Work Plan

Ecosystem Characterization and Monitoring Initiative (ECMI)

Strategic Environmental Research and Development Program Ecosystem Management Project (SEMP)

US Army Engineer Research and Development Center

Environmental Laboratory, Vicksburg, MS

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Foreword

This work is being conducted for the Strategic Environmental Research and Development Program (SERDP) under the "SERDP Ecosystem Management Project (SEMP) Ecosystem Characterization and Monitoring Initiative." Mr. Brad Smith is the Technical Director, SERDP. The technical monitor is Mr. Robert Holst, SERDP Conservation Program Manager. The SEMP manager is Mr. William Goran, USAERDC.

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Work Plan: SEMP Ecosystem Characterization and Monitoring Initiative (ECMI)

1. Introduction

Background

The Strategic Environmental Research and Development Program (SERDP) is the Department of Defense's (DOD) corporate environmental R&D program. Major goals of the program are to:

- Resolve environmental concerns in ways that enhance military operations, improve military systems' effectiveness, and help ensure the safety of personnel.
- Support technology and process development that reduce operational and lifecycle costs, including those associated with environmental cleanup and costs of full compliance with environmental laws and regulations.

The program focuses on four major technology areas: Cleanup, Compliance, Conservation, and Pollution Prevention. Within the conservation arena, SERDP enhances mission readiness through environmental research leading to prudent conservation measures that enhance training, testing, and operational readiness. Descriptions of recent and on-going conservation R&D projects supported by SERDP can be found at the SERDP web site at *www.serdp.gov*.

DOD policy has established ecosystem management as its approach to management of military lands. The overall goal is to maintain and improve the sustainability and native biological diversity of terrestrial, freshwater, and marine ecosystems while supporting human needs, including the DOD mission. (DUSD[ES] 8 August 1994 Memorandum to all Services; DOD Instruction 4715.3, *Environmental Conservation Program;* see also Leslie et al, 1996*)*. Presently, there are gaps in fundamental knowledge and understanding of ecological processes that hinder the ability of DOD to achieve this goal. Filling these knowledge gaps is critical to long term sustainability of DOD lands for mission essential training and testing activities.

Having recognized that SERDP is in a unique position to address this problem, the SERDP Scientific Advisory Board recommended organization of a workshop to help identify critical deficiencies and research opportunities in fundamental ecological science applicable to ecosystem management problems on defense installations. This workshop, the *Management Scale Ecological Research Workshop*, was held during June 1997. It included leading ecological and environmental scientists, DOD natural resources managers, and advisors and observers from relevant Federal agencies and nongovernmental organizations. The major findings to emerge from the workshop follow (Botkin et al. 1997):

- <u>Ecosystem Science:</u> It is now recognized that ecosystems are non-steady state. Previously, management plans typically were based on the assumption that ecosystems exist under natural conditions in a single steady state. Under the old paradigm, disturbances were prevented to achieve a natural condition. Under the new paradigm, the focus shifts to sustainability of the system within intrinsic boundary conditions.

- <u>Adaptive Management:</u> Adaptive management is a requirement driven by the inherent uncertainty in natural systems that are non-steady state. The dynamics and unpredictable behavior of these systems requires development of a systematic learning process that helps to improve management over time to achieve sustainable end points.

- <u>Disturbance as a Key:</u> Ecosystems are subject to changes in state as a result of natural disturbance regimes.

Understanding such dynamics is key to management of the system.

- Historic Range of Variation: This provides a baseline for determining whether ecosystem management strategies are successful. Therefore, an important activity is to characterize ecosystem trajectories and historic range of variability.

- Disturbance Caused by Military Activity: This can be a means to learn how to manage efficiently and effectively for ecosystem recovery. Integrating ecosystem research and monitoring with military training may provide insights to improve management iteratively. Shortening the restoration time has direct timely benefits to the mission.

- Ecosystem Health: Efforts to identify indicators of ecosystem health or sustainability have largely been unsuccessful. Measures are needed and should be incorporated into long term monitoring.

- Ecological Thresholds: Some evidence exists that ecological thresholds do exist, and these have serious implications for establishing thresholds for management action.

SERDP Ecosystem Management Project

Results of the *Management Scale Ecological Research Workshop* (the Workshop) serve as the basis for SERDP's Ecosystem Management Project (SEMP) which was initiated in December 1997 with the assistance of the US Army Engineer Research and Development Center (USAERDC) (Goran 1998). The overall goal of the SEMP is to orchestrate an ecosystem management research and monitoring initiative that addresses DOD requirements and opportunities for ecosystem management research as identified by the Workshop. Specific objectives are to:

- Establish a long term research sites on DOD lands for military-relevant ecosystem research.
- Conduct ecosystem research and monitoring activities relevant to DOD requirements and opportunities.
- Facilitate the integration of results and findings of research into DOD ecosystem management practices.

Fort Benning, Georgia, has been selected as the first site for implementation of the SEMP. Known as the "Home of the Infantry," this182,000 acre area is of critical importance to the Army's training mission. The Fort is located in portions of both the Piedmont and Upper Coastal Plain physiographic provinces in southwest Georgia and southeast Alabama. It is an area of significant biological diversity, harboring a number of threatened and endangered species and natural communities.

