 1936. Money and manpower for science in the parks were greatly reduced during World War II and the years immediately after the war.

In the postwar years and continuing through the 1950s, NPS philosophy reverted to the original emphasis on development. Tourism increased dramatically during this period, and the Service responded with "Mission 66," a billion dollar program for construction of new facilities. Science was not given high priority during this period.

In the 1960s, scientists inside and outside the Service renewed George Wright's efforts to establish science-based management in national parks. Two reports released in 1963 were particularly influential. The National Academy of Science's Robbins' Report (prepared by a committee chaired by Dr. William J. Robbins) reiterated that parks were part of ecosystems in which the components were interrelated and that management should be based upon intensive scientific research to assure preservation of natural resources. The Leopold Report (prepared by a special advisory board chaired by Dr. A. Starker Leopold) has been the foundation for natural resource management in the parks for the past 25 years. The Leopold Report also indicated that credible scientific information should be the basis for natural resource management but went a step further and described the biotic associations that should be maintained. It put forward the idea that national parks should be managed as "vignettes of primitive America," meaning that the biotic assemblages should be what existed, or would have evolved, without the discovery of

America by Columbus and subsequent European settlement. Although the "vignettes" concept may have been unrealistic (Johnson and Agee 1988), the Leopold Report has been a significant positive influence on natural resource management because of its emphasis on maintaining overall biological integrity.

In spite of acceptance of natural resource management based on principles of ecology, the NPS did not establish a comprehensive long-term monitoring program in the years following the Leopold Report. Serious scientific endeavors have been undertaken, but most of these have been short-term studies directed toward solving immediate problems. There have been a few examples of long-term monitoring programs in national parks such as the unique marine resource program at Channel Islands National Park and the wolf-moose studies at Isle Royale National Park. Several parks (e.g., Olympic, Sequoia, and Rocky Mountain) have used their participation in the National Acid Precipitation Assessment Program (NAPAP) to initiate long-term studies.

In the past three years, there has been the most serious interest in the history of the NPS for establishing long-term monitoring programs. Draft I&M guidelines (NPS-75) were prepared in 1989. Following an extensive period of review and change they were approved in 1992. This document includes the Inventorying and Monitoring Policy Statement, which was derived from the Natural Resources Inventory and Monitoring Initiative of May 1987 (revised July 1987): "It is the policy of the National Park Service to assemble baseline inventory data describing the natural resources under its stewardship, and to monitor those resources forever - to detect or predict changes that may require intervention, and to provide reference points to which comparisons with other more altered parts of the home of mankind may be made."

Important definitions are given for natural resource inventorying: "the process of acquiring, managing, and analyzing information on Park resources, including the presence, distribution, and condition of plants, animals, soils, water, air, natural features, biotic communities, and natural processes;" and long-term monitoring: "the systematic collection and analysis of those resource data at regular intervals, in perpetuity, to predict or detect natural and human-induced changes, and to provide the basis for appropriate management response."

It would have been ideal if the scientific programs begun by George Wright had been adopted as standard policy and continued to the present. More than 50 years of ecological data from national parks would now be available! Even though there has been a 50-year delay in recognizing the significance of ecological monitoring for managing the natural resources of national parks, the need has never been more critical than at the present.

Many students of NPS history and management describe the national parks as being at a crossroads. Significant management and protection problems were listed in a 1980 report by the Park Service titled, "State of the Parks: A Report to Congress." Seventy-three types of threats to the parks were listed. The sources of more than 50 percent of the problems were outside of the parks. Industrial and commercial development on adjacent lands, air pollution, urban encroachment, and roads were the most frequently cited external threats. Scenic resources were reported as threatened in more than 60 percent of parks, air quality in more than 45 percent, and animal, plant, and freshwater resources in more than 40 percent. A clear indication of the need for long-term monitoring programs is that 75 percent of the perceived problems were reported as being inadequately documented and in need of research. It is doubtful that

any of the threats have lessened since the State of the Park Report, yet most park databases are still considered to be inadequate to document such environmental impact (Stottlemyer 1987).

Quantification of ecological changes brought about by anthropogenic causes is difficult because ecosystems are continually changing, and these changes are not always predictable (Johnson and Agee 1988, Brubaker 1988). It is now recognized that a variety of natural disturbances play an integral role in the long-term maintenance of virtually all ecosystems (Christensen 1988). The only hope for distinguishing natural and unnatural changes is to have a reliable database of ecological information.

Recommendations have been made that national parks, because of their reasonably natural conditions and the diversity of ecosystems represented, can be used to develop scientific knowledge and to help solve environmental problems beyond their boundaries. As protected areas dedicated to the preservation of natural ecosystems, national parks present many advantages as sites for conducting long-term ecological studies (Parsons 1989). The large national parks may be particularly important to the ecological health of the planet by serving as reservoirs of genetic diversity (Sellars 1989). With appropriate long-term monitoring programs, national parks can provide benchmarks for measuring local or global environmental changes (Commission on Research and Resource Management Policy in the National Park System 1989).

The concept of ecosystem management has been suggested recently as the most effective means for appropriate stewardship of national parks (Johnson and Agee 1989, Agee and Johnson 1989). They explain this strategy as follows: "ecosystem management involves regulating internal ecosystem structure and function, plus inputs and outputs, to achieve desirable conditions. It includes, within a chosen and not always geographic setting, the usual array of planning and management activities but conceptualized in a systems framework: identification of issues through research, public involvement, and political analysis; goal setting; plan development; use allocation; activity development (resources management, interpretation); monitoring; and evaluation."

With regard to monitoring, one of the principles of ecosystem management that they emphasize is that high quality information is necessary to identify trends and respond to them.

In 1988, the National Parks and Conservation Association (NPCA), with funding from the Andrew Mellon Foundation, established an independent 17-member Commission on Research and Resource Management Policy in the National Park System, chaired by Dr. John C. Gordon. The commission was charged to review the Leopold Report and to become its successor. In its report (Commission on Research and Resource Management Policy in the National Park System 1989), the commission was generally complimentary to the Leopold Report and did not suggest that it be discarded; however, the commission did suggest some modifications. Included was a recommendation for the NPS to change its natural resource management policy to the holistic approach of ecosystem management. A specific recommendation was for "establishing an integrated inventory and monitoring program."

Central to the NPS I&M initiative was the completion of NPS-75, **Servicewide Guidelines for Natural Resource Inventory and Monitoring**, which provides a general guideline for developing I&M programs in the parks. Outlined in this plan are the three generalized phases associated with the design of a

monitoring program as described in Figure 1 of NPS-75. This chart has been incorporated as Figure 1 in this plan for easy reference. Phase I is the initial inventory phase which focuses on identifying the resources using both historical information and additional inventories to fill in fundamental data gaps. Phase I includes the first three boxes in the conceptual flow chart which are: evaluate the available data, develop a conceptual model, and the inventory process. The Phase I inventory phase is never complete because an inventory not only consists of individual resources but an assemblage of information on biotic communities, natural processes , and human-induced changes. However, an initial baseline inventory of a majority of the resources is necessary in order to progress to Phase II.

