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The SEMP Approach

Plans and Progress of the Strategic Environmental Research and Development Program (SERDP) Ecosystem Management Project (SEMP)

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Foreword

This study was conducted for the Strategic Environmental Research and Development Program (SERDP) under Work Unit CS-1114 "SERDP Ecosystem Management Project (SEMP)." The technical monitor was Dr. Robert W. Holst, Conservation Program Manager. Brad Smith is the SERDP Executive Director.

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Cover Photo: Longleaf pine community at Fort Benning, GA.

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Executive Summary

According to numerous memorandums and policies, Department of Defense (DoD) lands and waters are to be managed from an "adaptive ecosystem management" approach. The overriding goal of these policies is twofold: (1) to support sustainable mission use of DoD lands, waters, and airspace, and (2) to restore, sustain, and protect valuable natural and cultural resources occurring on/in the lands and waters.

To practice adaptive ecosystem management, DoD land/water resource managers are asked to inventory and monitor ecosystem resources, processes, and conditions; to understand the relationship between mission operations, management actions, and ecosystem conditions; and to adjust ecosystem management practices and mission usage patterns based on goals, observations, analysis, and previous management actions. In addition, guidance calls for DoD land/water managers to incorporate the best scientific understanding of their ecosystem and mission interactions with ecosystems into their adaptive management practices. The Strategic Environmental Research and Development Program (SERDP) Ecosystem Management Project (SEMP) is a venture to help DoD managers address this challenging guidance.

The SERDP Investment

SERDP is the DoD's major environmental research program, responding to environmental issues, concerns, and formal requirements emerging from all DoD services. SERDP normally translates requirements and issues into Statements of Need (SONs). These SONs are used as solicitations for government agencies, academics, and private sector researchers to submit proposals. With SEMP, the

SERDP responded to an enduring need to better understand the complex dynamics between various ecosystems and DoD operations through a managed set of investments that include multiple SON solicitations, a long-term monitoring program, a proactive partnering with DoD installation managers, and the eventual development of a adaptive ecosystem management protocol, based on a continuously improving cycle of ecological observations, data analysis, and management adjustments.

SEMP was initiated in 1998, following a SERDP-sponsored workshop of DoD ecosystem managers, academics, and nongovernmental organizations (NGOs), that focused on Landscape Scale Ecosystem Management Research. From this workshop, a series of research themes emerged as fundamental to improving management understanding of ecosystems. These themes, which included ecosystem change or status indicators and disturbance thresholds, helped form the SEMP SON solicitations. After the workshop, a team of DoD researchers and conservation policy proponents formed a "working group" to translate these workshop themes into a research program. This team, led by senior staff from the Corps of Engineers' research laboratories, identified the southeastern United States as the preferred location to initiate an ecosystem management research effort, and then selected the Army installation Fort Benning, in western Georgia and eastern Alabama, as the host location for this research. The team developed an overall plan for this research effort, issued an initial SON, and designed a long-term monitoring program.

Status and Approach

SEMP now has five research teams addressing two different SONs (FY [Fiscal Year] 99, "Indicators of Change;" and FY00, "Thresholds of Disturbance") in addition to an ongoing long-term monitoring effort and an emerging analysis effort. The host installation has actively supported and shaped the program, and one key element of "the SEMP approach" has been to link the Fort Benning Integrated Natural Resources Management Plan (INRMP) with SEMP. All DoD installations are required to develop INRMPs as a means to bring together and reconcile the diverse plans that affect installation natural resources. These plans include overall goals for each specific installation; these goals become important measures of what ecosystem conditions are desired by installation managers.

The SEMP long-term monitoring program has two main purposes: (1) to provide a basic set of background data that can inform various research efforts, and (2) to provide installation managers basic information on overall ecological

conditions and trends on the installation. While this monitoring program is not designed to specifically monitor protected species or land restoration projects, monitoring data does provide measures that can be evaluated in terms of trends toward or away from broad ecosystem management goals. In addition, promising observations (or indicators) from the research projects that more specifically address measures of trends to or away from installation goals can be incorporated into the baseline monitoring program.

One of the goals of SEMP was to provide a "landscape level" research environment that helped support enduring mission use and ecosystem health. Already, this goal has clearly succeeded, as numerous additional research efforts beyond the SERDP-funded SEMP are underway and/or proposed for the Fort Benning area. Another goal is to share approaches and results with other installations in the region. Such efforts are already underway through the "Partners Along the Fall Line" initiative and the linkages to the multi-agency Southeast Natural Resources Leader's Group.

SEMP is a "work in progress" and much hard work is still needed to ensure this SERDP investment brings benefits to DoD land/water resource managers. Efforts are just beginning to bring SEMP data and analysis tools into a common environment, yet this step is critical to gain both local and transferable benefits from SEMP. There is still an open question as to what sets of approaches and technologies will benefit other resource managers across the Southeast and regions beyond.

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1 Ecosystem Management Research in the Department of Defense (DoD)

DoD Conservation Objectives

The DoD developed a wide range of policy guidance in the 1990s that provides a basis for research programs, such as the Strategic Environmental Research and Development Program (SERDP) Ecosystem Management Project (SEMP), that have an ecosystem-wide focus. The following brief overview of major environmental policy documents will serve to illustrate this trend. The sequence starts with guidance from the DoD level, followed by that from the military branches.

DoD Policy

DoD Instruction (DoDI) 4715.3, Environmental Conservation Program, 3 May 1996

This instruction implements policy, assigns responsibilities, and prescribes procedures for integrated management of natural and cultural resources on property under DoD control. The Instruction also establishes the DoD Conservation Committee that reports to the Environmental Safety and Occupational Health (ESOH) Policy Board.

A few of the important policy statements for natural resource management include:

1. Natural resources under the stewardship and control of DoD shall be managed to support and be consistent with the military mission, while protecting and enhancing those resources for multiple use, sustainable yield, and biological integrity.
2. Integrated natural resource management plans (INRMPs) shall incorporate principles of ecosystem management. INRMPs shall be prepared, maintained, and implemented for all lands and waters under DoD control that have suitable habitat for conserving and managing natural ecosystems.

3. Sensitive natural resources or species shall be inventoried and managed to protect these resources, and to promote biodiversity.
4. DoD lands shall be managed for the goal of no net loss of wetlands. The development of mitigation "banks" is encouraged as sound conservation planning.

Deputy Under Secretary of Defense (Environmental Security) [DUSD(ES)] Memo "Implementation of Ecosystem Management in the DoD," 8 Aug 1994

The goal of the memo from the Deputy Under Secretary of Defense (Environmental Security) is to maintain and improve the sustainability and native biological diversity of terrestrial and aquatic, including marine, ecosystems while supporting human needs, including the DoD mission. "Ecosystem management" is defined to include:

1. Ecological approach — The DoD will continue to shift its focus from protection of individual species to management of ecosystems.
2. Partnerships — The DoD will form partnerships to achieve shared goals. Ecosystems cross political boundaries, making the need for cooperation, coordination, and partnerships essential for managing ecosystems.
3. Participation — Public involvement, communication, and incorporation of public needs and desires into management decisions will be emphasized.
4. Information — The best available scientific and field-tested information will be used in making decisions and selecting the most appropriate technologies in management of natural resources.
5. Adaptive management — Resource managers will incrementally implement adaptive management techniques.

According to the memo, on DoD installations, ecosystem management is supposed to be achieved by developing and implementing INRMPs and ensuring they remain current. Ecosystem management is already being implemented at some installations and these efforts are being expanded by DUSD (currently Director, Defense Research and Engineering [DDRE]) participation in the Interagency Ecosystem Management task force. The task force's activities include regional ecosystem management initiatives (e.g., Mojave Desert) with DoD as a lead in partnership with the Department of Interior (DOI).

Army Policy

Deputy Assistant Secretary of the Army for Environment, Safety, and Occupational Health [DASA(ESOH)] Memo "Conservation Policy," 8 Jul 1995

The DASA (ESOH) established three new conservation goals for the management of the Army's training and testing lands. These are:

1. The Army will manage its land resources to ensure their useful and perpetual availability for training and testing.
2. The Army will, within its capability, protect the natural and cultural resources entrusted to its care as the national treasures that they are.
3. The Army will be a national leader in environmental, natural, and cultural resource stewardship for present and future generations as an integral part of our mission.

The Army's primary peacetime mission is to be prepared to conduct combat operations. The Army must carefully protect its lands to ensure their availability and usefulness into the future. Training and testing must be made sustainable for the Army. Unnecessary damage must be prevented and damaged land must be repaired, maintained, or restored by natural processes or through engineering efforts.

Army Regulation (AR) 200-1, Environmental Protection and Enhancement, 21 Feb 1997

This regulation prescribes Department of the Army (DA) responsibilities, policies, and procedures to preserve, protect, and restore the quality of the environment. It incorporates all applicable statutory and regulatory requirements in the areas of research and development; water resources management; air pollution abatement; hazardous materials management; solid and hazardous waste management; noise abatement; oil and hazardous substances spill contingency planning, control, and emergency response; environmental restoration; asbestos management; radon reduction; and other environmental programs.

AR 200-1 also lists the responsibilities of various Army offices and major commands (MACOMs). The installation commanders' overall responsibility to execute environmental programs for the Army as well as for tenant activities and to comply with applicable Federal, state, regional, and local environmental laws and regulations is also outlined. Programs and actions to be considered will be

planned, initiated, and carried out in such a way as to prevent, minimize, or mitigate degradation of environment or endangerment of human health.

AR 200-2, Environmental Effects of Army Actions, 23 Dec 1988

This regulation establishes policy, procedures, and responsibilities for integrating environmental considerations into Army planning and decision-making and assessing the environmental effects of Army actions. It implements the Council on Environmental Quality's (CEQ's) National Environmental Policy Act (NEPA) regulations. AR 200-2 also establishes criteria for determining what Army actions are categorically excluded from the requirement to prepare an Environmental Impact Statement (EIS). The Assistant Secretary of the Army for Installations and Logistics was designated to serve as the Army's responsible official for NEPA matters.

AR 200-3, Natural Resources - Land, Forest, and Wildlife Management, 28 Feb 1995

This regulation prescribes current Army policies, procedures, and standards for the conservation, management, and restoration of land and the renewable natural resources thereon consistent with and in support of the military mission and in consonance with national policies. The scope includes the conservation, management, and utilization of the soils, vegetation, water resources, croplands, rangelands, forests, and fish and wildlife species.

It is the Army's goal to systematically conserve biological diversity on Army lands within the context of its mission. The Army recognizes that natural ecosystems play a vital role in maintaining a healthy environment and these ecosystems can best be maintained by protecting the biological diversity of native organisms and the ecological processes that they perform and are a part of.

Special consideration will be given to soil and vegetation characteristics; surface and subsurface water; wetlands; archaeological and geological sites; flood plains; and wildlife resources in the development, design, construction, and maintenance of an installation and the performance of its mission.

The Integrated Training Area Management (ITAM) is the primary Army program for balancing land use for military training and testing with natural resources conservation requirements, including protection of listed species and critical habitats. ITAM methodology is used to monitor land condition trends and mitigate adverse impacts of the military mission on long-term training land viability.