A working group consisting of DOD land managers and scientists and academicians was convened during FY98 to develop the SEMP research agenda and formulate statements of need (SON) for research to begin in FY99. The current agenda addresses four major research themes: ecosystem indicators, disturbance regimes, ecological thresholds, and adaptive management. SERDP released an SON addressing ecosystem indicators in June 1998. SON's addressing the other research themes are in development. An ecosystem characterization and monitoring plan is also being developed with the express purpose of supporting SERDP's research and development investment under SEMP. The latter is the focus of this work plan.

2. Goals and Objectives

Ecosystem monitoring is a daunting task simply because ecosystems are poorly understood, complex systems subject to stochastic variation and unpredictable behavior (Noon et al. 1997). Consequently, ecosystem monitoring and research are inextricably entwined and mutually dependent. Success of the SEMP research effort is dependent upon integrated monitoring and research programs.

The goal of the ECMI is to design, develop, and demonstrate an ecosystem characterization and monitoring concept that meets the needs of the SEMP. While Fort Benning will serve as the initial demonstration site, the ECMI is intended to have broad applicability across the DOD. Research issues identified in the workshop findings and the information needs of DOD installations, as reflected at Fort Benning, will serve as a framework in this effort. The monitoring program itself will complement and support the SEMP research initiative and on-going land management by providing a baseline of ecological data and information on selected sites for use by SEMP research participants and partners and DOD land managers. Broadly speaking, the intent is to characterize the biotic and abiotic elements and associated processes and properties within the ecosystem(s) associated with selected research sites. The ECMI will address both spatial and temporal dynamics within aquatic, riparian, and terrestrial settings in a manner consistent with the needs of the research and land management communities.

3. Approach

This work will be executed by the US Army Engineer Research and Development Center. External support will supplement the USAERDC as appropriate. Work is on-going with Clark Atlanta University, and pertinent coordination will continue with various SEMP working group members, the newly formed SEMP Technical Advisory Committee (TAC), and state, federal, and nongovernmental agency personnel, and others. Primary stakeholders in development of the ECMI include researchers funded by SERDP to execute SEMP research on Ft. Benning and Fort Benning land and range managers. The primary contacts at Fort Benning for this effort are Mr. John Brent and Ms. Theresa Davo. Research participants are not yet determined.

Specific tasks necessary to accomplish the above goals and objectives include:

- Inventory and document existing data and on-going monitoring programs
- Design the baseline monitoring program
- Implement the baseline monitoring program
- Establish and maintain a data repository
- Adapt the monitoring program

4. Scope

The ECMI will address national, regional, and local ecosystem level monitoring issues relevant to the DOD. While the present focus is on the Fort Benning demonstration, guidelines developed are intended to be generic enough to apply to other installations in the region, and serve as a model for application in other ecoregions. The ECMI will provide access to available data and information compiled in electronic format via the proposed repository. Primary monitoring data will be made accessible through this same repository for use and analysis by appropriate research and land management personnel. Needs for specific data analyses, information syntheses, and reporting will be determined during the course of the first year effort. Priorities will then be established for future work addressing specific syntheses and reporting requirements.

A prototype ECMI concept is described in Appendix A and illustrated in Figure 1. Initial design criteria are presented in Appendix B. Monitoring variables recommended by the National Science and Technology Council's Committee on Environment and Natural Resources to fit into a proposed framework for a National environmental monitoring and research network are listed in Appendix C.

5. Work Plan

Each of the following tasks is a critical element in meeting the goals and objectives of the ECMI as described above. A summary of the milestone and product delivery schedule is presented in Table 1.

Task 1. Inventory and Document Existing Data and On-going Monitoring Programs

An inventory will be conducted of data existing on site at Ft. Benning and of data available pertaining to the applicable ecological region around Fort Benning. A matrix will be developed documenting the type of data (aerial/satellite imagery, geospatial, weather, wildlife, LCTA plots, water quality, etc.), and identifying data format, spatial and temporal frequency, and method of collection. This task will address both spatial and nonspatial data.

Specific subtasks necessary to accomplish this task are:

1. Inventory and document on-site data: Develop an inventory of data currently existing at Ft. Benning. The inventory will include geospatial data, non-spatial tabular data, and in-house and contractor reports which contain data. The documentation will include the data POC, physical location, format, definitions of all variables and attributes, data collection techniques and sampling design, planned uses, etc. Additional work under Task 5 below will be conducted to evaluate the available data and identify the most efficient means of making these data accessible to research partners.

2. Inventory and document regional data: Work will be initiated with appropriate government and nongovernment agencies to document and evaluate existing environmental data relevant to a suitable, ecologically defined region surrounding Fort Benning. The geographic extent of this region is being established as a separate action under the direction of The Nature Conservancy.

3. Inventory and document existing and on-going monitoring programs: Recent and on-going natural resource characterization and monitoring programs throughout the region will be identified and documented. Other national or regional inventory and monitoring programs outside the region will be examined to the extent that the methodology used may be relevant to ECMI.