Phase II consists of the monitoring or analysis of resources. Phase II corresponds to the next two conceptual steps in the flow chart: design the monitoring program and the actual monitoring process. The most difficult process associated with designing an effective I&M program is to determine which resources or processes can be effectively monitored within the bounds of staff levels and funding. The process of monitoring builds new knowledge which will be added to the Phase I inventory as the program progresses.

Phase III consists of the integration of information to evaluate large scale processes such as population dynamics, community ecology, and ecosystem dynamics. Phase III is the analysis and synthesis component of the conceptual model flow chart. Continuous feedback from Phase III helps guide the design and development of new monitoring needs as well as to determine the temporal scale required to capture the process information of interest.

The development of a successful I&M program does not necessarily result in the systematic completion of the individual phases described. Program development and continuous feedback or evaluations help mold the development phases. Individual research projects and associated funding can be used to further the level of knowledge in one resource area over others. The ability to capture specific resource knowledge with the long-term intent of incorporating this information into a monitoring program often leads to the progression of individual resource monitoring components through the various phases at an accelerated time schedule. Such was the case at SNP. Funding for watershed acidification work in the early 1980's led from Phase I to watershed dynamics, Phase III, before the initial completion of a comprehensive I&M program. Funding for gypsy moth-related research also led to early monitoring protocol development for forest and aquatic community level response work.

Figure 1. Conceptual Overview of the Inventory and Monitoring Process In Natural Area Parks (from Natural Resources Inventory and Monitoring Guidelines, NPS-75, page 13).

The development of an I&M program begins with the development of the thought processes necessary for incorporating study results and research into a long-term program. Effective leadership which can capitalize on individual bits of information already in existence or being developed is necessary for the initial planning stages of a comprehensive I&M program. Much of the initial groundwork can be accomplished without additional staff or funds, provided that the staff is willing to work cooperatively toward the goal of developing an I&M program.

The following sections will describe both the existing and proposed program development over the next five years. The various steps associated with development of SNP's program are referred to as Stages. Stage I was the initial I&M program development which occurred prior to the initiation of Servicewide I&M Program. Stage II occurred after the Park was accepted into the Servicewide I&M Program and additional funding was allocated.

VI. OVERVIEW OF INVENTORY AND MONITORING PROGRAM DEVELOPMENT IN SNP

The decision was made in 1984 to develop a comprehensive I&M program for Shenandoah National Park. Realizing that this program would take several years to establish, it was initially divided into stages. The first stage of this effort, Stage I, was to evaluate the existing natural resource inventory and to design and implement a core monitoring program. This stage includes Phases I and II of the typical progression for designing a monitoring program.

Park records were consolidated and a literature search was conducted to determine the current status of the natural resource inventory. A plan was developed to obtain the necessary data to fill in identified omissions and limitations in the inventory. Various types of agreements were developed with cooperating federal and state agencies to assist the Park staff in the collection of a broad range inventory data. The inventory process was recognized as an ongoing activity and it will not be feasible to conduct an exhaustive search for all possible species. However, we expect that a comprehensive inventory of vascular flora and vertebrate fauna can be achieved within three years to coincide with the initial completion of the second stage of the monitoring program. Continued progress can be made on the remaining taxa. The outline for species inventory is similar to that described in the section on long-term monitoring.

The Stage I core of the Long-Term Ecological Monitoring Program was designed to monitor a basic set of ecological parameters that would characterize the broad types and rates of changes likely to take place in the Park and will provide appropriate information to address management needs. The monitoring of specific populations or discreet ecosystem parameters would be added later. Of particular concern was the future impacts of the alien gypsy moth (Lymantria dispar) on forest systems. Therefore, much of the early monitoring design was focused on those ecosystem components most likely to be affected by widespread defoliation, such as forest composition and aquatic systems. Other likely perturbations such as wildfire, acid deposition, air pollution impacts, and visitor use impacts were also considered when determining the monitoring design and protocols. By considering these other types of disturbances, the basic monitoring design would capture a range of change wider than those caused solely by gypsy moth.

The first three years of this effort (1985-1987) were focused on the establishment of the Park's

monitoring objectives, program design, selection of monitoring protocols, and the field testing of data collection methods. Two key factors considered at this time were what to monitor and how to do it. This might seem simple on the surface but in reality it turned out to be the most difficult issue to settle. It quickly became obvious that we could not monitor everything. The program had to be designed in such a manner as to address critical resource management issues and concerns. The agents of change and specific ecosystem responses to those agents initially may be unknown, so a monitoring design must anticipate general resource threats and potential responses. What was needed was a list of constraints which could be used to prioritize the laundry list of monitoring possibilities. The constraints that were eventually selected to determine what would be monitored in the Park's I&M program included the following in order of priority:

1) Resources specifically mentioned in the Park's enabling legislation, listed as threatened or endangered, or otherwise given special status by law.

2) Key ecosystem processes that can be well defined and accurately assessed.

3) Species or processes that may impact on public health or safety or are locally controversial.

4) Events such as fire, flood, erosion, weather patterns, etc. that could drastically alter normal ecosystem processes.

5) Resources being directly threatened by human activities.

6) Baseline monitoring of species, populations or compositions that enhance our understanding of particular phenomena, relationships or population dynamics.

7) Species or populations that are of interest but of no particular management or ecological concern.

Four levels of monitoring were determined to be necessary in order to adequately address the priority resource issues: community monitoring for both aquatic systems and terrestrial vegetation systems, population monitoring for individual species of concern, watershed ecosystem monitoring for acquiring intensive scientific knowledge to develop interconnected resource relationships, and landscape monitoring for determining large scale changes both within and outside park boundaries.

Community level monitoring was determined necessary for both aquatic systems and terrestrial vegetation systems primarily because of the perceived threats to the entire Park. A community is an assemblage of populations of living organisms in a prescribed area or habitat. The aquatic communities were delineated by geology types because stream water chemistry is a direct function of the underlying parent material, soil, and associated vegetative communities that develop. Aquatic monitoring focusses both on the stream water chemistry and the associated biological components living within those systems.

The terrestrial vegetative communities were delineated using forest cover types which were developed in a previous effort to document bear habitat requirements. Forest cover types provide the basis for

evaluating terrestrial vegetative communities which are the result of soils, available moisture, elevation, and disturbance history. It is recognized that the disturbance history of the land has created temporary community associations, but the monitoring program will allow the park to document community changes as well as to further refine cover type delineations.

Population level monitoring was established for individual species of concern. Initial efforts at SNP included black bear and brook trout monitoring. Population level monitoring develops the understanding of population dynamics or the ways in which populations change spatially and temporally. Parameters of populations such as abundance, distribution, age structure, reproductive effort, and growth rate are relatively easy to measure, are often sensitive to chronic stress, and can be used to predict future conditions. Population monitoring is especially valuable because organisms integrate the effects of environmental conditions such as predation, competition, and pollution and can therefore indicate the quality of environmental conditions. Also, many management controls operate at the population level, so application to management issues is direct and measurable. Many population level questions can not be adequately addressed by monitoring and must be done through related studies or research such as was done at SNP with both bears and brook trout. Especially of interest to the program is the population of threatened or endangered species.