Army installations are currently developing a local INRMP, which will be used as a planning and operations tool for installation programs. These plans are considered to be integrated when all renewable natural resources of critical or special concern are adequately addressed. An INRMP is supposed to include current inventories and conditions of natural resources, management methods, schedules of activities and projects, priorities, responsibilities, monitoring systems, protection and enforcement systems, land use restrictions, and resource requirements including professional and technical manpower.

Navy Policy

Assistant Secretary of the Navy, Installations and Environment [ASN (I&E)] Memo, "Department of the Navy Natural Resources Strategic Plan," 11 Jul 1994

The Office of the Chief of Naval Operations established a central guide for natural resources management policy in the Department of the Navy. Each installation was encouraged to adopt the plan's three strategic pillars in its environmental management policy by emphasizing stewardship of natural resources, preserving biological diversity, and developing partnerships for conservation. The three goals contained in the strategic plan are:

1. Preserve our mission access to air, land, and sea resources.
2. Strengthen national security by strengthening conservation aspects of environmental security.
3. Preserve the opportunity for a high quality of life for present and future generations of Americans.

The Navy's mission is "...to support the requirements of the United Commanders so that our nation can deter aggression, encourage political stability, provide forward presence, establish sea control, and project power from the sea against any threat and win." Implicit in this mission is a responsibility to deter aggression and encourage political stability by working to achieve ecologically sustainable development at home and abroad.

Three main strategies mentioned in the strategic plan are:

1. Emphasize stewardship of natural resource,
2. Preserve biological diversity, and
3. Develop partnerships for conservation.

The main objective of the first strategy is to develop and sustain strong natural resources programs at installations. The processes outlined to meet this objective include: preparation and implementation of installation integrated natural resources management plans; ensure optimum utilization of land and water resources while maintaining ecological integrity; plan, program, and budget for natural resources projects and functions as a cost of doing business; ensure attention to natural resources conservation opportunities and constraints when formulating land use and management decisions; use geographic information systems (where available) to integrate natural resources management objectives with mission requirements on Department of the Navy lands; and strengthen internal audit systems regarding natural resources issues and compliance requirements.

The main objective of the second strategy is to preserve endemic, diverse natural habitats, protect threatened and endangered species (TES), and achieve an increase in net functional value of wetlands. The processes outlined to meet these objective include: establishing ecological reserve areas and research natural areas warranting special protection because of their biological attributes; implement land-use policies to support diversity of biological species, consistent with mission requirements; participate in recovery efforts for TES; adopt an ecosystem management approach on all Department of Navy lands; and complete and maintain inventories of federally listed and proposed TES and of legally defined wetlands on Department of Navy land.

The main objective of the third strategy is to solve conservation problems and enhance natural resources by inter-organizational cooperation in the application of technology, expertise, and other resources and to focus on ecosystem integrity issues. The processes outlined to meet these objectives include: expanding Department of Navy involvement in regional ecosystem planning, management, and restoration initiatives; conduct community outreach and educational programs on environmental issues; organize collaborative, environmental problem solving partnerships with non-DoD stakeholders; and fully integrate the objectives of installation environmental programs into regional watershed plans and goals.

Office of the Chief of Naval Operations Instruction (OPNAVINST) 5090.1B, Navy Environmental and Natural Resources Program Manual, 1 Nov 1994

The Chief of Naval Operations (CNO) has defined the Navy's environmental vision to be "Navy recognized as an environmental leader while effectively executing naval operations." Thus, an important part of the Navy's mission was

identified as pollution prevention, protection of the environment, and protection of natural, historic, and cultural resources.

This instruction/manual provides Navy policy, identifies key statutory and regulatory requirements, and assigns responsibility for management of Navy Environmental and Natural Resources programs for cleanup of waste disposal sites, compliance with current laws and regulations for the protection of the environment, conservation of natural resources, pollution prevention, and technology.

Chapter 22 of the document summarizes the natural resources management (NRM) program for managing Navy lands, waters, forests, fish and wildlife, and outdoor recreation resources. It covers the Navy's policy for good stewardship, which is to act responsibly in the public interest to restore, improve, preserve, and properly utilize natural resources on Navy administered lands. Ecosystem management is also covered, as a basis for planning and management of Navy installations. The goal is to preserve and enhance ecosystem integrity, and to sustain both biological diversity and continued availability of those resources for military and other human uses.

The instruction places the responsibility on the commands for conservation of natural resources. The protection, conservation, and management of watersheds, wetlands, natural landscapes, soils, forests, fish and wildlife, prime and unique farmland, and other natural resources are listed as vital elements of an optimum natural resources program.

It becomes the responsibility of the Deputy Chief of Naval Operations (DCNO) (Logistics) to ensure an adequate, Navy-wide organizational capability and the programming of resources necessary to establish and maintain an integrated, natural resources program.

Office of the Secretary of the Navy Instruction (SECNAVINST) 5090, Policy for Environmental Protection, Natural Resources, and Cultural Resources Programs, 18 Dec 2000.

This instruction states in paragraph 4d that it is Department of the Navy policy to design and implement natural resource management plans and programs that are built upon the principles of ecosystem management and support present and future military and civilian activities, in accordance with DoD Instruction 4715.8.

Air Force Policy

Air Force Policy Directive (AFPD) 32-70, Environmental Quality, 20 Jul 1994

This directive establishes that the Assistant Secretary of the Air Force for Manpower, Reserve Affairs, Installations and Environment (SAF/MI) is responsible for environmental protection policy matters. Achieving and maintaining environmental quality is an essential part of the Air Force mission. The directive establishes policies for carrying out the Air Force commitment to: cleaning up environmental damage resulting from its past activities; meeting all environmental impacts; managing responsibly the irreplaceable natural and cultural resources it holds in public trust; and eliminating pollution from its activities wherever possible.

The Air Force Environmental Quality program is composed of four pillars: cleanup, compliance, conservation, and pollution prevention. Under the conservation program, the Air Force will conserve natural and cultural resources through effective environmental planning. The environmental consequences of proposed actions and reasonable alternatives will be integrated into all levels of decision making. Environmental opportunities and constraints will be the foundation of comprehensive plans for installation development.

Air Force Instruction (AFI) 32-7061, The Environmental Impact Analysis Process, 24 Jan 1995

This instruction implements AFPD 32-70. It provides procedures that are essential to achieving and maintaining compliance with NEPA and CEQ regulations for implementing procedural provisions of NEPA (40 Code of Federal Regulations [CFR] 1500-1508). SAF/MI promulgates and oversees policy to ensure integration of environmental considerations. This office also determines the level of environmental analysis required for especially important, visible, or controversial Air Force proposals and approves selected Environmental Assessments (EAs) and Findings of No Significant Impact (FONSI). SAF/MI is also the approval authority for all EISs prepared for Air Force actions.

Wherever they are the host unit, Major Commands (MAJCOMs), Air Force Reserve (AFRES), Air National Guard (ANG), and Field Operating Agencies (FOAs) establish procedures that comply with the instruction for preparing and using required environmental documentation in making decisions about proposed actions and programs within their commands. The Air Force Center for Environmental Excellence (AFCEE) Environmental Conservation and Planning

Directorate provides technical assistance to major commands and the Air Force Base Conversion Agency.

AFI 32-7064, Integrated Natural Resources Management, 8 Mar 1994

This instruction explains how to manage natural resources on Air Force property in compliance with Federal, state, and local standards. It provides MAJCOMs and installations with a framework and process to comply with AFPD 32-70. It lists the installation integrated natural resources management plan as the chief tool for managing ecosystems. The integrated natural resources plan is suppose to integrate all aspects of natural resources management with each other and the rest of the installation's mission. Installations are supposed to contact their state forestry office, state game and natural resources department, U.S. Fish and Wildlife Service (USFWS), or the Natural Resources Conservation Service (NRCS) to determine if sufficient habitat warrants an integrated natural resources plan.

Since the development, approval, and implementation of an integrated natural resources plan may constitute a potentially significant Federal action, environmental impact analysis process documentation should be prepared at the same time the integrated natural resources plan is developed.

Strategic Environmental Research and Development Program

SERDP is a multi-Agency program funded through the DoD and reporting to the DDRE. As such, it responds to environmental requirements of the DoD including those which the DoD shares with the Department of Energy (DOE), the Environmental Protection Agency (EPA), and many other Government agencies, including the National Institute of Standards and Technology (NIST), the National Oceanic and Atmospheric Administration (NOAA), the National Institutes of Health (NIH), the DOI, the United States Geological Survey (USGS), and the National Aeronautics and Space Administration (NASA). The Program seeks to identify, develop, demonstrate, and transition technology from four thrust areas: Cleanup, Compliance, Conservation, and Pollution Prevention. These thrusts are synonymous with DoD's Environmental Quality Program. Efforts in two additional thrust areas, Energy Conservation/Renewable Resources and Global Environmental Change were completed in Fiscal Year (FY) 1996. Beginning in FY1997, appropriate remote sensing and energy technologies have been encouraged and supported in the remaining four SERDP thrust areas.

SERDP identifies and develops technology to enhance capabilities to meet environmental commitments and to foster the exchange of scientific information and technologies among the participants, other governmental agencies, and the private sector. SERDP leverages and interacts with other environmental programs to identify and solve defense-specific needs, extends applications of defense information to others, and builds on existing science and technology to derive more usable and cost-effective approaches for achieving reductions in environmental risks.

SERDP Ecosystem Management Project

As can be seen from the above review of the policy documents of each service and from the DoD itself, furtherance of the knowledge and skills required to actually characterize and manage the ecosystem is explicitly or implicitly requested by each department. Further, the actions of SERDP in promoting such ecosystem-based research are clearly consonant with the SERDP charter and goals. There can be no question but that the DoD is committed to proactive ecosystem management of military lands and waterways. Installations in all of the services conduct active and often award-winning ecosystem management programs, supporting both the sustainable mission use of military lands and stewardship of the valuable ecological resources on these lands. Guidance was developed for DoD installations to pursue ecosystem management principles. A report was published, in collaboration with The Nature Conservancy, to provide background and guidance for DoD ecosystem managers (Leslie et al. 1996).

All of the DoD services have expressed (in formal research requirements and through other mechanisms) the need for better understanding of ecological processes and trends on military lands in relation to the surrounding lands, and the interactions between mission activities and ecological processes. In response to these expressed needs, SERDP held a workshop, in June 1997, entitled "Management-Scale Ecosystem Research." The workshop identified some of the critical knowledge gaps in understanding ecosystem status, especially as they relate to military land management concerns. The primary themes that emerged from the workshop included:

- ecosystem health or change indicators;
- thresholds of disturbance;
- biogeochemical cycles and processes; and
- ecosystem processes as they relate to multiple temporal and spatial scales.

After this workshop, SEMP was developed as a new SERDP project to pursue ecosystem research relevant to DoD ecosystem management concerns, including the research themes from the 1997 SERDP Workshop.