Milestones and Products

This task will result in a documented environmental data inventory covering both Fort Benning and the surrounding ecoregion. Specific milestones and products follow.

Milestone	**Date**
Complete on-site data inventory	12/98
Complete regional data inventory	02/99
Complete ongoing monitoring program inventory	03/99

Products	**Date**
Technical Report - Inventory Report	04/99

Task 2. Design Baseline Monitoring Program

The objective of this task is to identify the baseline ecological attributes that will be initially monitored at Fort Benning and to develop protocols for the collection of this information. This task will also identify gaps in existing characterization and monitoring data.

1. Identify research and management information needs: Information needs will be identified as an extensive list of potential baseline monitoring variables. Determination of information needs will be made in conjunction with scientists and land managers from Fort Benning, and the surrounding ecoregion. Evaluations will be made of available literature, ecological models, and environmental data and information. Two workshops will be conducted as part of the identification process.

2. Establish criteria for selection of baseline monitoring variables. This subtask will establish criteria for evaluating, and prioritizing the list of information needs identified in subtask 1. The purpose of these criteria is to provide an objective, scientifically based rationale for the final selection of characterization and monitoring variables to be included in the ECMI program. Potential criteria include but are not limited to:

- Research and management goals
- Ecological processes most directly associated with those goals
- Relevance to key ecosystem processes and properties
- Military training activities that impact underlying ecological processes and potentially affect the attainment of management goals
- Requirements of current and emerging ecosystem models
- Ability to detect meaningful change
- Relationship to human caused change and management objectives
- Availability of suitable data acquisition methodologies
- Cost and logistics of data collection

A selection process that incorporates these factors will ensure that ecological characterization and monitoring variables selected will adequately address research and management needs at Fort Benning. It will also help to identify redundant information so that new data collection efforts can be held to a minimum. Finally, it will allow prioritization of different information requirements. Since current and future information needs are expected to exceed available funding, prioritization of information needs will ensure that the most important information needs are identified and addressed first and most thoroughly.

3. Evaluate, prioritize, and select baseline monitoring variables: The selection criteria established in subtask 2 will be applied to the information requirements list developed in subtask 1. The selection process will serve to reduce the universal set of information requirements to a limited number of baseline variables proposed for implementation.

4. Develop sampling and data analysis protocols for selected baseline variables: Sampling plans will be developed for the attributes selected in subtask 3. These plans will be designed to provide the a) spatial and temporal coverage necessary to meet characterization and monitoring objectives, b) the sample sizes needed to achieve an appropriate degree of precision, and c) the optimal balance of precision, accuracy, and cost. Development of sampling protocols will be an iterative process that involves potential users of the data. Data collected by sampling methods must be summarized in ways that are useful to participating research ecologists as well as site managers. Issues of stratification and eventual data role-

ups will be important considerations. Statistical data analysis procedures, appropriate for each variable and sampling design, will be specified as part of the sampling design.

Milestones and Products

This task will result in the final logical, physical and statistical sampling design for ECMI at Ft. Benning. Specific milestones and products follow.

Milestone	**Date**
Identify information needs	01/99
Establish criteria for selecting baseline variables	01/99
Select baseline variables	02/99
Complete sampling and analysis protocols (including peer review by the TAC)	04/99

Products	**Date**
Technical Report - Selection Process of Baseline Monitoring Variables for Ft. Benning ECMI	03/99
Technical Report - Sampling design and recommended data analysis procedures for Ft. Benning ECMI program	05/99

Task 3. Implement Baseline Monitoring Program

This task implements, at Ft. Benning, the monitoring plan designed in Task 2. It includes acquisition, testing, calibration, deployment and maintenance of automated and non-automated field equipment. Appropriate quality control procedures will be employed in every phase of implementation. It also includes the initial reduction of raw field data and the temporary data storage prior to submission to the repository.

1. Develop implementation plan: An implementation plan will be developed. The plan will include an instrumentation and automation sub-plan designed to maximize the use of COTS electronic measuring devices, automation equipment and remote sensors for the acquisition, processing, and transmission of field collected data. For portions of the sampling design that cannot be automated, appropriate manual data collection procedures will be defined. The implementation plan will take into account the need to fill data gaps identified during the sampling design phase. The plan will also address the acquisition and calibration of monitoring equipment, personnel training, and logistical and organizational issues pertinent to field implementation and testing of the monitoring program

2. Conduct reconnaissance of proposed monitoring locations. A field team will conduct a reconnaissance level examination of all the proposed monitoring locations to assess their suitability, physical access requirements, and potential as a long term field monitoring site. The team will also determine the need for survey ground control to support the monitoring program.

3. Acquisition, test and calibration of field equipment and sensors. Sensors and field monitoring equipment will be evaluated, selected, acquired, tested and calibrated. The task will include a bench test of new equipment, limited field tests and if necessary full up tests at a site off-base in preparation for deployment at Ft. Benning. For each sensor type to be used, establish data handling, initial data reduction

and temporary data storage procedures.