Landscape level monitoring will be used to document the patterns of landscape change occurring in and around the Park. The initial inventory associated with this effort will also be used to determine the locations of nearby significant natural and cultural resources. Landscape by its name implies a broad view. Landscape level monitoring focusses on the entire land surface of an area. Landscape changes can be as dramatic as changes associated with large natural events such as earthquakes or landslides or as subtle as the geologic weathering of subsurface rocks. Landscape changes generally are the result of complex ecosystem interactions and monitoring at this level usually represents monitoring intervals of decades or even centuries. However, due to the disturbance history of the Park and the increasing development activities around the Park boundaries, landscape level changes have been accelerated. Monitoring time scales needed to document these changes have been shortened from decades to years. Landscape monitoring is primarily based on maps or data created from aerial photographs or satellite imagery. Analysis and manipulation of this type of data is the focus of the GIS program and will be the backbone of the landscape monitoring component.

Stage II of Shenandoah's I&M program development began with the initiation of the Servicewide I&M initiative which included an appropriation of Washington Office funds for the development of a comprehensive monitoring program. The accomplishment of the Stage II program depends on obtaining and maintaining the full funding allocation from the Servicewide initiative.

VII. NATURAL RESOURCE INVENTORY PROGRAM

The primary focus of the natural resource inventory is to determine the presence or absence of species, their general abundance, and to delineate the range of each species or group of related species. Some inventory work has been done over the years. During the initial planning stage, the status of the current inventory was defined, and an outline to guide the attainment of the total inventory was determined. This inventory outline is by no means exhaustive. For species lists and associated bibliographic references see SNP's Resource Management Plan. The following outline includes a code

that describes the current (1991) status of the inventory for each resource element. Specific resources with considerable historical research and inventory data are listed individually. Otherwise, resource categories are used.

The first character (letter) of the code identifies the level of effort which has been made to determine whether or not the species is present in the Park. The second character (number) defines the status of knowledge regarding the abundance, and the third character (number) defines the status of knowledge of the distributional range.

Codes: First Character: (K) = Presence/absence known.
(P) = Presence partially known
(U) = Presence/absence unknown.

Second Character: (1) = Abundance known (surveyed).
(2) = Abundance partially known.
(3) = Abundance not known.

Third Character: (1) = Range known (surveyed).
(2) = Range partially known.
(3) = Range unknown.

INVENTORY OUTLINE

A. FLORA

A.1 VASCULAR PLANTS

A.1.1 Terrestrial Vegetation K11

A.1.2 Unique Vegetation Communities

A.1.2.1 The Big Meadow K11

A.1.2.2 Big Meadows Swamp K11

A.1.2.3 Limberlost Hemlock Grove U33

A.1.2.4 Threatened and Endangered Vascular Plants K22

A.2 NON-VASCULAR PLANTS

A.2.1 Mosses K12

A.2.2 Lichens and Liverworts P12

A.2.3 Algae U33

B. FUNGI K22

C. FAUNA

C.1 VERTEBRATES

C.1.1 Mammals

C.1.1.1 White-tailed Deer K12

C.1.1.2 Black Bear K11

C.1.1.3 Eastern Bobcat U33

C.1.1.4 Natural Heritage Species K11

C.1.1.5 Mammals, General K33

C.1.2 Birds

C.1.2.1 General Resident Breeding Birds K12

C.1.2.2 Migratory Birds K22

C.1.2.3 Natural Heritage Species (Peregrine Falcon) K11

C.1.3 Fishes

C.1.3.1 Eastern Brook Trout K11

C.1.3.2 Fish, general K13

C.1.4 Reptiles K22

C.1.4.1 Timber Rattlesnake K11

C.1.5 Amphibians K22

C.2 INVERTEBRATES

C.2.1 Mollusks P33

C.2.2 Crustacea P22

C.2.3 Arthropods (1) (Arachnids) U33

C.2.4 Arthropods (2) Gypsy moth K11

C.2.5 Arthropods (3) (Other terrestrial insects) P32

C.2.6 Arthropods (4) (Aquatic insects) K22

D. GEOLOGY K11

E. SOILS P22

F. WATER QUALITY K11

G. AIR QUALITY K11

H. METEOROLOGY K11

The inventory of most elements is expected to be completed by the end of the Stage II inventory. Some of the difficult ones such as fungi and arthropods may never be considered to be 100 percent complete.

VIII. LONG-TERM ECOLOGICAL MONITORING PROGRAM

STAGE I

Developing the Conceptual Model

The first task in designing the monitoring system was to develop a conceptual model of the resources to be monitored. This was based on the total array of resources present and a perception of the type of information needed to protect the resources under NPS stewardship. This thought process was discussed in Section VI, Inventory and Monitoring Development in SNP. Following a rather lengthy period of study and analysis, a set of parameters that were both a high priority and were technically feasible within the projected budget and staffing constraints were selected for Stage I. These included broad parameters that were most likely to detect changes brought about by gypsy moth defoliation and other major disturbances. Others were set aside for inclusion in the program during later stages.

The next step was to determine if the technology existed to accurately monitor the selected high priority parameters. As an example, stream macroinvertebrate community structure was high priority on the list of species populations to monitor. It was finally determined that the technology did exist to make the measurements and that it was feasible for us to do it. This process was continued for each priority on the list.

Numerous meetings and brainstorming sessions with subject matter experts from nearby academic institutions, cooperating federal and state agencies, and the private sector were held to assist with this process. The final product was a list of high priority resource elements to be monitored during the initial stage of program implementation.

Resource Elements to be Monitored

A critical evaluation of the seven major priorities listed in Section IV led to the initial I&M model representing Stage I of the program development. The following outline indicates the level of monitoring established and the individual monitoring categories that required specific data collection protocols. Individual monitoring components are listed below each category heading. Funding for the six year period that made up Stage I of the I&M program was obtained through the NPS Natural Resources Preservation Program (NRPP).

COMMUNITY MONITORING

*Terrestrial Vegetation
- Overstory trees
- Shrubs
- Woody regeneration
- Ground cover classes
- Herbaceous plants

*Aquatic Communities
- Aquatic mollusks
- Aquatic crustacea
- Aquatic insects
- Stream habitat
- Stream physical measurements (depth, width, flow)
- Water chemistry

Air Quality
- Gaseous pollutants (ozone, SO2)
- Particulates
- Precipitation chemistry
- Visibility

POPULATION MONITORING

Black bear
Brook trout
*Gypsy moth

WATERSHED MONITORING

Watershed Chemical Processes
Forest Dynamics

METEOROLOGY

Solar Radiation
Events (unusual storms, tornados, earthquakes)
Wind (speed and direction)
Relative Humidity

* Indicates new protocols were developed during this segment.