Objectives

The overall program objective for SEMP is to plan, coordinate, execute, and manage, on behalf of SERDP, an ecosystem management project initiative that focuses on ecosystem science relevant to DoD ecosystem management concerns. This includes:

- addressing DoD requirements and opportunities in ecosystem research, as identified by the 1997 SERDP Ecosystem Science Workshop;
- establishing and managing one (or more) long-term ecosystem monitoring sites on DoD facilities for DoD-relevant ecosystems research;
- conducting multiple ecosystem research and monitoring efforts, relevant to DoD requirements and opportunities, at these and/or additional facilities; and
- facilitating the integration of results and findings of research into DoD ecosystem management practices.

2 SEMP Organization and Activities

SEMP is organized with a Program Manager, a Technical Advisory Committee (TAC), an Ecosystem Characterization and Monitoring Team, Host Site(s) Points of Contact, and Research Teams. The Project Manager (PM) works with the TAC and the SERDP Program Office to develop statements of need for research efforts. These SONs are then handled like other SERDP SONs, with solicitations made through the SERDP website (http://www.serdp.org/) and other mechanisms. Responses are then sent out for a scientific peer review. The SEMP TAC performs the second level of review, and makes recommendations for funding to the SERDP Executive Director and Scientific Advisory Board. Figure 1 reflects the roles and functions of all participants within the SEMP project.

The Ecosystem Characterization and Monitoring Initiative (ECMI) Team is led by researchers from the U.S. Army Corps of Engineers' Engineer Research and Development Center (ERDC) Environmental Laboratory (EL). This team works with the host installation to gather, assess, and document historic and current ecological data sources and monitoring efforts. In addition, this team is responsible for long-term ecosystem monitoring. Data from the characterization effort, the monitoring efforts, and the research teams all flow into the common data repository, shared by all teams and the installation managers.

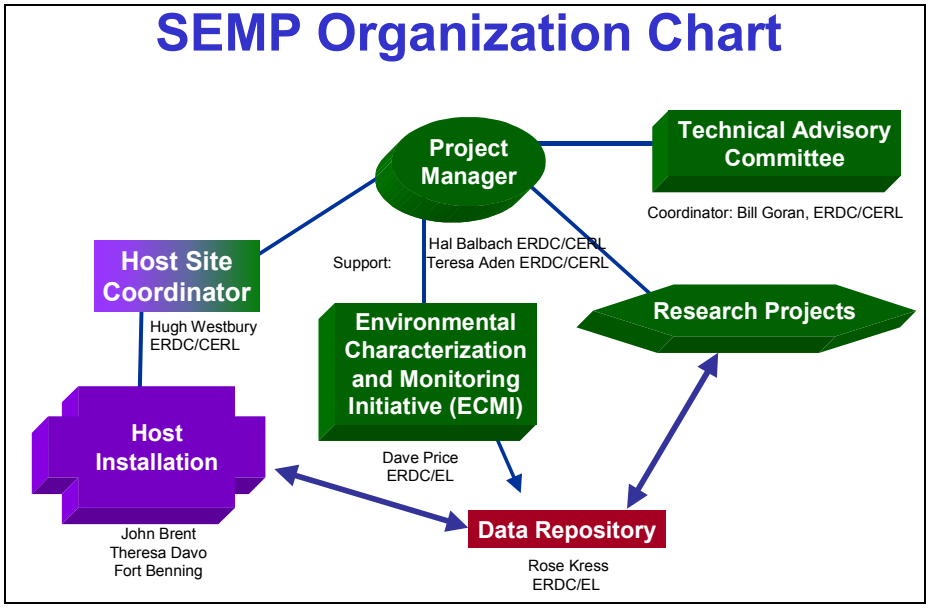


Figure 1. The SEMP organizational chart.

The overall program technical approach for SEMP includes the following:

- long-term research host site selection;
- assessment and site characterization of host site;
- development and implementation of a monitoring protocol;
- prioritizing, soliciting, selecting and conducting research in support of DoD objectives at selected site(s); and
- facilitating integration of results into DoD ecosystem management practices.

SEMP Technical Advisory Committee

Purpose of the TAC

The purposes of the SEMP TAC are: (1) to provide technical direction, review, and oversight of SEMP activities and plans, (2) to provide linkages to related research activities and findings, (3) to provide continuity across the diverse research efforts, and (4) to assist in transfer of SEMP findings and outcomes to the scientific and Defense Land Management communities.

TAC Functions

Shaping New Research Directions. TAC members are very influential in shaping SEMP research directions. The TAC is the forum in which strategic directions, research needs, and new initiatives are presented and discussed. Any decision to initiate, alter, or cancel a project involves the TAC, either directly at a TAC meeting or through electronic or telephone discussions.

TAC members may also chair or serve on subcommittees that pursue and mature specific new research directions. For example, a subcommittee may develop a research SON from an initiative idea that was framed in a TAC meeting. The entire TAC, the SEMP Program Manager, the SERDP Conservation Program Manager, the SERDP Executive Director, and others review draft SONs. The FY99 SEMP SON (Appendix A) was developed by the original SEMP Working Group, before the creation of the TAC, but the FY00 SEMP SON (Appendix A) engaged TAC membership as this research effort was conceived and refined, and when proposals were reviewed.

Reviewing Research Proposals. One of the key responsibilities of the TAC is formal review of proposals that respond to SONs. Once a SON has been released (on the SERDP Website and elsewhere), individuals and teams of researchers from government, academia, and industry develop preproposals and/or full proposals (depending on the solicitation). The SERDP Program Office staff screens

these preproposals; the investigators that submit the most relevant and promising preproposals are invited to submit full proposals. Once received, full proposals that are submitted on time are sent out from the SERDP Program Office for external peer review, and are evaluated on the basis of technical merit, feasibility of approach, and cost. The top proposals are then forwarded, through the SERDP Program Office, to the TAC. Each TAC member submits an evaluation of these proposals, and all of the evaluations are discussed at a formal TAC meeting. Also, the host installation provides review of these proposals. Following discussion of all proposals being considered, the TAC recommends funding for a subset of the proposals, working within the budget guidelines for this SON. The SEMP Program Manager forwards these recommendations to the SERDP Executive Director. The SERDP Executive Director then determines whether or not to submit these recommended proposals to the SERDP Scientific Advisory Board (SAB) for approval for funding (if available) in the next SERDP funding cycle.

Reviewing Progress on Research Projects. One of the critical roles of the TAC is to provide technical evaluation and feedback to the SEMP research and monitoring teams. These teams prepare quarterly and annual reports on their progress, and also provide directly to the TAC a briefing on their activities and outcomes once or twice each year. The TAC meetings provide the forum for review, discussion, and inquiry in project activities, direction, approach, and progress. After each presentation, the TAC deliberates and develops specific feedback to the research team presenters. Initial feedback provided during the TAC session includes comments on both direction and approach and on specific action items. The Action Item recommendations are then captured in the "Notes and Action Items" document, which is developed by the SEMP TAC Coordinator. Progress by the research teams on Action Items is tracked by the SEMP Program Manager and reported at subsequent TAC meetings and teleconferences.

Participation in SEMP Forums. There are a variety of teleconferences, meetings, workshops, and virtual discussion forums that relate to SEMP. TAC members are sometimes asked to chair or participate in specific forums. TAC members are also asked to be familiar with the content and organization of the SEMP website, and to provide comments to help improve this website.

Coordination and Guidance. Another important role of TAC members is to provide linkages between SEMP and other programs and activities. The SEMP TAC members represent many different organizations that have expertise, programs, technical approaches, and resources that can strengthen the SEMP. TAC members help bring SEMP researchers and planners together with those in

other agencies and organizations that have knowledge, experience, data, tools, facilities, or resources that can help SEMP achieve improved outcomes.

Representation. TAC members often represent SEMP at scientific, professional, agency, and organizational forums. They may perform this role through facilitating presentations and sharing the overall goals, results of research investment, technology infusion results, and specific approaches of the DoD in improving ecosystem understanding.

TAC Membership

Duration of TAC Membership. TAC members do not serve for explicitly designated timeframes. However, new TAC members are asked to make a multi-year commitment when joining. TAC members are of course free to "resign" when their professional and personal duties demand their attention elsewhere.

Size of the TAC Membership. The TAC is composed of 10 to 12 "voting" members. When resignations occur from the TAC membership, the Membership Committee reviews requirements and the "balance" with the remaining members. After discussion, the Membership Committee then solicits new members.

Remuneration. TAC members are not paid for labor, but travel expenses are provided when attendance at TAC meetings requires travel.

Selection of New Members. New members are recruited through the TAC Membership Committee, which strives to find the right balance of scientific and technical background, organizational affiliations, and regional expertise to help advance both the state of the art and the state of the field in ecosystem management through SEMP. Once new recruits are identified and contacted for interest, the full TAC membership and the SERDP Program Office have the opportunity to review the recruit's credentials and comments on/consents to the nominees.

The Membership Committee. The TAC Membership Committee is composed of two or three TAC members, the current TAC Chair, and the current TAC Coordinator. Membership Committee members serve for an unspecified period. When necessary, the TAC Coordinator recruits new members for the Membership Committee from the general TAC membership.

Conflict of Interest. While serving on the TAC, TAC members cannot themselves respond to SEMP-related solicitations as either lead or associate investigators. TAC members are also not allowed to provide information about solicitations to

investigators within their organizations preceding the public announcement of these solicitations. When proposals are submitted from an investigator who is part of an organization with which a TAC member is affiliated (e.g., from the same laboratory or unit), the TAC member will recuse himself or herself from review of that specific proposal. If a TAC member is uncertain about potential conflicts of interest, he or she should discuss the situation with the TAC Coordinator and/or the SERDP Program Office.

Consideration is also given to select some TAC members that serve dual roles on both the SEMP TAC and on other SERDP and DoD forums. Specific SERDP forums include the legislatively mandated SERDP SAB, a forum of national experts in various environmental sciences, and the conservation Technology Thrust Area Working Group (TTAWG). This forum is composed of conservationists from each of the SERDP participating agencies (e.g., DOE, EPA, and across DoD). The Conservation TTAWG shapes and reviews the entire SERDP Conservation research investment, including the investment in SEMP.

TAC Membership Roles

TAC Members Duties. TAC members are primarily responsible for technical oversight of the SEMP. This oversight is accomplished through participation in TAC meetings, review of research proposals, review of meeting outcomes, and evaluation of products and processes that result from TAC-recommended action items. Often, TAC members also serve on specific committees to help advise SEMP researchers and others on specific tasks, and TAC members also frequently help facilitate interactions between SEMP and academic, non-governmental organizations (NGOs), and/or agency groups. Besides the "voting" members of the TAC, there are also several ex officio members, such as the SERDP Conservation Program Manager, the SEMP Program Manager, the SEMP Host Site Representatives, and the SEMP TAC Coordinator. The TAC Chair, the TAC Coordinator, and various ex officio members have specific roles, beyond the duties of TAC voting members.