4. Deploy monitoring network and test non-automated monitoring activities. Automated monitoring equipment will be deployed and tested at selected sites. Manual techniques to be used will be tested and evaluated.

5. Initiate field monitoring program. All remaining monitoring sites and equipment will be put into place and tested.

6. QA/QC equipment operation, measurement procedures and data flow. During the first year of operation, continuous QA/QC of equipment and procedures will be conducted. Equipment replacements, re-calibrations, and modifications to data handling procedures will be made.

Milestones and Products

Milestone	**Date**
Site suitability reconnaissance	03/99
Implementation plan	04/99
Equipment acquisition and calibration	06/99
Deploy and test field equipment and procedures	07/99
Initiate monitoring program	09/99

Products	**Date**
Report – Implementation Plan	05/99

Task 4. Establish and Maintain Data Repository

Environmental data are useful only to the extent that they can be made readily available to potential users. An electronic data repository will be developed that incorporates the information delivery requirements of potential users. It is anticipated that the data repository will incorporate information from different sources and hardware platforms, will provide data exploration capabilities, and will be accessible to users via the Internet. The repository will accommodate geospatial data, tabular data, and electronic documents.

1. Data repository conceptual and physical design: Recommend a format for compiling and storing currently available data and future monitoring data. Determine the most appropriate means for making these data and information available to research personnel, site managers, and others as appropriate.

2. Construct phase I repository and compile available data: Available baseline data and information will be compiled into the repository as a test of the design. Both the installation and regional data and information will be included to the extent possible and appropriate.

3. Methodology for screening and approving contributions to the repository: Standards and procedures for submitting data to the repository will be developed and a methodology for evaluating data submissions against these requirements will be established.

4. Establish repository access, search and retrieval procedures: Repository access and retrieval will initially be password limited to those directly involved in the ECMI. Procedures will be established and tested for long term access to the repository after the initial period.

5. Develop QA/QC protocols: Develop a plan for periodic quality assessment of the repository contents, documentation and access protocols. Recommend modifications for adaptation to technology enhancements and changes in the monitoring program.

Milestones and Products

Milestones	**Date**
Repository design	06/99
Phase I repository	08/99
QA/QC Plan	12/99

Products	**Date**
Report – Design document	07/99
Phase I repository on-line	09/99
Report – QA/QC plan	12/99

Task 5. Adapt Monitoring Program

The baseline monitoring program will be reviewed annually. Modifications and improvements will be proposed based on results of the monitoring activity, SEMP research results, emerging technology opportunities, and new management requirements and priorities. A conservative approach will be taken in order to maintain the integrity of the database for the long term.

1. Evaluate first year monitoring data. As part of the ongoing ECMI performance evaluation, the monitoring data collected during the first year of the program will be summarized, documented, presented and critiqued. An independent technical review of these data will also be requested.

2. Solicit recommendations for improvements and modifications. Recommendations for modifications to all aspects of the ECMI will be reviewed annually including sampling design, data reduction and handling and repository function.

3. Incorporate enhancements as appropriate. Approved modification to the monitoring plan will be implemented in appropriate manner, mindful of the need to conserve the integrity of the long term data set.

Milestones and Products

Milestones	Date
Evaluate first year data	12/00
Assess adaptation recommendations	02/01
Implement adaptations	04/01

Products	Date
Report – First Year Data	12/00
Report – Documented Changes to Monitoring Plan	annual

6. Estimated Cost

Estimated cost to complete the proposed work during FY99 and FY00 by task is identified below. Costs are tentative depending upon the results of the data and information inventory, the extent of critical data gaps, and the ultimate scope of the monitoring program.

Tasks	FY99 (000)	FY00 (000)
1. Inventory Existing Data and Monitoring Programs	$100	
2. Design Baseline Monitoring Program	$300	$70
3. Implement Baseline Monitoring Program	$500	$130
4. Establish and Maintain Data Repository	$100	$200
5. Adapt Monitoring Program	$50	$200
Total	**$1050**	**$600**

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Appendix A: Preliminary Ecosystem Characterization and Monitoring Concept–Measuring Selected Variables in Time and Space to Detect Change.

The preliminary concept for the ECMI is illustrated in Figure 1; it is adapted from MacDonald (1994). Individual steps in the process are described below. It is not essential that each of the steps be executed in the order shown, but each is a necessary component in the process of developing a monitoring program serving the diverse needs of relevant stakeholders.

Formulate objectives: General objectives of the monitoring program are to be identified by appropriate stakeholders. The latter include, at a minimum, research scientists and DOD land and range managers as the ECMI is intended to support the needs of both ecosystem research and management. Both groups, however, must be fully aware of the overriding resource management issues at stake in supporting the ultimate goal of DOD, which is to maintain a trained and ready fighting force.

Define resource constraints: This is necessary to ensure that the subsequent monitoring plan is realistic in scope.

Compile/review existing data: An inventory and compilation of available and relevant data are necessary in order to assess the magnitude of the spatial and temporal variability of the system to be monitored. It is also important to avoid repeating mistakes of the past and to use this information base in developing a conceptual model of the ecosystem under management.