Implementation

A cooperative agreement was established with Virginia Polytechnic Institute and State University (VPI&SU), to assist the Park staff in developing and writing the Stage I protocols and manuals.

Pilot measurement protocols for the selected Stage I elements were then designed and field tested. Numerous adjustments were made to perfect techniques. A great deal of care was taken to assure that all measurements would be both accurate and repeatable. Quality assurance and quality control (QA/QC) factors were developed along with the protocols. The Mid-Atlantic Regional Chief Scientist was consulted on numerous occasions for input on critical issues and to arrange for peer review of draft protocols.

An extremely important portion of the Stage I program development was the structure and design of the database management system. It was recognized from the onset that custom designed database programs would be needed to store, analyze, and process the large amounts of data that would be collected in connection with the LTEM program, and to prepare data summary reports. The database for Stage I parameters was designed during the same time period when the protocols were developed so that as changes were made to collection protocols corresponding changes would be made to the database system.

The Park's Geographic Information System (GIS) is used to store and spatially display the various inventory and monitoring data sets as they are developed. The capabilities of the GIS have been used on several occasions to determine where monitoring plots should be located. Themes that have been particularly useful for this purpose include: forest vegetation, soils, geology, and topography. The GIS will be used to support the inventory portion of the I&M program by storing a spatial record of each recorded species' locations, densities, and related critical habitats. Figure 2 represents a map of monitoring, watershed and ecological research sites in the Park.

The goal of the second three-year period of Stage I (1988-1990) was to establish the core forest vegetation and aquatic plot systems which would facilitate the measurement of the selected elements.

Since test plots were already worked out during previous years, little further modification was necessary. Three hundred thirty terrestrial plots were established on 117 sites. Baseline data was acquired during this period and some valuable inventory information was collected in the process. All of the 17 aquatic plots on 11 streams were established in the first year. One fifth of the forest plots were established each year so that the re-measurement cycle of once every five years could be established. Ideally, during the fourth year each plot should be revisited for the purpose of re-establishing any lost corners and to accomplish any other needed maintenance. However, the site

selection process was extremely time consuming and it took five years to insure that all combinations in the theoretical site matrix were filled or determined not to exist.

A monitoring program of this magnitude requires a considerable amount of dedicated staffing to maintain and operate. The staffing level for Stage I activities included:

.5 FTE Natural Resource Specialist, GS-12

I&M Program Manager: GS-11 Ecologist

GIS Support: .5 FTE GIS Technician

Field Technicians: 3 FTE Temporary Biological Technician

Total expenses including contracts for sample analysis to operate the Stage I program in 1990 was $230,000.

STAGE II

Stage II started in l991, and includes the expansion of the monitoring conceptual model to include all resources of interest, development or refinement of protocols and manuals for the Stage I elements, research and development for protocol design, monitoring manual production, and monitoring protocol implementation for the remainder of the resource elements.

The following list of resource elements to be monitored is considered to be complete. However, it would be wise to say that this list will be modified as we continue to expand our understanding of the resource base and monitoring technology. Elements included in Stage I are shown in **bold**.

A.1.1 **Terrestrial Vegetation**

Terrestrial vegetation monitoring was established during Stage I of the I&M program development with the objective to measure changes in the forest vegetative communities, especially the response to gypsy moth defoliation. Vegetation types based on forest canopy composition were used as the basis for delineating plant community boundaries. Factors affecting plant growth and development such as slope percent, aspect, and elevation were used to stratify plant communities. Permanent plot establishment and the initial inventory were conducted between 1987 and 1991 resulting in 330 plots established representing 117 sites. Plots are being re-inventoried on a five year schedule. Monitoring components

include overstory trees, shrubs, woody regeneration, and ground cover classes.

A.1.2.1 The Big Meadow Historic Area

Big Meadows is an open meadow of approximately 120 acres located at 3509 feet in elevation. The area was historically maintained as an open area by both humans and domestic animals. The meadow is the only large open area maintained in the Park and it contains a wet spring area. A Meadow Management Plan was developed in the 1980's which requires the annual removal of trees by using hand cutting and the stem application of herbicides. The result of this management effort has allowed diverse herbaceous and shrub communities to develop. Included in the plant communities are several plants which are State listed as threatened or endangered. The meadow area will be monitored in order to evaluate the effectiveness of maintenance strategies as well as to document the natural changes occurring with the vegetation. Monitoring efforts will focus on mapping changes in vegetative communities using low altitude aerial photography and developing a field vegetation inventory program.

A.1.2.2 Big Meadows Swamp Ecosystem

A high elevation wetland plant community is located adjacent to the Big Meadows Historic Area. The swamp or wetland occurred in a bowl shaped depression at the headwater springs of Hogcamp Branch. The area is a unique vegetative community containing many rare plants. The potential threats to the area are deer browsing, human use, and water level changes. A well used to supply water to the Big Meadows developments was reducing the water table in the swamp and after several years of monitoring the well was shut down. Prior to Park establishment the area was maintained as an open area by previous owners. Natural succession and some of the identified threats are changing the vegetative composition. A vegetation inventory including a detailed map has already been developed. Monitoring of the area will consist of mapping changes in the vegetative communities using low altitude aerial photographs and additional field vegetation monitoring.

A.1.2.4 Threatened and Endangered Vascular Plants

The Division of Natural Heritage, Virginia Department of Conservation and Recreation, developed a comprehensive inventory of the threatened and endangered vascular plants of SNP during 1990-92. Results of the survey were mapped locations of individual plant populations and associated plant community zones as well as management recommendations. Potential threats to these resources include air pollution, deer browsing, human trampling, changes in park development, changes in maintenance activities, and alien plant species competition. Monitoring protocols will be designed in consultation with the Division of Natural Heritage for high priority species. Monitoring will include the evaluation of the present health of individual plant populations and also the associated communities using standardized plant survey techniques. A GIS theme will be developed to map both the individual plant locations and the associated communities.

C.1.1.1 White-tailed Deer

The white-tailed deer, Odocoileus virginiana, has recovered from near extirpation to be a dominant mammal in SNP. High deer numbers in the developed areas and along the Skyline Drive are causing

increased motor vehicle accidents and it appears that they are affecting some plant communities due to continued heavy browsing. Basic research in the early 1980's indicated two different population densities in the park and differences in average home ranges between front country and backcountry populations. Minimal baseline data exists on deer population levels or herd health. Deer effects on woody regeneration, herbaceous plants, small mammals, and breeding birds is being studied through a cooperative project with the Conservation Research Center of the Smithsonian Institution. Monitoring will focus on deer health and distribution.

C.1.1.2 **Black Bear**

Black bear, Ursus americana, is a high profile animal of interest to most visitors. Although the park supports one of the highest bear densities ever reported in the United States, greater than one bear per square mile, bears are rarely seen by visitors. Research during the late 1970's and early 1980's documented stable bear populations with many young bears dispersing to adjoining lands. Research during the late 1980's and 1990's focussed on the effects of gypsy moth on bear habitats and bear health. Shenandoah initiated a bear survey in 1983 to determine a relative population index and has had an active bear management plan in place since 1976. The bear monitoring program will continue at the present level unless new information indicates radical population changes.