TAC Chair. TAC members select the Chair annually from the TAC membership. A Chair can be retained from year to year. The primary responsibility of the TAC Chair is to synthesize and communicate the consensus opinion of the TAC as input to the SERDP Conservation TTAWG and the SERDP SAB. These communications focus on recommendations regarding the plans, progress, organization of, and requirements for SEMP. Dr. Penelope Firth of the National Science Foundation is the current (2002) Chair for the TAC.

Ex Officio Members

TAC Coordinator. The TAC Coordinator is an ex-officio member of the committee and is responsible for the logistical support and effective operation of the TAC. Duties include organizing TAC meetings; setting agendas in coordination with the TAC Chair; recording, finalizing, and distributing meeting notes and action items; and coordinating with the SEMP Program Manager to ensuring that TAC action items are understood and addressed. Travel and labor for the TAC Coordinator are supported through the SEMP budget under TAC support and management. Selection of a new TAC coordinator is a joint decision by the SEMP Program Manager, the TAC, and the SERDP Program Office. The SERDP Program Office must approve the TAC Coordinator. William Goran of the U.S. Army Corps of Engineers, Engineer Research and Development (ERDC/Champaign, IL) is the current TAC Coordinator.

SERDP Program Office, Conservation Program Manager. The Conservation Program Manager attends the SEMP TAC meetings and represents the SERDP Program Office in TAC forums. Formal budget recommendations are coordinated through the SERDP Conservation Program Manager. Also, all actions involving the support and approval of the SERDP Program Office are coordinated through the Conservation Program Manager. Dr. Robert Holst is the current SERDP Conservation and Compliance Program Manager.

Host Site Representative(s). The SEMP Installation Host Site selects individuals who represent host site concerns and interests to the TAC and to the SERDP Program Office. These individuals also provide host site input into the review of proposed research. All proposed SEMP activities related to the host site, must be reviewed and approved by the Host Site Representative(s) before on-group work may begin. The host site representatives also review documents and data, relevant to the host site, that are planned for "release" by SEMP researchers or managers. John Brent and Theresa Davo, both from Fort Benning, are the current Host Site Representatives.

SEMP Program Manager. The SEMP Program Manager has responsibility for execution of all SEMP programs, including formal research projects, the monitoring and repository operations, and special efforts and forums related to SEMP. The Program Manager assembles an annual execution plan for SEMP and reports progress through quarterly and annual reports (required by SERDP) and through briefings to the SEMP TAC, the SERDP SAB, and the SERDP Conservation TTAWG. To ensure that TAC input is understood, captured in plans, and carried out according to intent, the SEMP Program Manager attends TAC func-

tions (in an ex-officio capacity) and reports on SEMP progress and issues. Dr. Harold Balbach of ERDC/Champaign is the current SEMP Program Manager.

TAC Activities

TAC Meetings. The SEMP TAC meets twice a year. The meetings are 1 to 3 days in duration, with dates selected to best fit the schedules of the greatest number of TAC members insofar as possible. The schedule for these meetings is sometimes influenced by external events, such as other SERDP, scientific, or DoD events. The purposes of these meetings include (1) review of ongoing research efforts, (2) review of proposed new efforts, (3) discussion of future directions and plans, (4) recommendations to the SERDP Program Office regarding ongoing and or proposed work and budgets, and (5) review and recommendations regarding technology transition and infusion and transfer efforts related to SEMP.

After each meeting, the TAC Coordinator produces a document entitled "Notes and Action Items." This document is circulated to all TAC members (and relevant meeting participants) for review and comment. Once all comments have been received and a revised document redistributed, the document is distributed once again to all TAC members and SEMP researchers/participants as "final." The TAC Coordinator assigns a respondent and due date for each action item. The SEMP Program Manager tracks all action items. Progress on action items is reported (either verbally or in writing) at the next TAC session.

Other Meetings. TAC members are not required to attend any other SEMP or SERDP program events. However, TAC members are encouraged to participate in the SERDP forums, such as the annual SERDP Symposium (typically in December), and SEMP activities such as the annual SEMP Research Coordination Meeting (typically in the Autumn).

Information Access

SEMP information is being provided through the SEMP website. All documents, briefings and meeting minutes are being posted at this site. This website is open to all interested parties.

There is also a password-protected DoD site that can be accessed in DENIX. A password can be obtained through on-line registration, by selecting "Registration" on the DENIX main menu (http://www.denix.osd.mil/). Once you have a password, select the DoD menu, then "Work Groups," and then the "SERDP Eco-

system Management Program (SEMP)." A variety of listserve and discussion forums are available through the SEMP public and working group websites. There is also an events calendar that links to both sites. Figure 2 shows the SEMP public homepage.

Appendix B contains a list of SEMP reports available on the SEMP website and a list of related websites.

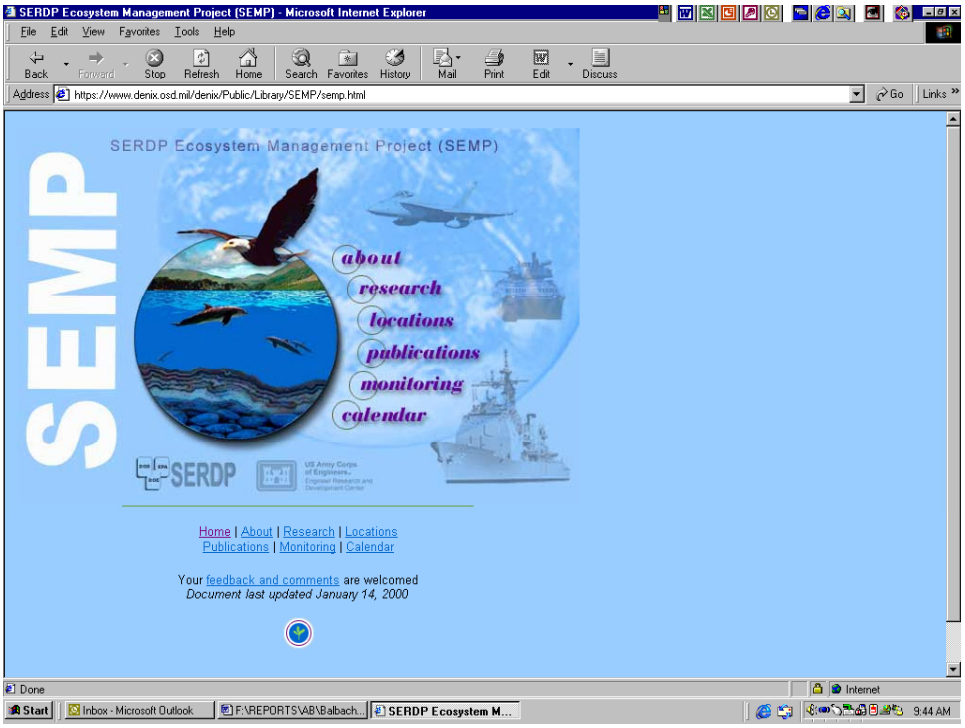


Figure 2. SEMP public website homepage.

3 Implementation of SEMP at Fort Benning, Georgia

Fort Benning was selected with concurrence from its MACOM (U.S. Army Training and Doctrine Command or TRADOC). This selection was made in May 1998, and a working group meeting for SEMP was hosted at Fort Benning in June 1998.

Selection of a Long-Term Research Site

One of the goals of SEMP is to establish one or more long-term (at least 10 years, but probably much longer) research and monitoring sites. Initially, only one site has been established. This chapter describes the site selection process and provides an overview of the selected site.

SEMP Research Site Selection Process

Selection of a host site for SEMP was a task undertaken by the SEMP working group, an interim group formed to help translate the outcomes of the Management-level Ecosystem Workshop into a coordinated project with multiple research and monitoring elements relevant to DoD ecosystem management goals and objectives.

Members of this working group, which included participants from the Air Force, Army, and DoD, favored an initial focus on the southeastern region of the United States. Reasons for this focus include:

- High density of DoD installations from all the services across the southeastern United States.
- Concentrations of previous DoD ecosystem management initiatives in the western states (e.g., Mojave Desert, Southwest) where xeric conditions, mountainous terrain, and extensive public land ownership represent very different conditions from the southeastern United States. An effort focused on the southeast would provide insights into ecosystem management and ecoregional planning issues in the southeastern sand hills and/or coastal plain.

- Significant mission operations constraints experienced by DoD facilities located in the southeast related to TES populations and habitats, and the need for ecosystem approaches and ecoregional partnering to avert future mission operations constraints.

After deciding to focus on the southeast, the working group developed a set of criteria to select a host installation, again consulting with the services. These criteria include the following considerations:

- Enduring and important installation for service mission.
- Relatively large installation with significant mission activities (diverse mission activities desirable)
- Proactive ecosystem management emphasis at the site, including efforts towards implementation of an Integrated Natural Resources Management Plan, extensive field data collected, effective use of gepgraphic information systems (GIS) technology, and ongoing monitoring activities.
- Proactive interest in hosting SEMP, with support from both trainers and environmental resource managers.
- Preferably located in an ecoregion with other DoD facilities.

A short list of sites was developed, including Eglin Air Force Base in Florida, Camp LeJeune Marine Corps Base in North Carolina, and Army bases Fort Benning, GA, and Fort Bragg, NC. While all these sites would have been suitable host sites, Fort Benning met all the criteria and was very proactive in a willingness to be the first SEMP Host Site.

Memorandum of Agreement

The initiation of the SEMP program at Fort Benning requires a long-term commitment of resources by all parties involved with SEMP at the Fort Benning site. To ensure that there is sufficient planning and coordination of SEMP activities at Fort Benning, a Memorandum of Agreement (MOA) was developed by the SEMP Project Manager and Fort Benning hosts. This MOA, Appendix C, is between ERDC/CERL (the local laboratory of the SEMP Program Manager), Fort Benning, and TRADOC. The 10-year agreement describes the roles and responsibilities of each participating organization. It was signed by the Director of CERL (Jan 99), the Garrison Commander of Fort Benning (Feb 99), and the Assistant Deputy Chief of Staff for Base Operations Support at TRADOC (Mar 99). The agreement is posted on the SEMP Working Group Website.

One element of this MOA involves the assignment of SEMP POCs for Fort Benning. Two POCs have been assigned: John Brent, Chief of the Environmental

Management Division, represents the Directorate of Facilities, Engineering, and Logistics, and Theresa Davo, of the Environmental Management Division, represents the Land Management and Conservation Branches. Robert Anderson is the SEMP POC for TRADOC.

Finally, the MOA specifies that SEMP will submit an annual "license" request for each upcoming year of anticipated field activities. A request was submitted in March 2000 that covers liabilities, supervision, environmental constraints, and additional issues for the subsequent year. A similar license request will be submitted for each year SEMP activities will be conducted at Fort Benning.

Host Site Coordinator

Within the MOA, CERL agrees to provide a SEMP Host Site Coordinator to act as liaison, problem solver, and research coordinator. These duties were originally performed by Patricia Kosky of HydroGeoLogic. This role is funded through CERL, but Fort Benning provides office and logistical support for the Host Site Coordinator. Hugh Westbury assumed these duties in June 2000 as a new ERDC/CERL employee.