Develop a conceptual model of the ecosystem: A conceptual model of the system under management provides both a summarization of our current understanding of the ecological processes and the impact of land use and land management on those processes. It also provides the basis for articulating specific hypotheses that can be evaluated through the monitoring program. Such a model and attendant hypotheses, at whatever level of specificity can be attained, are guides for selecting key variables for monitoring.

Identify specific objectives and information requirements: This is perhaps the most difficult yet important step of the process. Managers, scientists, and technical staffs must work together to clearly define specific goals and objectives of the monitoring program and use these as a basis for identifying specific information requirements.

Define monitoring variables, sampling frequency and location, and procedures: Selecting the variables to be monitored and the specific sampling design developed follows directly from: (1) agreed upon goals and objectives; and (2) current understanding of the structure and function of the system under study and management, and (3) the research and management questions important in helping us better understand the system (Soballe 1998). Frequency, duration, and location of monitoring are determined based on statistical considerations in the context of agreed upon goals and objectives. There will be takeoffs among sample size, variability, confidence level, and power. Quality control/quality assurance procedures must be addressed here as well.

Evaluate whether data meet proposed monitoring objectives: Specific hypotheses may be evaluated with existing data, if available. This will be helpful in refining field procedures and determining whether the specific monitoring objectives are attainable. For any given variable, there may be a variety of procedures and sampling designs that could be applied. Evaluating these with available, or even hypothetical, data will help in refining the definition of experimental units to ensure relevance to the questions at hand.

Evaluate whether the proposed monitoring program is compatible with available resources: This provides an opportunity to evaluate takeoffs between cost and data collected. Informed choices can be made regarding needed modifications in the scope and objectives of the program or in the resources budgeted. Note, however, that there is a danger in adjusting sampling intensity to reduce costs to the extent that expectations remain unchanged while the capability of the monitoring program itself is reduced.

Peer review: Peer review is essential to reduce the likelihood of serious problems, and helps maximize the efficiency and relevance of the monitoring project.

Initiate monitoring on a pilot basis: This step begins the data collection process. However, it is intended as a pilot under the realization that there are many uncertainties that need to be overcome – technical and logistical. Data will need to be evaluated in a timely manner so that adjustments can be made before subsequent rounds of data collection. Extending the design phase of the monitoring project in this way is the basis for an adaptive approach. It also provides an opportunity for users of the data and information (researchers and land managers in this case) to evaluate the utility of the data to their particular needs. Clearly, it is better to make changes early in the monitoring program to avoid discontinuities later.

Analyze and evaluate data: Provisions need to be made for timely analysis of data collected.

Evaluate whether the monitoring program met objectives: This is another check on the merits of the program relative to the objectives and information needs defined above. This evaluation should include review by both research and land management personnel.

Continue monitoring, data analysis, and data storage: When the monitoring program is determined to meet agreed upon objectives and information needs, the monitoring, analysis, and data storage protocols are finalized. Changes in data collection procedures and sampling design are to be discouraged beyond this point.

Evaluate data relative to system thresholds, standards, and hypotheses: Resulting data can now be evaluated relative to specific thresholds and standards of importance in determining the need for management actions (Hardesty et al. 1997). They can also be evaluated in terms of specific hypotheses defined with regard to ecosystem structure and function.

Synthesize available data and make recommendations: The resulting data and information are further synthesized on a periodic basis in accordance with documented needs. Recommendations may also be made with regard to implications for management and research and to enhancements warranted in the program.

Appendix B: Design Considerations

There are four major principles upon which the ECMI will be developed beyond parameters set by SEMP's major research themes.

- Elements of Ecosystem Management
- Incorporate Monitoring within an Ecosystem Management Protocol
- Link Science, Land Management, and Data/Information Requirements
- Incorporate Adaptation into the Monitoring System

Elements of Ecosystem Management

Ecosystem management can be defined as "management driven by explicit goals, executed by policies, protocols, and practices, and made adaptable by monitoring and research based on our best understanding of the ecological interactions and processes necessary to sustain ecosystem composition, structure, and function" (Christensen et al 1996). Key to this and other definitions is the concept of sustainability, i.e., sustaining ecosystem structure and function to meet the needs (social, economic, and environmental) of present and future generations. Balancing these competing needs to achieve the goal of sustainability is one of the essential challenges of ecosystem management (e.g., Kaufmann et al. 1994). It is applicable across federal land management agencies, including the DOD.

Variables selected for monitoring under the SEMP should be linked to key elements of ecosystem management (see Christensen et al. 1996). Specifically, they should:

- Focus on long term sustainability of key ecosystem processes rather than on system outputs in the short term., including forces that enhance the ability of the system to maintain resiliency in the face of disturbance.
- Be based on measurable goals defined in terms of key ecosystem processes as they relate to sustainability.
- Utilize sound ecological models to define system understanding and as a basis for selecting measurement data at all levels of organization.
- Include measures of system complexity and connectedness.
- Characterize the dynamics of the ecosystem under study.
- Define the context and scale in terms of both mission and stewardship goals and activities.
- Incorporate mission use and stewardship as primary factors affecting ecosystem dynamics beyond natural disturbance regimes.
- Be adaptable in response to new models and information while providing information relevant to land management activities.