C.1.1.3 Eastern Bobcat

The Eastern bobcat, Felis rufus, is one of the least known mammals in SNP primarily because of its secretive ways and large territories. Due to the overall lack of knowledge associated with this species and its role as a predator in a protected system, this species was selected for inclusion in the I&M program. Initial monitoring efforts will likely be associated with a research effort with the intention of collecting baseline data as well as to evaluate the feasibility of developing monitoring protocols.

C.1.2.1 Resident Breeding Birds
C.1.2.2 Migratory Breeding Birds

Present knowledge of breeding birds in SNP is primarily based on observational data from surveys taken at various times of the year. The focus on breeding birds is preferred rather than focussing on all birds because breeding birds can be linked to the habitat requirements necessary for the perpetuation of individual species. Presence or absence data has been used to create a park bird checklist, however, detailed data associated with specific habitat types is missing. Population and community level data is nonexistent. The focus of the I&M program will be breeding bird surveys and continuous mist netting on six permanent sampling sites located in two different forest cover types. The protocols for this effort have been developed by the Monitoring Avian Productivity and Survivorship (MAPS) study and has been adopted by the Northeast Neotropical Migratory Bird Working Group of which SNP is involved. Additional breeding bird survey routes have also been established in cooperation with the U.S. Fish and Wildlife Service. Initial site selection and monitoring was contracted with the Breeding Bird Institute, California. Future efforts will include solidifying the bird monitoring protocols for inclusion in a protocol manual and absorbing the monitoring field work as part of the NR&S operation.

C.1.3.1 **Eastern Brook Trout**

Salvelinus fontinalis, the brook trout, is found throughout the Park in the cool clear mountain streams. SNP contains some of the best brook trout fishing in the eastern United States. Because the fish can be harvested in a majority of the fishable streams, the Park initiated a brook trout monitoring program in 1982 to assess the effects of angling on brook trout populations. Monitoring efforts include size class determination and abundance for trout and presence or absence for other species of fish. All fishable streams are surveyed biannually and other streams of interest are surveyed on a longer rotation unless a stream is identified as having problems. The brook trout monitoring program will continue as it presently exists until a total fish monitoring program can be developed. Future changes in fish regulations such as the designation of more streams to catch-and-release would permit longer time intervals between surveys.

C.1.3.2 Fish (other)

Biologists classify all of SNP's streams as sensitive to watershed acidification with a portion of the streams classed as extremely sensitive. Present brook trout monitoring only provides presence or absence data on other species of fish and the methods are not appropriate for describing changes in the populations. A three-year research project (1991-1994) through the University of Virginia (UVA) and Virginia Polytechnic Institute and State University (VPI&SU) will be evaluating the effects of stream water chemistry on fish. This project known as FISH, Fish In Sensitive Habitats, will provide an important link between stream water chemistry and biological effects. Included in the research contract is the requirement to develop monitoring protocols for all fish species, including brook trout. Results of the project will be field tested, reviewed, and incorporated into the monitoring program.

C.1.5 Amphibians

Recent reports from the scientific community state that amphibian populations are declining worldwide. Minimal baseline data exists concerning amphibian populations in SNP, and the present inventory is primarily a species list indicating presence or absence of individual species within the Park boundaries. The Shenandoah salamander, a T&E species, is the exception due to the long-term interests of two park VIPs. Specific range maps and distribution information has been collected for the Shenandoah salamander and detailed field notes associated with other amphibians encountered in the park have been kept by the volunteers. The initial inventory for the Shenandoah salamander was carried out in a cooperative effort by the Virginia Division of Natural Heritage, the USFWS, and park staff. Monitoring efforts will include the development of protocols specifically for determining population information on the Shenandoah salamander and the development of protocols for other amphibians which represent unique habitats or the common aquatic and terrestrial habitats found throughout the Park.

C.2.1 **Mollusks**

The monitoring of mollusks is not an individual monitoring effort but one component of the aquatic community monitoring (C.2.6). Mollusks are collected as incidentals in both the quantitative and qualitative benthic samples on an occasional basis. Samples are separated by a contract lab and individual specimens are identified then preserved. There are no plans to develop an individual monitoring component for mollusks.

C.2.2 **Crustacea**

The monitoring of crustaceans is also not an individual monitoring effort but one component of the aquatic community monitoring (C.2.6). Crustaceans are collected as incidentals in both the quantitative and qualitative benthic samples on an occasional basis. Individual specimens are preserved for future identification questions. There are no plans to develop an individual monitoring component specifically for crustaceans.

C.2.4 **Gypsy Moth**

Gypsy moth, Lymantria dispar, has been a major driving force in the development of the I&M program. The widespread effects of defoliation are devastating to plant communities and the associated effects on other resources is a major concern. Money for gypsy moth population monitoring and gypsy moth related effects work provided initial funding for the development of SNP's I&M program.

The first gypsy moth infestation occurred in the park in 1986 and by 1991 the entire park had been infested. Widespread overstory tree mortality is occurring throughout the park. Gypsy moth related research and monitoring led to the development of a gypsy moth component in the I&M program. A standardization of survey techniques for gypsy moth populations was also developed through Appalachian Integrated Pest Management (AIPM). Since AIPM protocols were being used throughout Virginia and surrounding states and SNP was required to use these for justification of suppression activities, AIPM protocols have superseded the Park's protocols. Other projects have provided substantial new knowledge associated with the effects of gypsy moth defoliation. No new I&M efforts are planned for gypsy moth monitoring except to determine if previously developed gypsy moth monitoring components could be integrated into the permanent terrestrial plot inventory.

C.2.5 Arthropods (terrestrial insects)

Inventory information associated with the terrestrial insects of SNP is far from complete. In fact, there is less known about terrestrial insects than any other taxonomic group. Insect population numbers, the total diversity of terrestrial insects, and the sensitivity of insects to changes in environmental conditions lends this group of organisms to provide outstanding opportunities for developing cause and effect environmental relationships. At the present time, many of the pressing resource management issues in SNP are insect related including the effects of gypsy moth, southern pine beetle (Dendroctonus frontalis), and hemlock wooly adelgid (Adelgis tsugae) on forest trees. Techniques and protocols for inventorying and monitoring terrestrial insects on an ecosystem level are lacking. Monitoring protocols will be developed for determining insect diversity and change for various representative habitat types found throughout the Park. Special emphasis will be to inventory and monitor unique habitats that contain specific plant hosts.