This position is responsible for coordinating field visits for all SEMP teams, developing a calendar of planned field activities, managing shared field equipment (radios, field vehicles) and assisting with field site selection and some data gathering activities. The Host Site Coordinator develops a monthly report to keep SEMP teams informed of all SEMP related host site activity, and assists Fort Benning staff in developing briefings and planning for SEMP events.

Fort Benning Natural Resource Overview

The following overview of Fort Benning is largely extracted and modified from D. Jones and T. Davo's 1997 document "Land Condition Trend Analysis Program Summary. Fort Benning, GA: 1991-1995; Supporting the Training Mission and Resource Sustainability." Center for Environmental Management of Military Lands (CEMML), Colorado State University, Fort Collins, CO.

Location and Regional Ecology

Fort Benning is located in west-central Georgia south of the city of Columbus, GA and east of Phenix City, AL. It occupies approximately 73,533 hectares (ha) in Chattahoochee, Muscogee, and Marion Counties, Georgia, and Russell County,

Alabama. Figure 3 shows Fort Benning and other selected military installations in a regional ecological context. The ecological units in Figure 3 are those proposed by the U.S. Forest Service (1995) for the southeastern United States. In this classification, Fort Benning lies on the border between the Coastal Plains and Flatwoods, Lower; Sand Hills ecological unit and the Coastal Plains, Middle, Upper Loam Hills ecological unit. Fort Benning falls within the Subtropical Division of Bailey, 1995.

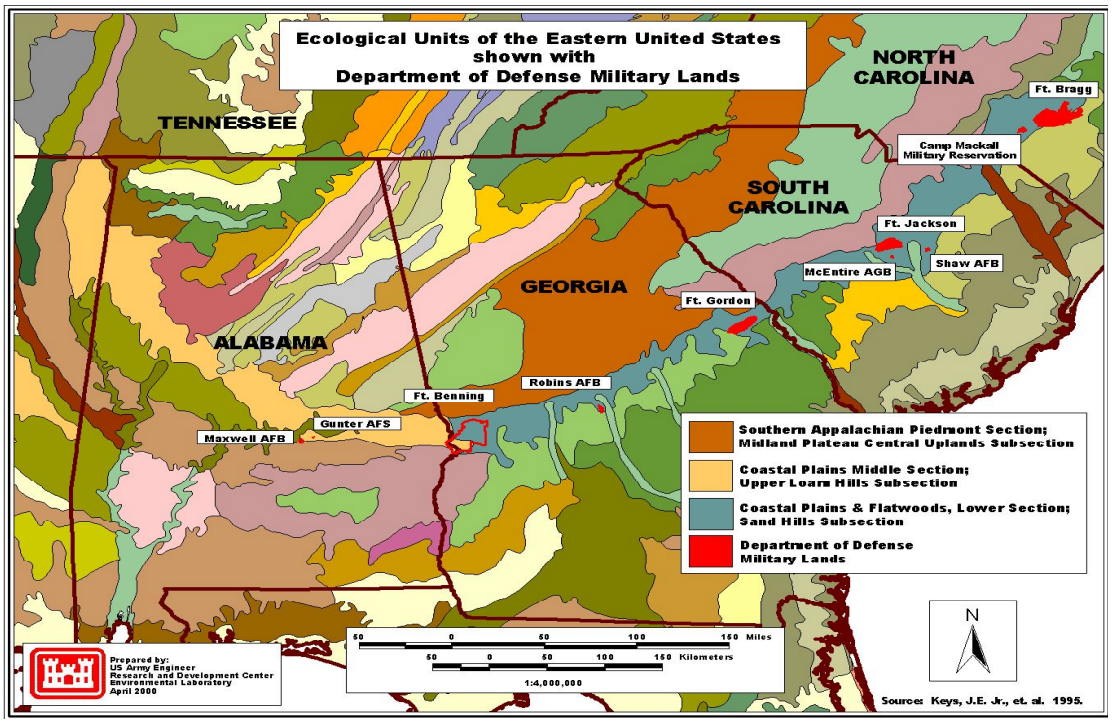


Figure 3. Fort Benning and other selected military installations in a regional ecological context.

Installation Mission

Fort Benning is a TRADOC installation (Department of the Army 1994). U.S. Army Forces Command (FORSCOM) units constitute about 50 percent of military personnel on post. These latter units include the 3rd Brigade, 3rd Infantry Division (Mechanized) and the 36th Engineer Group (Department of the Army 1994).

The peacetime missions for Fort Benning are as follows: (1) to conduct basic, infantry, airborne, and Ranger training and the non-branch specific Officer "Candidate" School, (2) to support infantry combat and its relationship to other Army branches and armed forces, and (3) to house and provide training opportunities for the 3rd Brigade, 3rd Infantry Division (Mechanized). The mobilization missions are the following: (1) to deploy Active Army and Reserve Component units,

(2) house the Continental U.S. Replacement Center to mobilize and deploy personnel from all branches of service, and (3) house the Individual Deployment Site to deploy non-unit personnel involved in non-war related operations (Department of the Army 1994).

Installation History

Fort Benning was established in 1918 under the name Camp Benning. Prior to its use as a military facility, several sites on Fort Benning were occupied by prehistoric people, native Americans, and European-Americans. An overview of Fort Benning prehistory and post-European settlement history is presented by Elliott et al. 1996). By the late 1800s, several small communities including Roland, Halloca, and Shell Creek developed in the area around mills that were used to process corn, wheat, and lumber. Fertile land adjacent to the Chattahoochee River supported large plantations and the upland areas were generally farmed by small families.

The original site was 38,627 ha on a plantation south of Columbus. In 1922, the name was officially changed from Camp Benning to Fort Benning after Major General Henry Lewis Benning, a native Georgian and Confederate war veteran. In response to the doubling of World War II troop strength, the U.S. Army purchased approximately 34,400 ha in Georgia and Alabama for training purposes (Gulf Engineers and Consultants, Inc. 1995). After World War II, a parachute school, the Ranger Training School, and the 11th Air Assault Division were added. Currently Fort Benning is home to 12 major units and provides year-round training to over 100,000 troops.

Transportation Infrastructure

The installation contains approximately 15 km of interstate, 35 km of 4-lane highway, 220 km of 2-lane highway, 145 km of paved roads, 220 km of unpaved roads, and 1300 km of trails. This infrastructure is important to the SEMP in two respects. Roads are an integral component of the dynamics, including disturbance regimes, of the military landscape under study. On a practical level, roads represent accessibility to study sites and also artificial, human-created dividers or fragments of ecosystems.

Physical Structure

Climate

The climate at Fort Benning is characterized by long, hot summers and mild winters. Precipitation occurs regularly throughout the year. The majority of precipitation occurs in the spring and summer, often in the form of thunderstorms. Heavy rains can occur in any month. Snow occurs occasionally but quickly melts. Droughts of short duration occur occasionally during the summer.

Surface hydrology

The installation lies almost entirely within the eastern half of USGS hydrologic unit code (HUC) number 03130003 and contains watersheds from 1st to 6th order. The Strahler method of stream ordering (Strahler 1952) was applied to the entire stream network on the eastern side of the HUC. Using this method, Upatoi Creek is a 6th order stream. Ephemeral and permanent streams are included. Approximately 33 km of the Chattahoochee River flows through the installation. The majority of Fort Benning in Alabama is in the Chattahoochee River floodplain and exhibits a poorly organized drainage pattern. Stream ordering was not applied to these stream segments.

Surface watersheds

Surface watersheds were delineated for the Georgia-side HUC using the digital elevation model (DEM) and the surface drainage network. The Upatoi flows roughly through the center of the installation; with its five major and numerous smaller tributaries, it drains most of the installation in Georgia. Table 1 lists the frequency and area of watersheds by order.

Table 1. Frequency and area of watersheds by order for Fort Benning, GA.

Watershed Order	Frequency in HUC 03130003	Frequency on Fort Benning	Total Area on Fort Benning	Cumulative Area on Fort Benning
1	2599	1194	39827	39827
2	599	297	12137	51964
3	142	92	3044	55008
4	31	23	6465	61473
5	8	6	3690	65163
6	1	1	2862	68024
Alabama*	—	—	5793	73817

* Watersheds on the Alabama side of the installation were not assigned orders.

Stream ordering and watershed delineation on the Alabama side of Fort Benning is problematic. Both procedures require connected, organized drainage patterns and topographically definable drainage divides, which are absent in the Chattahoochee River floodplain. Assignment of the correct order to Uchee Creek would require development and ordering of the entire network within the Alabama-side HUC. This was not attempted.

Development of the DEM, ordering of the stream network, and delineation of watersheds was a major component of the ecosystem physical structure characterization accomplished during the design and characterization phase of the Ecosystem Characterization and Monitoring Initiative.

Soil

Modern U.S. Department of Agriculture (USDA) county soil surveys are available for all of Fort Benning (USDA 1983, 1995). The exceptions are the live-fire impact areas within these counties, which were not mapped. Old soil surveys (1928) did map impact areas and have been incorporated into the Fort Benning soil survey map. The dominant soil texture in the Sand Hills ecological unit is loamy sand. The dominant surface soil texture in the Loam Hills ecological unit is sandy clay loam.

Biological Structure

Flora

The two primary sources for information on the current vegetation cover and condition at Fort Benning are the Timber Management Section of the Land Management Branch (LMB) and the Land Condition Trend Analysis (LCTA) Program conducted by the Directorate of Operations and Training.

The LCTA program is a long-term land use and disturbance, vegetation, and wildlife monitoring program initiated at Fort Benning in 1990. Figure 4 shows locations of the 200 LCTA core measurement plots. The existing LCTA database provides detail on the composition and structure of vegetation at these locations.