Incorporate Monitoring within an Ecosystem Management Protocol

A challenge faced by the ECMI as well as the SEMP overall, is the need to integrate the monitoring effort into a recognized ecosystem management process or protocol.[1] The underlying assumption here is that for SEMP and the ECMI to result in direct benefits to DOD ecosystem management activities, it is necessary that the science and monitoring be tied to an explicit business process or management model.

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[1]While an ecosystem management protocol is being addressed by another subgroup of the SEMP working group, this issue presently cannot be ignored in development of the ECMI.

Otherwise, the SEMP and ECMI activities risk being irrelevant to their ultimate purpose – supporting DOD ecosystem management capabilities and, ultimately, national defense readiness.

While the ECMI is intended to support the SEMP scientific research agenda, its ultimate utility in enhancing military land management hinges on its establishing relevance within a land management context. Thus, in regard to the process of ecosystem management, the protocol illustrated in Figure 2 is proposed (modified after Stanford and Poole [1996]). This protocol provides a useful basis wherein to view the role of science in ecosystem management as well as more specifically to view the mutually supporting roles of research and monitoring, as envisioned under the SEMP. It also illustrates the role of stakeholders, or the human dimension, in ecosystem management, i.e., the need to address human values. In the present case, this includes, at a minimum, both military mission and stewardship values. The following description of Figure 2 is modified from Stanford and Poole (1996) to meet the needs of the SEMP:

- *Synthesize the Knowledge Base:* A common pool of empirical information should be established at the outset to ensure that the ecosystem management process is based on facts rather than opinion. A sound knowledge base is necessary throughout the ecosystem management process to separate opinion and bias from empirically generated knowledge. The best available science and information must be used to define the composition, structure, and function of the ecosystem. This includes identifying key ecosystem properties and developing conceptual models of critical ecosystem processes. The SEMP is founded on the principles that there are significant gaps in our understanding of ecosystems, and that scientific research is needed to advance our understanding of key ecosystem processes as a basis for improved ecosystem management capabilities. Key ecosystem processes and properties are those for which fundamental understanding is needed to help ensure that the goals of ecosystem sustainability can be achieved. At the most basic level, these include (Christensen 1996):

    - Hydrologic flux and storage
    - Biological productivity
    - Biogeochemical cycling and storage
    - Decomposition
    - Maintenance of biological diversity

- *Define the Ecosystem:* Ecosystem boundaries are open with respect to the flux of energy and materials. Although difficult to define spatially, regional synthesis and modeling of available information provide a starting point. At a minimum, the ecosystem must incorporate the area necessary to address the largest ecological processes of concern without ignoring processes at smaller scales and linkages among scales.

- *Identify Goals:* Goal setting is based on both scientific synthesis and stakeholder values. This should involve some form of scoping process including a debate on the relative importance of different ecosystem values as they relate to DOD's military and stewardship missions. The objective is to seek consensus about management goals rather than specific management alternatives, the latter often being more contentious than the former.

- *Develop a Management Strategy:* Having synthesized knowledge about the system under management and identified the management goals, it will be possible to design a management strategy that includes either a single best approach to achieving goals or a set of reasonable alternatives that can be tested via a research plan.[1] A research agenda and monitoring plan should be incorporated into the strategy to address critical uncertainties

[1]Stanford and Poole (1996) advocate a single strategy without competing alternatives.

and risks. The monitoring plan may include elements of effectiveness, validation, and baseline monitoring depending on the situation.

- *Implement the Management Strategy:* Implementation of the management strategy will proceed assuming that a consensus is achieved that the plan will meet the goals and that associated risks and uncertainties are adequately addressed.

- *Conduct Research and Monitoring:* New information is to be generated through research and monitoring to better define and understand ecosystem boundaries and processes, refine management goals, improve management strategies, and alter management actions as appropriate.

This approach demonstrates a clear role for science throughout the ecosystem management process. This is consistent with the SEMP's goal of improving fundamental understanding of ecosystem processes and properties as a basis for improved ecosystem management.

Link Science, Land Management, and Data/Information Requirements

While the SEMP research initiative is a primary driver for the ECMI, land management issues must also be addressed to maximize value-added. Lacking a close tie among these elements will lead to a one-dimensional monitoring protocol that will be impossible to sustain in the long run. Thus, it will be necessary to explicitly link the needs of scientific research and land management to the specific data and information collected and developed through the ECMI.

While this linkage may be established in several ways, one certainty is the requirement for a common understanding of the system under study and management. In its simplest form, as illustrated in Figure 3, this involves coming to agreement on a conceptual model (s) of the ecosystem under management. Components of this conceptual model are expected to relate to fundamental ecosystem processes.