C.2.6 **Arthropods (aquatic insects)**

The initial stage of the I&M program included the inventory and monitoring of aquatic insects as a component of aquatic community monitoring. Aquatic insects spend the majority of their lifetime in the

confines of the stream environment and changes in water conditions will directly affect both the abundance and diversity of the associated organisms. Inventory and monitoring protocols were developed between 1985 and 1987 and data collection began in 1986. Both quantitative and qualitative samples are collected twice each year on 17 sites representing 11 different streams. Aquatic sites represent the range in water chemistry found in the park. Sample times are late spring for maximum diversity and ample water flow and in late summer when stream temperatures are peaking and water flows are reduced. Using the six years of data a research project has been initiated to analyze the body of data and to develop statistical measures which can be used to classify community health and diversity. Plans for the next stage of aquatic insect monitoring is to continue the present monitoring schedule and to collect additional samples downstream from the wastewater treatment facilities.

E. SOILS

Soils inventory data presently exists for all counties except Page county. Page county's inventory is slated for completion in 1993. Soil mapping resolution is at the lowest classification level and most of the data is presently only available as paper maps. The SCS is working toward the conversion of all Virginia soil maps to a GIS system and we intend to acquire the applicable computer data when available. Soil monitoring in SNP has primarily been a research focus in the intensively monitored watersheds. The results of soils research has led to a soils component in a watershed acidification model. Future plans for soil inventory is only in the formative stage. As soil acidification processes continue to be understood through research, efforts will be made to evaluate the need for soil monitoring in the Park. Monitoring efforts are being considered in association with the permanent vegetation plots.

F. **WATER QUALITY**

Water quality monitoring in SNP was initiated as a research component during the initial stages of stream water acidification research. This research was a University of Virginia effort which was funded through the National Acid Precipitation Assessment Program (NAPAP), EPA, and the Virginia Trout Stream Sensitivity Study. Research efforts led to the weekly monitoring of four streams within the park and associated studies focussing on geology, soils, precipitation chemistry, and hydrology. Water chemistry includes testing for alkalinity, sulfate, nitrate, chloride, calcium, magnesium, potassium, sodium, and silica. This work has resulted in the development of a vast amount of information on water quality. To insure the continued collection of these valuable datasets, the intensive water quality work has been maintained as a monitoring effort.

The development of the aquatic community monitoring component in the I&M program included a water quality section. Water samples are collected from the 11 streams on a quarterly basis each year and chemical analysis is the same as that done for the weekly samples. Unusual trends associated with the quarterly water quality parameters can be checked by comparing the results to the weekly sample results. Future plans include the continuation of the inventory and monitoring program that presently exists, the inclusion of water quality monitoring sites downstream from the five wastewater treatment facilities, and an evaluation of need for the present intensive watersheds. Initial comparisons between intensive watersheds indicate that some streams have drought stress problems and other nearby streams may provide better long-term data.

G. AIR QUALITY

Air quality has been a focus of the park since the early 1980's primarily because deteriorating conditions in air quality were thought to be affecting the resources and reductions in visibility were spoiling scenic vistas which are considered to be an important value to park visitors. An early commitment to understanding air quality effects and changes in visibility has led to a number of cooperative research projects and long-term monitoring of air components, wet and dry deposition, visibility, and associated meteorological parameters. The majority of the air quality research in the park has been through the University of Virginia or in association with the NPS Denver Service Center. Funding sources for research have been primarily from EPA, NAPAP, and the NPS. Monitoring efforts have been closely correlated with national programs such as the National Acid Deposition Program (NADP), National Dry Deposition Network (NDDN), and the Interagency Monitoring of Protected Visual Environments (IMPROVE) program. Monitoring components include ozone, SO2, particulates, visibility, and acid precipitation. Monitoring protocols and equipment requirements have been based on the necessary compliance standards of the related national programs. Collected data is shared with national data networks. Monitoring protocol development for SNP will be the compilation and clarification of the present monitoring protocols associated with the various national programs.

H. METEOROLOGY

The primary objective for meteorological monitoring is to document the atmospheric conditions and concomitant weather parameters that influence the environmental conditions in and around SNP. Meteorology monitoring has been closely tied to the air quality program as previously mentioned. Meteorological measurements include solar radiation, wind, relative humidity, precipitation, dew point, temperature, and the documentation of weather events. Protocols have not been written for SNP but are a collective result of national requirements for the air quality programs. Monitoring plans include the development of SNP meteorological protocols including the development of data management requirements to insure the inclusion of data into SNP's I&M database.

WATERSHED CHEMICAL PROCESSES

Watershed chemical processes were not included in the initial inventory list due to the lack of a resource process category. Water chemistry has been primarily a research effort that was initiated as a result of acid deposition research funding. This research effort was implemented through the University of Virginia and focusses on four watersheds which were described as a part of the water quality monitoring section. The most important watershed and the focal point for our long-term watershed chemical process monitoring effort is the Shavers Hollow watershed known as the Shavers Hollow Research Natural Area (RNA). The objective of watershed monitoring is to determine specific chemical process relationships. The result of this intensive effort has been the development of a computer model, Model of Acidification of Groundwater in Catchments (MAGIC), which allows for the prediction of changes in stream water chemistry based on inputs and chemical process relationships. MAGIC and associated research provided the basis for determination of adverse impacts of air quality deterioration on related Park resources in SNP. Continued funding from the park supports the water chemistry monitoring in the watershed.

Future research efforts are likely to focus on calibration and tuning of the MAGIC model as well as the

integration of the model with other watershed chemistry research. Future plans for watershed chemical process monitoring are focussed on developing ongoing cooperative research efforts, the acquisition of data sets for long-term archiving of information, and the evaluation of the park for development of an east side research natural area which will provide additional information on chemical process changes occurring on other representative geology types.

WATERSHED FOREST DYNAMICS

In association with the watershed chemical process monitoring is the watershed forest dynamics monitoring in the Shavers Hollow RNA. This effort is also a research effort which was initiated in the mid 1980's through the University of Virginia. The focus of this research is to understand forest stand dynamics through computer modelling. Over 200 permanent vegetation plots scattered throughout the watershed are the data source for this effort. Initial work focussed on forest gap models which were used to characterize present and future forest succession patterns. The gypsy moth has defoliated the majority of the watershed more than once. Due to the potential changes in species composition following gypsy moth related mortality, remeasurement of the plots is being done in 1992. Future plans for watershed forest dynamics monitoring include the continued development of ongoing cooperative research efforts, the acquisition of data sets and reports for the long-term archiving of information, and an evaluation of SNP's involvement in watershed forest dynamics monitoring for the I&M program.

RELATED LANDS

The related lands issue is an issue of landscape monitoring. Landscape monitoring focusses on a broad land surface area. Because of the vast material extent of a landscape the natural processes that change it generally proceed at a very slow rate. This slow rate means that monitoring frequencies are generally measured in decades or centuries rather than years. However, the rate of change associated with human-induced landscape changes can be measured in months or years. Land-use patterns are rapidly changing from the predominantly rural landscape to a landscape dotted by housing developments and roads. The changes in land-use patterns have the potential to destroy the continuity of park ecosystems and wildlife with the surrounding areas. Increased conflicts over access and wildlife related problems are on the rise. The related lands monitoring effort is documenting land-use patterns around the Park by developing computer based inventories or map themes with the GIS. Information from this effort will provide specific information on development threats and resources which are likely to be impacted or even lost. The related lands study was a contracted effort with the University of Virginia in 1991 and 1992 for two counties. The related lands I&M plan will be developed to outline the methods needed for inventorying the six additional counties. Monitoring efforts will focus on the use of available maps, photographs, and satellite imagery for documenting landscape changes.