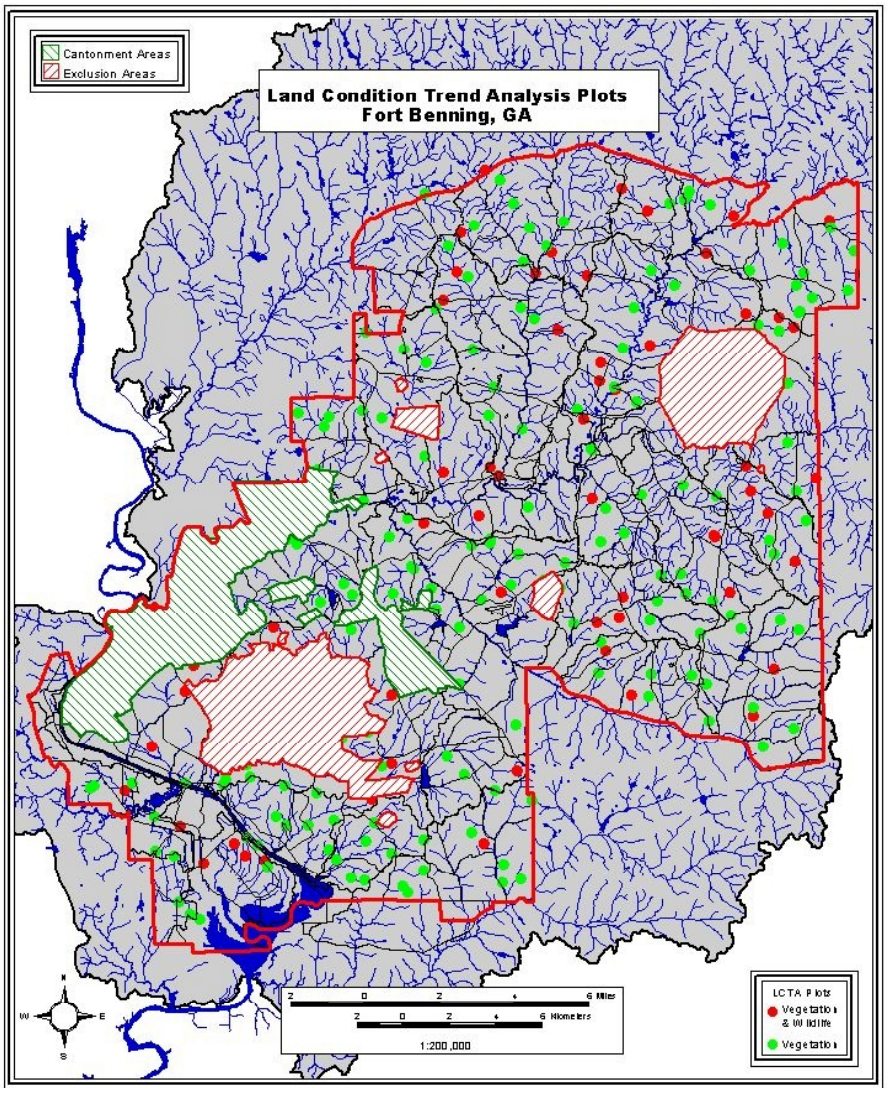


Figure 4. Distribution of LCTA program monitoring core plots at Fort Benning, GA.

Fauna

An extensive fauna and flora species list for Fort Benning has been compiled through various programs. Collectively these activities describe a rich and varied terrestrial and aquatic fauna. The LCTA program has specifically documented diverse bird and small mammal populations. The USFWS has conducted a 100 percent survey for federally TES and other species of conservation concern. The Conservation Branch conducts or cooperates with various levels of monitoring for certain listed, desirable, and undesirable species including red-cockaded woodpecker, gopher tortoise, gopher frog, southern bald eagle, American alligator, wood stork, northern bobwhite quail, wild turkey, white-tailed deer, and feral swine.

Land Use

Training

The major units on Fort Benning include the 3rd Brigade, 3rd Infantry Division (Mechanized); the 75th Ranger Regiment; the 11th Infantry Regiment; the 29th Infantry Regiment, 36th Engineer Group; the U.S. Army Infantry School; the Infantry Training Brigade; Military Police units; and the Ranger Training Brigade.

Figure 5 (on following page) shows the general distribution of training types. Fort Benning has 73 live-fire ranges, 64 potential maneuver training areas, 1 airfield, 43 field artillery and mortar firing points, 1 large and several small airborne drop zones, numerous specialized non-live-fire training assets, and 4 large and 5 small dudded impact areas (Department of the Army 1997). The Alpha Range Complex, the Malone Range Complex, and the Oscar-Kilo Range Complexes dominate the training landscape. Maneuver training areas include those used for light and heavy training. Other training facilities include bivouac sites and assembly/staging areas.

Table 2 lists the total daily average number of troops using Fort Benning ranges and training areas from 1991 through 1995. During 1991 and 1992, training levels increased in response to Operations Desert Shield and Desert Storm. In 1993, selected troops were deployed to Somalia in support of Operation Restore Hope, a United Nations relief mission. In 1995, the 586th Engineer Company was deployed to support NATO forces in Bosnia (Jones and Davo 1997).

Table 2. Daily average troops per year using Fort Benning training compartments.

Fiscal Year	Total Daily Average Number of Troops/Year
1991	22,798
1992	23,433
1993	21,386
1994	20,539
1995	18.273

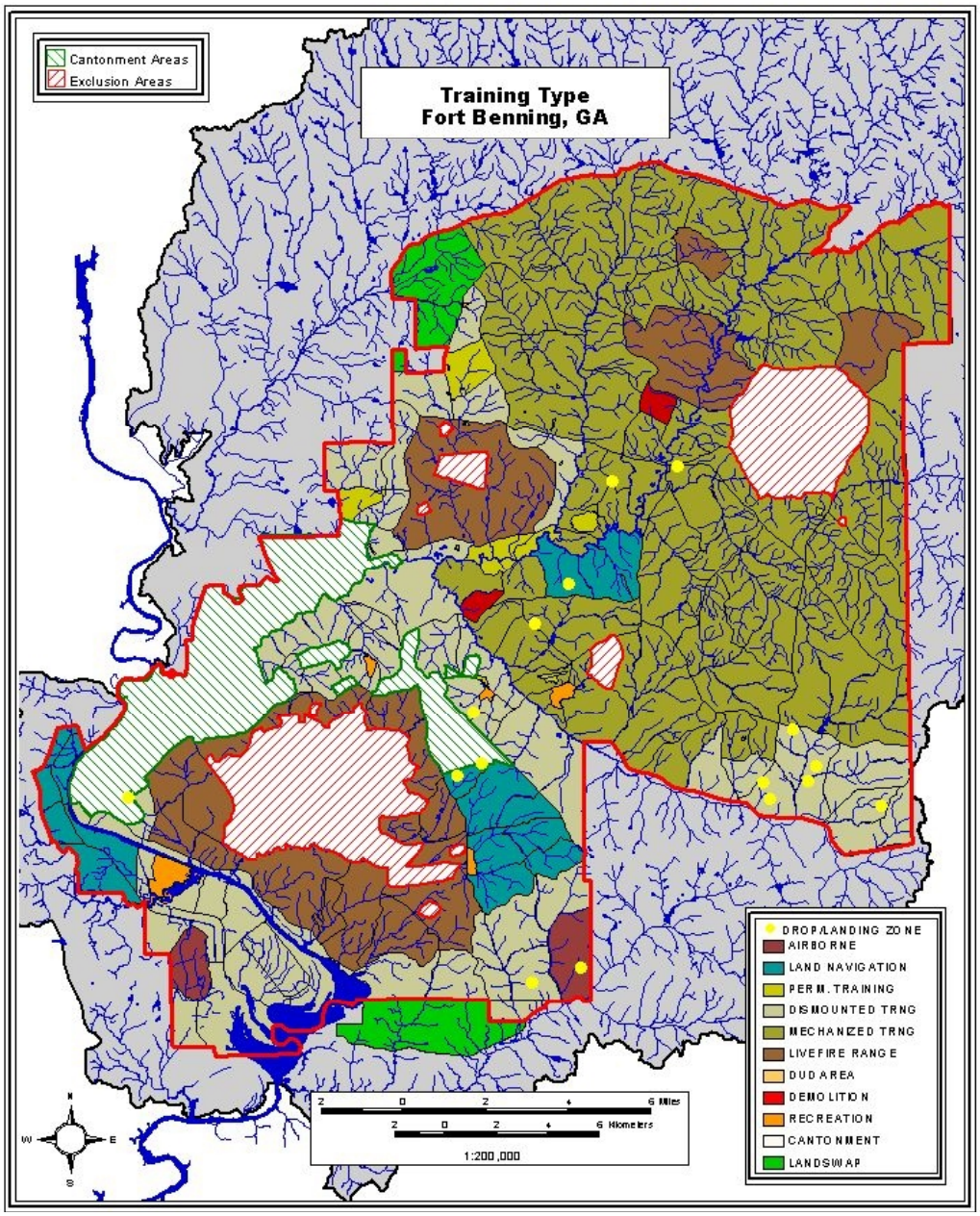


Figure 5. Dominant training type by compartment at Fort Benning, GA.

Natural resource management

Timber Management. Timber management activities include creating a suitable military training environment, managing wildlife habitat, and managing for a diverse and healthy forested ecosystem. Rotation and cutting cycles are implemented to create habitat for wildlife including the red-cockaded woodpecker (RCW [*Picoides borealis*]) and to produce timber suitable for processing. The southern pine beetle is of special management concern.

Prescribed Burning. Prescribed burning is a forest management practice that improves habitat for the RCW. Variable intensity burns control hardwood regeneration, maintain habitat, maintain fire-dependent communities, reduce forest fuel loads, and prepare the site for regeneration. The burning season begins around the end of December or the beginning of January and ends the first of September. An adaptive rotation schedule interval (2 to 3 years) for burning has been adopted.

Wildlife Management. An aggressive wildlife management program is directed at managing native fish and wildlife populations and minimizing the effect of military training on wildlife habitat. Habitat and population trends are monitored. Wildlife species targeted for management include the RCW, bald eagle, white-tailed deer, bobwhite quail, eastern wild turkey, and gopher tortoise. The RCW is of special management concern as Fort Benning has been designated as one of 15 recovery populations. Relict trillium (*Trillium reliquum*), a federally endangered plant species, is also of special management concern.

Outdoor recreation

Recreational opportunities on Fort Benning include dispersed hunting, fishing, and use of the Uchee Creek Recreation Area. Hunting privileges are restricted to military and federal civilian employees and their guests. Hunting occurs on the entire installation as allowed by training and other installation activities. Species hunted include waterfowl, small game, turkey, deer, and feral swine. Fishing is permitted on installation ponds and streams. Other recreational facilities include the riverwalk hiking trail, two 18-hole golf courses, a football stadium, gymnasiums, and softball fields.

Available Data/On-Going Monitoring

An inventory of available data (Appendix D) and a review of on-going monitoring activities relevant to the ECMI were conducted (Inventory of Fort Benning, GA Existing Data and Summary of On-Going National Monitoring Initiatives, 1999). The data inventory included both data available on-site at Fort Benning and data available from various sources for the larger ecoregion surrounding Fort Benning. The review of monitoring activities included installation-specific activities and national monitoring initiatives. The ECMI will leverage these data and programs to the fullest extent possible.

4 Fort Benning Ecosystem Management

Existing Natural Resources Management Programs at Fort Benning

The sections below are adapted from the Fort Benning Army Installation's Integrated Natural Resources Management Plan, completed October 2001. Together they provide the natural resources management context for identifying potential technical outcomes of SEMP research. To fully exploit the potential of SEMP to provide installation managers with relevant research, SEMP's research framework and individual research projects must account for the installation's management philosophy, goals, objectives, and desired future ecosystem conditions, all in the context of a military training environment. SEMP is intended to impact all DoD installations, not just Fort Benning. However, all DoD installations have INRMPs; therefore linking SEMP to integrated natural resources management is an opportunity to "infuse" SEMP to both the host site and other DoD installations.