Coming to agreement among the stakeholders as to the appropriate conceptual model(s) of the ecosystem will help ensure that the data collected and information generated will have common utility among both researchers and land managers. While this might not fully limit the monitoring data and information required to support the SEMP, it will go a long way toward focusing on those data most pertinent to advancing the cause of ecosystem management within the DOD.

Incorporating Adaptation into the Monitoring System

Here we accept that there is a considerable degree of uncertainty both with regard to the dynamics of the system under study and the considerable challenges in the logistics of fielding the monitoring system. In order to maximize benefits to both science and management over the life of the initiative, i.e., to best address the range of possible research and management issues, it is necessary that means be established to incrementally improve the system through learning over time without disrupting program continuity.

According to Ringold and co-workers (1996), there are several technical and institutional barriers to implementing a sound and usable regional monitoring program that are applicable to our efforts:

- Objectives are often qualitative making it difficult to specify quantitative indicators for monitoring. Policy choices must be made, and this requires on-going interaction between the scientific community and the policy process.

- Appropriate monitoring methods may be unavailable, unharmonized, or inconsistent. For example, monitoring based on classification data rather than continuous data create problems when policy changes dictate different classification schemes.

- Information may not be available to estimate the characteristics of environmental features over the relevant time or space scales.

- Priorities will not be apparent or well articulated at the beginning of the monitoring strategy development process and may change over time in unforeseen ways. An objective basis for establishing priorities will emerge only after data sets, their analyses, and costs are available.

The best way to overcome these problems is to recognize that they do exist and extend the design phase of monitoring over one or more years.

The process for iteratively improving the monitoring program over time is illustrated in Figure 4. After initial development and implementation, information is presented to stakeholders, namely land managers and researchers. The utility of the data and information to each is evaluated and recommendations made for improvements. The monitoring developers integrate this information with modifications made and implemented in subsequent rounds of monitoring as appropriate.

Additional Design Considerations

Metrics: There is no single accepted or standard list of data used to characterize and monitor status and trends in ecosystem conditions, although extensive lists of candidate variables are available (Noss 1990 and Noss and Coopperider 1994). A considerable effort will be required to identify metrics most suitable for addressing ecosystem research needs and installation management goals. There are three general categories of variables that might be addressed (Dr. Daniel Botkin, *pers. comm.*), namely:

- <u>Fundamental data on ecosystem state:</u> These are variable that are universal across ecosystems and that can be monitored on any DOD site. Examples include standing biomass, carbon, nitrogen, phosphorous and a host of biotic variables. See also the preliminary list of descriptors and variables proposed by the National Science and Technology Council's Committee on Environment and Natural Resources (Appendix B).

- <u>Indices of regional ecosystem characteristics:</u> These should be generally applicable across the ecological region under study. They are indirect measures of ecosystem state. Examples include, index of biotic integrity, species diversity, various species or community indicators, etc.

- <u>Site- and question-specific data:</u> These are variables specific to the locale under study and may be related to site-specific management and research needs. Applicability to other sites in the region may or may not be appropriate. Examples include demographics of species of local interest, status of protected or unique communities, results of site specific land restoration activities, and evaluation of selected restoration techniques.

Scale: The intent of the ECMI is to address ecosystem level biotic and abiotic indicators of ecological conditions, going beyond the traditional species-based approaches. While species indicators might be a target of monitoring, they will only be of value to the extent that they reflect conditions at higher levels of organization, e.g., community, watershed, and landscape. For example, microbial processes and decomposition and mineralization are important small-scale processes that influence nutrient dynamics and can be detected accurately only at small scales. However, the effects of these processes may only emerge for management purposes at a larger scale, as might be reflected via species indicators.

Technology Considerations: The ECMI should take maximum advantage of available and emerging technology tools in design, development and implementation of the monitoring program. While cost and efficiency are important driving factors, we must also:

- Minimize/avoid intruding on military mission and burdening land management activities.
- Ensure rapid acquisition, handling, storage, synthesis, and display and visualization of results.
- Enhance efficiency of QA/QC protocols

This will include reliance on state of the art remote sensing (RS), geographic information systems (GIS), global positioning systems (GPS), field site instrumentation, sensors, and automated remote data acquisition and handling capabilities. Advanced technology applications will be determined in the context of evaluating the right mix of large and small scale data and information needs and priorities.

Impact on Host Organization: It is important to ensure that the EMCI does not interfere significantly with the military mission nor create an unwanted burden for installation land managers. This highlights the requirement for use of remote and other unobtrusive data collection and acquisition technologies to the extent appropriate. The ECMI needs to tie into existing and planned monitoring activities to the extent appropriate to ensure proper leveraging and coordination. This should include the LCTA program and inventory and monitoring initiatives being developed under the integrated natural resources management plan (INRMP). Results of the ECMI should provide valuable information on spatial and temporal dynamics in key variables relevant to the installation's own developing ecosystem management monitoring program. ECMI will also attempt to leverage its data and information acquisition activities with ongoing land use and management activities to maximize the value-added of this activity to land management information and assessment requirements.