HUMANS (VISITORS)

Visitor impacts on Park resources tends to be the result of trampling or the removal of a particular resource, however, the effects of visitors on overall park resources is primarily related to backcountry use. Trampling damage or compaction damage associated with campsites tends to be concentrated in human use zones such as around developed areas and along roads and trails. Resource removal such as

collecting rocks, plants, etc. can occur throughout the park but tends to also be associated with human use zones. The monitoring of visitors is the responsibility of the Division of Resource Protection and Visitor Management (RP&VM) and RP&VM staff are presently rewriting the Backcountry Management Plan. This plan will include a strategy on how the backcountry staff will monitor visitors and their effects. People monitoring includes determining how many are using the Park, where they are going, and how long they are in the various areas. Visitor monitoring and associated resource effects monitoring will be designed in association with natural resource inventory and monitoring efforts and should use NR&S staff expertise in developing appropriate related databases. Natural resource monitoring efforts can easily be expanded to include monitoring of resources in visitor use areas when feedback from backcountry visitor data indicates that visitors may be damaging or affecting the resources. An important focus of the backcountry management effort will be to correlate visitor use levels with a resource based carrying capacity.

IX. DATA MANAGEMENT

The Inventory and Monitoring Program is primarily a data collection process. It is an understatement to say that there will be a very large volume of data collected. Since monitoring is an ongoing process, the data sets will continue to grow indefinitely. The need to establish a good data management process early on in the program is absolutely critical.

A very thorough and comprehensive database format and management system was developed in Stage I as a model. The stage I database system is a customized software program written in DBASE III PLUS and compiled in Clipper. The emphasis was to standardize the database variables and develop a user-friendly data entry system. The program has a set of menus to guide the user through the various data entry and correction processes. Each data entry screen is similar in appearance to the specific data sheet which data is being read from and as the user enters the data, the program error checks the entries for spelling errors and values which are out of range. Data entry is easy and can be mastered by a field technician in a few hours. The custom software program will produce basic summary reports by plot. The system also allows the user to download data for individual plots or a combination of plots based on a specified common variable or variables.

The database is housed in a Dell System 325 microcomputer with a 327 Mb hard drive. Data is backed up on 20 Mb Bernoulli cartridges after each data entry or modification session. Backup copies of the database system and data are housed in the safe at SNP Headquarters. Additional I&M data summaries and analysis will be completed using SPSS Inc.'s SPSS/PC+ Version 2.0 statistics software or Ashton Tate's DBASE STATS program.

Future plans include the development of a local area network (LAN) for the new office building. A LAN will provide easy access to analysis software, backups for the entire system can be done on a regular basis by one person, and software updates or changes can be made in a consistent and timely fashion. The system will support individual work stations for each professional position, have a stand alone server computer, and a tape backup system.

Each resource protocol manual will have a DBASE III PLUS database (or dBASE IV when the program has proven to be reliable) developed to store, analyze and produce reports that are specific to the

particular needs of the manual. The initial approach to managing the Park's specialized database resulted in the present custom software program. Due to the dynamic process of monitoring, there will be a continued need to add data values to existing databases. The current software program does not allow for easy updating without having the original software developer rewrite the program. Future database efforts will concentrate on using simpler data entry approaches or preferably using hand-held electronic data entry devices in the field. Once the data is in a database, simple error checking programs could be used to verify data quality. Once the data is cleaned, error free data would then be summarized and analyzed using statistical analysis programs then appended to the original database for future use. Additional summary reports could also be written in dBASE III PLUS. With this procedure, an addition of one or more new variables will require only slight modifications to the summary programs rather than rewriting an entire data entry and summary program. Data collected will be entered into the computer during the field season so that huge volumes of data do not build up and become overwhelming.

The GIS will continue to be used to store, analyze and display selected data sets for which mapped information is useful.

X. QUALITY ASSURANCE AND CONTROL

Efficient design and appropriate standardization of monitoring methods is critical for valid integration, synthesis, interpretation, and assessment of results. The ability to implement standardized measurement procedures for data collection greatly enhances the assurance of quality data and directly influences the level of confidence placed on assessment and management decisions that are based on the results obtained from data analysis. For the LTEM program, where the primary objective is to determine changes in the ecosystems that occur over time, the use of standardized methods and procedures is an absolute necessity. Without standardized methods and consistent procedures for taking measurements across time, it will be impossible to determine if there are real differences in the attributes used to characterize and quantify a particular community, or if the differences are due solely or in part to the methods and procedures used to measure the attributes chosen to quantify the ecosystems in question.

Stage I of the I&M program established standardized methods and procedures for monitoring forest ecosystems, aquatic ecosystems, and gypsy moth populations so that data quality is documented and can be assessed, and that future measurements will result in valid comparisons. In order to ensure that the most applicable techniques and methods were used, the Park contracted with leading researchers to develop those techniques which are most reliable and have the greatest precision. An example of this approach can be found in Appendix II-D of the forest section of the "Shenandoah National Park Long-Term Ecological Monitoring System User Manual" where standard operating procedures (SOPs) for individual measurement techniques are described. Use of SOPs should reduce inter- and intra-site variability, reduce documentation requirements for future monitoring elements, and provide the management team with information on defined and documented quality. Standard operating procedures were based on the document "Quality Assurance Methods Manual For Forest Site Classification and Field Measurements" by S. M. Zedaker, and N. S. Nicholas, November 1989. The standard operating procedures outlined for other forest measurement instruments have been used as a standard for other measurements not listed in this prototype manual.

One of the first steps in assuring quality data and repeatable measurements is an intensive training

program for the employees who will collect the monitoring data. Before each field season begins, a training session is conducted which not only shows each participant the SOPs but also requires that each person demonstrate that they can carry out the procedures. Each crew member is also required to have a copy of the SOPs with them for reference when performing monitoring duties. Project managers also work with the crews on a regular basis to ensure that standard techniques are being

adhered to and to resolve any discrepancies that arise in the field. Field technicians are also checked for accuracy on a regular basis.

During Stage II of the monitoring program, standardized methods and procedures as well as accuracy tolerance limits will be established for measurements associated with each resource element that will be monitored. Quality control guidelines are paramount for the success of a monitoring program. If accuracy limits are not adequate then it may be impossible to document change in the system being monitored.

A major concern for monitoring data is not only the quality but also compatibility. Efforts will be made to ensure that the data collected from new monitoring efforts will be compatible with information already collected or with other research being done. New monitoring protocols will be developed with the help of leading researchers and scientists through both contracts and informal consultation. Other outside researchers and resource managers will be sped to review and critique the newly suggested monitoring protocols.