Management Philosophy: Application of an Ecosystem Management Approach

Fort Benning's approach to natural resources management is embodied in the installation's vision of the relationship between its military mission and the natural resources upon which that mission depends. The installation also has developed a natural resources management mission statement that provides an overarching premise for how Fort Benning will manage its lands. The vision and mission statements are provided below. Because Fort Benning's natural resources management philosophy relies heavily on an ecosystem-based approach, this section also includes a brief overview of ecosystem management policy, conservation concepts, and ecosystem management principles and guidelines and their relation to the installation's management philosophy. The section concludes with the relationship of Fort Benning's natural resources management philosophy to the installation's military mission.

Vision and Mission Statements

Fort Benning's vision

Support the military mission while promoting the ecological integrity of the Fort Benning landscape.

Fort Benning's natural resources management mission

Through a collaborative effort between natural resource professionals and military personnel, Fort Benning will strive to promote the long-term ecological sustainability of its lands for multiple-use opportunities. Fort Benning will apply sound land management practices and adaptive management strategies that conserve ecological integrity through the restoration, maintenance, and preservation of natural biotic communities and otherwise promote the health of installation ecosystems through rehabilitation and maintenance. This ecosystem management approach will encompass stakeholder interests, regulatory requirements, and fiscal constraints.

Ecosystem Management Approach

In its simplest form, ecosystem management represents a proactive approach to Federal environmental policy. Because of their vast land holdings and the nature of their activities that have the potential for significant adverse impacts on the environment, Federal agencies such as the DoD can make important contributions to sustaining healthy ecosystems and conserving ecological integrity by using an ecosystem management approach (*National Performance Review* 1993). Moreover, although military lands represent only about 3 percent of the total Federal land inventory (the Department manages about 25 million acres, of which the U.S. Army manages about half of the total), they have disproportionate value with respect to their biodiversity (Leslie et al. 1996). This value is especially true in the southeastern United States where Federal public lands are otherwise relatively lacking. Finally, although some military land uses are intensive and result in severely degraded landscapes, often significant acreage is used at low intensity or serves as buffer — these latter land uses can be compatible with the maintenance of ecological integrity.

Policy background

The DoD and Department of the Army have embraced the concept of ecosystem management. Both are signatory to a Memorandum of Understanding (MOU), along with 12 other Federal agencies, that fosters an ecosystem approach to

natural resource management (Memorandum of Understanding, 1995). The policy portion of the MOU states:

> The federal government should provide leadership in and cooperate with activities that foster the ecosystem approach to natural resource management, protection, and assistance. Federal agencies should ensure that they utilize their authorities in a way that facilitates, and does not pose barriers to, the ecosystem approach. Consistent with their assigned missions, federal agencies should administer their programs in a manner that is sensitive to the needs and rights of landowners, local communities, and the public, and should work with them to achieve common goals.

Even before the MOU was signed, the DoD already had made a strong policy commitment to implementing ecosystem management across the Defense complex (Memorandum from S.W. Goodman, 1994). The DUSD (ES) [currently DDRE] articulated an overall ecosystem management goal, as well as principles and guidelines. According to the Secretary's policy statement, an ecosystem management approach would include: a shift in focus from the protection of individual species to management of ecosystems, formation of partnerships to achieve shared goals, public participation, use of the best available science, and implementation of adaptive management techniques.

Conservation Concepts

Concepts have a formative stage during which accompanying definitions are conceived, applied, criticized, at times perhaps misused — or at least used to mean different things, and revised if necessary. As a relatively new discipline, the field of conservation biology has developed its share of variously defined normative (standard) concepts. These include such concepts as: biodiversity (biological diversity), ecological (biological) integrity, ecosystem health, ecological sustainability, and ecosystem management. Because these concepts have become institutionalized to different degrees and effectively act to set conservation agendas, the fact that they are more philosophical and strategic (that is, value-laden) than technical and tactical (Callicott, Crowder, and Mumford 1999) cautions against their indiscriminate use. A failure to define clearly the meaning of a concept and to apply it correctly can lead to inappropriate management decisions and/or misunderstandings between natural resource managers, military trainers, and stakeholders as to the intent of management actions.

Recently, Callicott, Crowder, and Mumford (1999) organized and interpreted standard conservation concepts. They suggested interpretations useful for conservation applications; but more importantly, they embedded the concepts within

two complementary approaches. These two approaches provide a useful framework for deciding whether an area is to be managed primarily to ensure viable native species and communities or simply to retain intact ecological processes. The latter approach is used when an area is to receive intensive human use that is compatible with more rigorous conservation goals. Within the preceding framework, for example, promoting ecological integrity would be the management goal in the first area, whereas promoting ecosystem health would be the goal in the second area. Note that the two concepts — ecological integrity and ecosystem health — are not synonymous, but rather are achieved in different ways and represent different end states.

This document contains an annotated Glossary (page 122) of terms that includes many of the conservation concepts identified by Callicott, Crowder, and Mumford (1999). The included terms are those that are important to an understanding of the management philosophy described in this chapter. Most importantly, although Callicott, Crowder, and Mumford (1999) restrict the use of the term "ecosystem management" to a consideration of ecosystem health, its use herein includes ecological integrity as a complementary management goal in appropriate applications. Throughout the remainder of this document, every attempt has been made to use terminology and concepts as they are defined in the glossary.

Ecosystem Management Principles and Guidelines

The ecosystem management principles and guidelines articulated by the Deputy Under Secretary of Defense for Environmental Security (Memorandum from S.W. Goodman 1994) provide a useful vehicle for outlining Fort Benning's ecosystem-based approach to natural resources management. The Secretary's principles and guidelines, in some cases restated to reflect the changes in the use of normative conservation concepts discussed above, are provided below and discussed briefly with respect to their use at Fort Benning.

Restore and maintain the ecological integrity of biotic communities; rehabilitate and maintain the health of ecosystems. The distinction between biotic communities and ecosystems and their respective management goals is critical to the application of ecosystem management in contexts in which both human exploitation of a particular environment and conservation of biodiversity must be accommodated. Such is the situation at Fort Benning. The installation must be able to accomplish its primary mission of military training, but at the same time it must be a steward of the environment. How can Fort Benning be both? How does the above distinction contribute toward resolution of this apparent conflict?

Although virtually every square inch of Fort Benning is either cantonment area or technically available for some form of training, much of the installation's landscape receives relatively low-intensity impacts (that is, the human footprint on the land is slight enough that the co-existence of naturally structured and interacting native biotic communities is feasible). A management goal of maintaining ecological integrity is appropriate for these areas and where integrity is degraded, ecological restoration is the appropriate management action. Some portions of the installation, however, such as those that are directly impacted by mechanized training, cannot be reasonably managed to maintain their ecological integrity; instead, it is the appropriate ecological processes and functions (the occurrence or absence of which determines ecosystem health) that need to be maintained or rehabilitated to ensure the continued ecological sustainability of the land. Although under the general scenarios described above specific areas would be managed differently, at the landscape scale (here the entirety of Fort Benning) the management goal is the restoration and maintenance of ecological integrity.

Administer with consideration of ecological units and timeframes. Ecosystem management compels resource managers to look beyond administrative boundaries and the present to consider spatial and temporal ecological scales that are relevant to natural systems and processes. To effectively manage its natural resources, Fort Benning resource managers must consider how the installation's biotic communities and their ecological integrity interact with and are affected by, or in turn affect, the biotic and human communities that exist outside the installation's boundaries. Consideration of ecological time scales, and their variety, also is important, especially when certain natural processes (for example, fire) have been disrupted and now must be mimicked by human managers in regard to their estimated intensity and periodicity.

Support ecologically sustainable human activities. Continued military training at Fort Benning ultimately is dependent on healthy ecosystems at a minimum and, from the perspective of being a responsible steward, also achieving and maintaining ecological integrity at the landscape scale. For a project or activity to be ecologically sustainable, it must not compromise ecosystem health.

Develop a vision of landscape ecological integrity. Because of Fort Benning's importance to regional biodiversity conservation, its conservation success at the landscape scale must be measured in terms of ecological integrity. In conjunction with conservation partners, technical experts, and stakeholders, Fort Benning will develop a vision of landscape ecological integrity for the installation. The installation's objective is to determine how the Fort Benning landscape should appear and function as a sustainable, natural (to the extent achievable),

managed forest within a military training environment. A vision of landscape ecological integrity should account for appropriate restoration of longleaf pine (*Pinus palustris*) communities (or at a minimum rehabilitation and maintenance of ecosystem components), including necessary conversion from other forest vegetation types. The vision should also address the maintenance of a diversity of alliance vegetation types appropriate to the physiognomic, soil, hydrologic, and microclimate diversity present at Fort Benning.

Develop priorities and reconcile conflicts. Preparation of the INRMP relied in part on the advice of technical experts to assist installation natural resource managers in the identification of management issues. These issues (see Chapter 8 of the INRMP) helped form the basis for the development of natural resource management goals, objectives, and guidelines (Chapters 9 and 10 of the INRMP). Individual management programs (see Chapter 12 and Appendix B of the INRMP) used the preceding information to develop and prioritize their day-to-day and long-term management actions. To reduce potential conflicts in management direction, program operational plans are fully integrated.

Develop coordinated approaches to work toward ecological integrity and ecosystem health at the geographic scales and places where each is appropriate. Coordinated approaches are needed from two perspectives. The first perspective is ecological. Coordination must reflect the complementary attributes of management for ecological integrity and management for ecosystem health. The success of restoring and maintaining certain portions of Fort Benning for their ecological integrity depends in part on ecologically rehabilitating and maintaining the human-inhabited and -exploited portions of the installation. At the same time, the ecosystem health of exploited areas relies on other proximate areas with their ecological integrity intact as reference sites for normal ecosystem function (Leopold 1941) and as reservoirs of native species for recruitment (Naeem 1998; Callicott, Crowder, and Mumford 1999). Similarly, at regional scales the ecological integrity of the Fort Benning landscape has a reciprocal beneficial relationship to the health of the surrounding matrix of human-inhabited and -exploited lands. To the extent that some of the surrounding matrix can be managed for its ecological integrity, the chances improve for successfully managing for ecological integrity at Fort Benning.

The second perspective reflects human organizational structures and their interactions and human systems for planning and prioritizing. Coordination and collaboration must occur across ownership and political boundaries and with diverse entities: other Federal agencies, tribal, state, and local governments, nongovernmental organizations, private landowners, and the public. Achievement of integrity and health at regional scales requires a shared vision and the par-

ticipation of all. Ecosystem-based management goals and objectives need to be incorporated into strategic, program, and financial planning and budget design.

Rely on the best science available. The INRMP is considered a living document. As new information becomes available, it will be incorporated into the INRMP and used to further guide management actions. Fort Benning's role as a "test" site for ecosystem-based research projects funded through the SEMP places the installation among the cutting edge of ecosystem science research efforts. These research projects began during 1999. The results of these studies will form a basis for management actions for years to come.

Use benchmarks to monitor and evaluate outcomes. Benchmarks can be used both to measure management success and to show accountability. The INRMP management objectives and guidelines are presented in a manner that enables the results of management actions to be determined, though in some cases these results may take several years to appear. For many of the objectives and guidelines, success can be measured by use of ecological monitoring data. Fort Benning uses several measures of accountability to ensure that planned management initiatives will be implemented and their effectiveness, including cost-effectiveness, will be evaluated. Examples include the Installation Status Report and Environmental Compliance and Assessment System. Chapter 17 of the final INRMP addresses the implementation of the INRMP.