Long Term Commitment: The value of a baseline monitoring program increases with age. Whereas effectiveness monitoring may be designed to evaluate the results of a particular land use or management action in the short term, baseline monitoring adds value to the extent that it elucidates long term spatial and temporal dynamics and trajectories. Not all data collected via baseline monitoring will be of immediate use to land managers. However, to the extent that these data reveal system dynamics and long term response to stressors, they establish a fundamental understanding of ecosystem sustainability and integrity in the face of mission and related land use and management activities. SERDP's commitment to this activity is assumed to be on the order of 10 to 20 years or more.

Keep it Simple and Cost-Effective: The prospects of maintaining an ecosystem monitoring program active over a long time period may be inversely proportional to its complexity and cost (Dr. Donald Kaufman, *pers. comm*.).

Appendix C. Preliminary List of Descriptors and Variables to be Considered within a Framework for a National Environmental Monitoring and Research Network (National Science and Technology Council 1997)

Site descriptors:
Site name
Latitude
Longitude
Elevation
Landscape position
Slope
Aspect
Land use history
Natural disturbance history (storm, fire, pest, etc.)
Soil profile and classification
Soils:
%Organic Matter
Water holding capacity
Water retention curve
Sat. hydraulic conductivity
Infiltration parameters
Soil Moisture
% Litter
Total N
Available N
Denitrification rate
N fixation rate
$^{13}C/^{12}C$ in SOM
$^{15}N/^{14}N$ in SOM
% Water-stable aggregates (< 100 um, 100-250 um, > 250 um)
Total N (by aggregate size)
Total C (by aggregate size)
Major cations (Ca++, Mg++, K+, Na+, NH_4+)
Major anions (SO_4--, $P0_4$--,C1-)
pH in water 1:2.5
CEC
Soil temperature (by horizon)
Exchangeable acidity
Toxic contaminants
Ground water:
Depth to water table
Total C
DOC
Total NO_3 -- and NH_4+
Toxic contaminants
Streams:
Discharge
Major cations (Ca++, Mg++, K+, Na+, NH_4+)
Major anions (SO_4--, PO_4--- $N0_3$--, C1-, F-) pH
DOC
DON
Sediment load
Metals (Al, Hg, Cd)
Toxic contaminants
Lakes:
Major anions (PO_4---, NO_2
Major cations (H+, NH_4+)
Temperature profile
Climate:
Rainfall
Snowfall
Photosynthetically Active Radiation
UV-B
Wind run
Humidity
Air temperature
Vegetation:
% cover (by species)
Demography (by species)
Size (DBH, height)
Leaf Area Index
Leaf % N, P
Leaf % lignin
Leaf ^{13} C/
Leaf "Nl'
Litter fall
Establishment (by species)
Flowering
Leaf budbreak
Phenological stages
Above-ground NPP
Below-ground NPP
Necromass
Leaf and stem lesions
Leaf wilt
Chlorosis

Animals:
Species presence/absence, density, diversity
Breeding demography
Insect herbivores (by group)

Landscape:
Patch size
Patch distribution
Edge area/length

Atmospheric Fluxes:
C02 flux
CH_4, flux
N_2, flux
Wet Deposition
Dry Deposition

Marine/]Estuarine:
Water Temperature
Salinity
Ambient Light
Turbidity
Water Movement
Water Depth
Nutrient Dissolved Oxygen
Dry and Wet Deposition
Sediment Grain Size
Sediment Total Organics
Sediment Toxic Contaminants
Sedimentary Oxygen Demand
Net and Gross Primary Production
Chlorophylls
Phytoplankton Biomass/Composition
Benthos Biomass/Composition
Zooplankton Biomass/Composition
Nekton Biomass/Composition
Decomposer Biomass/Composition
Resource Harvest

Table 1. Milestone (M) and product (P) delivery schedule.

Task	Oct-98	Nov-98	Dec-98	Jan-99	Feb-99	Mar-99	Apr-99	May-99	Jun-99	Jul-99	Aug-99	Sep-99	Oct-99	Nov-99	Dec-99
Task I. Inventory															
1) On-Site Data	x	x	x M												
2) Regional Data	x	x	x	x	x M										
3) Monitoring Programs	x	x	x	x	x	x M	P								
Task 2. Design Plan															
1)Identify Info Needs	x	x	x	x M											
2) Establish criteria		x	x	x M											
3) Evaluate and Select variables				x	x M	P									
4) Develop sampling design					x	x	x M	P							
Task 3. Implement Plan															
1) Implementation Plan			x	x	x	x	x M	P							
2)Site Reconnaissance					x	x M									
3) Acquire and test equipement							x	x	x M						
4) Deploy equipment									x	x M					
5) Initial full-up program										x	x	x M			
6) Recalibrate and adapt															
Task 4. Repository															
1) Design					x	x	x	x	x M	P					
2) Phase 1 repository							x	x	x	x	x M	P			
3) Standards for contributions									x	x	x	x			
4) Procedures for access									x	x	x	x			
5) QA/QC plan													x	x	x MP
Task 5. Adpat Plan															
1) Evaluate Year-One data															
2) Recommend modifications															
3) Implement modifications															