XI. 5-YEAR IMPLEMENTATION STRATEGY

This section of the plan contains the strategic part of the planning process. To simplify this process it was decided that the best way to present this complex set of information was to use charts rather than a lengthy narrative. This section can be easily updated without effecting the rest of the plan.

The principles of strategic planning include three primary actions: developing the vision, defining a course of action that is time referenced, and incorporating a process of evaluation and refinement. In the case of this plan the vision is the conceptual model of the completed monitoring program. The course of action is shown in a series of tables.

Table 1 lists each resource element outlined in the Stage II section describing the development of the conceptual model and the time frame for research and design, protocol publication, and protocol implementation. The intent is to adhere to this schedule, however because of the uncertainties of this new program, future adjustments may be needed.

Table 2 provides a cost analysis by program function. These costs include all NPS staff time dedicated to the monitoring program, infra-structure development, capitalized equipment, contract costs, equipment, supplies, and other program support. Two figures are listed in each column. The first figure is park base funding. The figure in parenthesis is base funding enhancement from WASO. The total of these two figures represents the full amount of funding applied to the I&M program.

Table 3 shows NPS staff positions that will be either totally or partially dedicated to the I&M program at

the full funding level, and the approximate personnel services costs of these positions. An asterisk (*) indicates those positions that exist at the present time.

Table 4 is a organizational chart that shows the relationship of the monitoring staff positions to the rest of the Natural Resources and Science Division.

Table 1.

Table 2.

TABLE 2 (Supplement): NARRATIVE DESCRIPTION

Management and Supervision:	1 FTE GS-12 Supv. Ecologist, .1 FTE GM-13 Supv. NRS.
Infrastructure Development:	Construct I&M Technical Center, furniture.
R&D for protocol Design:	.5 FTE GS-9 Botanist, .5 FTE GS-9 Natural Resource Specialist plus contracts.
Monitoring (Data Collection):	.5 FTE GS-9 Botanist, .5 FTE GS-9 Natural Resource Specialist, 4 FTE seasonal GS-5 Bio-tech, SCA & Volunteer quarters.
Sample Processing and D.A.:	Lab processing of water samples, macroinvertebrate I.D., etc. and data reduction.
Administrative Support & Publications:	1 FTE, GS-7 Office Automation Assistant, .5 FTE GS-3 Clerk Typist.

Capitalized Equipment: Vehicles, computers, scientific equipment.

Data Management:	1 FTE, GS-11 Data Manager, LAN installation, software.
GIS Support:	.5 FTE GS-7 Technician
Support and Supplies:	Building Maintenance, phone, electric, supplies.
MARO Assessment:	Regional Office assessment of budget allocation.

Table 3. NPS STAFF POSITIONS

Program Manager, Supervisory Ecologist GS-12..... $55,000 *

Database Manager, Ecologist GS-11..... $45,000 *

Publications & Admin. GS-7, Office Automation Asst..... $30,000 *

AQ Monitoring Technician GS-7/9 and Support..... $45,000 *

GIS Support, .5 FTE GS-7 Cartographic Technician..... $15,000 *

Data Collection and Field Supervision, GS-9 Botanist..... $40,000 *

Data Collection and Field Supv., GS-9 Natural Res. Specialist..... $40,000 *

Field Data Collection, 3 FTE GS-5 Seasonal Bio-Technician..... $60,000 *

Field Data Collection, 2 FTE GS-5 Seasonal Bio-Technician..... $40,000

Protocol Develop., Data Collection, GS-11 Ecologist (Invert)..... $45,000

Total $415,000

Table 4. Organization chart

XII. REPORTS AND PUBLICATIONS

An active I&M program is incomplete if the data that has been carefully collected and stored is not summarized and the results published and distributed and the information gained applied to management of the resources. The initial result of an inventory is a species list with abundance values and a set of locations that results in a range or distribution. The initial result of monitoring is usually a characterization of the resource element. The long-term objective of monitoring is to document changes in abundance, range or a relationship with an ecosystem process. It is recognized that several years or even decades of high quality monitoring data may need to be collected and analyzed for some elements before any significant trends can be detected. In spite of the long-term nature of monitoring, a program goal is to compile and analyze all data sets annually.

Phase I provided a basic resource inventory and the data necessary to characterize the forest vascular flora and several elements of the aquatic ecosystems. The continued development of species lists and data summaries are being used as a foundation for a complete resource characterization. Annual reports will document the progress of the program and will also be used to archive the data on paper. This process will be used for Stage II data sets.

The results of the Park's I&M program are and will continue to be distributed to a wide range of audiences. The following types of publications have been identified as potential outlets for I&M results:

1) Each year an annual report will be produced that will document the progress of the I&M program. This will be a summary report providing a printout of the data collected during the year, basic data summaries, and a narrative detailing the progress of the program. The report will be published one year after the completion of each field season.

2) Following the completion of an inventory project or the summary and analysis of a monitoring element, a special report will be written in an informative style and presented to the Division of Interpretation and Visitor Services (I&VS). The purpose of this report would be to provide a steady stream of information to the interpretive staff to be included in Park publications and interpretive activities.

3) The information summarized in number 1 and 2 above, as well as additional progress reports, will also be communicated to the public through short informative articles published through local newspapers and popular magazines. The objective of this effort would be to provide the public with pertinent information on the status and health of Park resources as well as to provide information about present and future threats. An ongoing effort will continue to be made to work with reporters and correspondents as they pursue stories which are of interest to the news media.

4) I&M protocols including methodology, techniques, and quality assurance requirements will continue to be published through the NPS Publications Office. New manuals would be added to the "Shenandoah National Park Long-Term Ecological Program User Manuals" series.

5) The characterization of Park resources and eventually the documentation of trends will be published, when considered appropriate, as peer reviewed monographs, or will be submitted for publication in one of the more recently established popular journals. In this way, basic ecological information will be shared with other professionals dealing with research or management of natural areas, parks, rare species, and land preservation.

6) I&M results can potentially lead to uncovering new scientific information, the documentation of ecological cycles, and the validation of ecological theories. Any new scientific information resulting from the I&M program would be published in peer reviewed articles in the appropriate scientific journals. The typical journals where some of the information would likely be published would be Castanea, Bulletin of the Torrey Botanical Club, Ecology, and Journal of Wildlife Management. Benefits associated with publishing in peer reviewed journals include: increased recognition that the NPS is producing scientifically-critiqued research and monitoring, a broader dissemination of scientific results to the scientific community, and the establishment of information which could potentially encourage additional research or monitoring in NPS areas. The additional activity that may be encouraged would highly benefit the SNP, especially since many of the research projects may be funded through grants from outside the NPS.

7) The other outlet where I&M information would be disseminated would be through the Biennial SNP Natural Resources and Science Research Symposium and other professional level meetings. A typical product associated with such a meeting would be the compilation of abstracts in a symposium summary document.

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