Use adaptive management. Biotic communities and ecosystems are complex dynamic systems. The management objectives and guidelines in the INRMP are designed to be flexible to accommodate changes in the status of natural resources at Fort Benning and new scientific understandings of how biotic communities and ecosystems function. A comprehensive natural resources monitoring program is a vital component of effective adaptive management. The SEMP, Ecosystem Characterization and Monitoring Initiative will provide a significant contribution to the installation's ecological monitoring needs.

Implement through installation plans and programs. The INRMP serves as a comprehensive plan for managing natural resources to attain and sustain stewardship requirements while optimizing the installation's ability to conduct primary activities on mission land and, where compatible, to conduct secondary activities. Included as part of the INRMP are operational plans for individual installation programs that play a role in natural resources management on the installation. The INRMP also is integrated with Fort Benning's Real Property Master Plan (Harland Bartholomew and Associates 1994), Range and Training Land Program Development Plan (Nakata Planning Group 1999), and overall aspects of the installation's training mission.

Relationship to the Military Mission

The training requirements of the units assigned to the installation dictate the manner and extent of natural resource impacts that result from military activities at Fort Benning. The requirement that a realistic training environment be maintained places further demands on the resource base. Impacts result from direct removal of or damage to vegetation, digging activities, ground disturbance from vehicles, use of obscurant smoke and teargas-like agents, and munitions detonation. The mechanized forces in particular, which use vehicles that include the M1A1 Main Battle Tank and the M2A2 Bradley Fighting Vehicle, can produce adverse direct and indirect impacts to natural resources. Often these impacts are related to soil compaction, disturbance, and movement that may result in soil erosion and eventually sedimentation of the installation's many streams. Fort Benning has numerous ranges, 6 (1 inactive) of which can accommodate fire from mechanized vehicles, and 10 dud areas (areas in which unexploded ordnance may be present) that can accommodate a variety of munitions. Cleared areas include bivouac sites, landing strips and pads for fix-winged aircraft and helicopters, and drop zones for airborne training. Proposed future range improvements, mechanized vehicle maneuver corridors, and increases in the number of tenant units stationed at Fort Benning necessitate a close integration with the resource management strategies specified in the INRMP to ensure a sustainable training environment.

A realistic training environment is a prerequisite for effective training at Fort Benning. For example, the presence of natural vegetation enables realistic training scenarios involving cover, concealment, or line-of-sight firing constraints. To ensure that Fort Benning can meet its mission needs now and into the future, the natural resources that provide the training context must be managed such that they are ecologically sustainable over the long term. The plant and animal communities that are locally adaptive are those that, once restored, can be sustained with a minimum of management action. Because of past land management practices, such as conversion of native plant communities to pine plantations, failure to adequately prevent and mitigate the effects of soil erosion and the introduction of non-native species, fire suppression, and inappropriate habitat removal, a portion of the present environment at Fort Benning is highly altered. For some of these altered areas, restoration of ecological integrity may be possible and may be compatible with present and future training missions. Other areas are either too heavily degraded or their present and/or future uses are intense enough to preclude restoration of ecological integrity as a management goal. For these latter areas, ecosystem health is the appropriate management goal and rehabilitation is the means to achieve that goal. A failure to maintain, restore, or rehabilitate the natural communities and ecosystems of the

installation could affect future training missions at Fort Benning. The INRMP builds on those important remnants of natural diversity that are present at Fort Benning and provides an ecosystem-based vision and management strategy for restoring or rehabilitating, where appropriate, the native biota and ecological processes characteristic of the installation.

The federally endangered RCW is a non-migratory bird endemic to the pine forests of the southeastern United States. A primary reason for the decline of RCW populations has been the loss of longleaf pine-dominated communities, such as those present at Fort Benning. In September of 1994, the USFWS determined that military training and related activities at Fort Benning are likely to jeopardize the continued existence of the RCW. As required by AR 200-3, Fort Benning complies with the reasonable and prudent management alternatives specified by the USFWS in its September 1994 Biological Opinion. These alternatives are those the Service believed, when implemented, would avoid jeopardizing the continued existence of the RCW. Implementation has resulted in some training restrictions over a relatively small portion of the installation. To date, these restrictions have not resulted in any substantial impact on overall training. Although other federally listed species also are present on Fort Benning, no noteworthy conflicts have arisen between training activities and the persistence of these species.

In summary, the INRMP focuses management efforts on achieving an ecologically sustainable training environment across the Fort Benning landscape by using an ecosystem approach that attempts to maintain landscape ecological integrity while at the same time addressing the needs of listed species and promoting the ecosystem health of exploited areas.

Management Goals and Objectives

The management goals and objectives stated on the following pages define the broad, overall natural resources management direction for Fort Benning. These goals and objectives are a subset of the goals and objectives contained in the installation's INRMP. These goals and objectives are those that were initially identified as relevant to SEMP. Each management goal is followed by a list of objectives most pertinent to the accomplishment of that goal. Nevertheless, accomplishment of a particular objective often will lead to the accomplishment of multiple goals. Goals are defined as the general target or end result to be achieved through integrated resource management. Objectives are defined as somewhat more specific targets, in some cases the attainment of which are

measurable, whose implementation contributes to the accomplishment of management goals.

The chosen subset of goals and objectives are those from which specific desired future ecosystem conditions are derived. The focused set of desired future ecosystem conditions provide SEMP researchers with an appropriate conceptual management framework for hypothesis testing and variable selection. A clear management framework is prerequisite for the efficient integration of research outcomes tailored to appropriate management actions that can meet management goals and objectives. Monitoring of goals and objectives is not emphasized, except as a means to determine if the goals are being achieved (e.g., see Goal 14, page 60). After each goal and its set of objectives, a brief discussion is included on the relevance to the SEMP Integrated Framework.

> *Goal 1. Maintain a realistic training environment, in accordance with an ecosystem approach, by managing for the sustainability of the installation's natural resources.*

Objective a. Match, to the extent feasible, military training location, type, and intensity with the ability of the natural resources to sustain training over the long term.

Objective c. Manage natural resources to provide for a variety of realistic military training experiences, each of which may require different degrees of cover, concealment, and maneuverability, by appropriately managing soil and vegetation.

Relevance to the SEMP Integrated Framework. The preceding management goal and its associated objectives provide the broad context for natural resources management at Fort Benning. Natural resources management activities must directly support military mission activities, but at the same time meet Federal stewardship requirements. They must ensure, in concert with the military activities themselves, that the Army's use of the land is sustainable. At appropriate temporal and spatial scales, achieving mission sustainability is wholly dependent on achieving ecological sustainability. The outcomes from SEMP research activities should provide information and tools that enable land managers to achieve ecological sustainability in the context of compatible military training.

> *Goal 2. Manage natural resources, to the extent feasible, within the contexts of watersheds, ecological groups, and land-use/-condition matrices.*

Objective c. Use watershed boundaries and stream order, as appropriate, as a framework for monitoring strategies, watershed restoration projects, and other management actions.

Objective e. Delineate the vegetation types that occur across the Fort Benning landscape and aggregate these into ecological groups according to association with similar environmental settings and ecological processes. Use these ecological groups to devise management guidelines appropriate to each group.

Objective f. Use land-use versus ecological condition matrices to determine the appropriate management objective (that is, ecological integrity versus ecosystem health) and strategy (that is, ecological restoration versus ecological rehabilitation) to reach the objective for each land-use area.

Relevance to the SEMP Integrated Framework. It is believed that research-derived information and spin-off management tools will often be more efficient when they can be integrated into an appropriate management framework. Fort Benning will be evaluating a number of complementary management frameworks as part of the implementation of its INRMP. Already, one of these potential frameworks — watershed units — serves as an organizing principle for some of the SEMP research activities and the Ecosystem Characterization and Monitoring Initiative. Ecological groups, at least for terrestrial ecosystems, are derivable from vegetation classification information obtained at either the alliance or association levels of the National Vegetation Classification System (Anderson et al. 1999). Ecological groups can be applicable across broad geographic areas and serve to aggregate vegetation community types that may be exposed to similar disturbance regimes and that may have similar management needs. Past, present, and proposed future land uses constrain what ecological conditions may be maintained, rehabilitated, or restored over a particular land area. From the SEMP research perspective, land use and ecological condition also may affect which ecological indicators, thresholds, and disturbance regimes are relevant to management at a particular site.

> *Goal 3. Restore and maintain a variety of ecosystems, with an emphasis on the longleaf pine* (Pinus palustris) *ecosystem, to conserve native biological diversity and the ecological processes that sustain it.*

Objective a. Establish an installation-wide vision of how the Fort Benning landscape should appear and function as a sustainable, natural (to the extent achievable), managed forest within a military training environment. This vision should account for appropriate restoration of the longleaf pine ecosystem,

including necessary conversion from other forest vegetation types. The vision should also address the maintenance of a diversity of alliance vegetation types appropriate to the physiognomic, soil, hydrologic, and microclimatic diversity present at Fort Benning.

Objective b. Restore and maintain ecosystems consistent with the maintenance of red-cockaded woodpecker (*Picoides borealis*) nesting (cluster locations) and foraging habitat, as well as future replacement stands needed for the foregoing.

Objective c. Use information on the historic vegetation and land use of Fort Benning, as well as current soil type information, to assist in developing restoration plans.

Objective d. Determine the present ecological condition of the installation's ecosystems to assist in developing restoration plans and setting priorities.

Objective e. Restore longleaf pine where it is ecologically appropriate using both natural and artificial means.

Objective f. Restore, by reintroduction and/or by the use of prescribed fire, those pyrophytic grasses and other native plants characteristic of the understory of the longleaf pine ecosystem.

Objective g. Use fire to restore and maintain the longleaf pine ecosystem, as well as those ecotonal communities that depend in part on fire to maintain their biological diversity.

Relevance to the SEMP Integrated Framework. The preceding management goal and its associated objectives highlight two important considerations relevant to the SEMP framework. First, in large measure independent of military training and its land-use requirements, past land-use practices (for example, agricultural and silvicultural) have resulted in ecological conditions that are altered from their pre-settlement conditions. The longleaf pine ecosystem is the expected upland matrix community for the Fort Benning area that would exist if human-induced land-use changes across the landscape had not altered the natural fire regimes and floral composition and structure characteristic of the area (Wharton 1978). Its decline at Fort Benning and elsewhere across the Southeast is a major contributor to the decline of species associated with longleaf pine, such as the red-cockaded woodpecker. As a result, Fort Benning intends to accomplish extensive restoration of its upland forested ecosystems to a longleaf pine ecosystem via appropriate silvilcultural manipulation. One consequence of this intent to change is that the system is dynamic, in response to a prescribed management

direction as well as to existing ecological processes. We cannot, however, ignore the effects of military training. Research under SEMP must account for the restoration trajectory of Fort Benning's upland ecosystems.

Second, although restoration of the longleaf pine ecosystem is a focus of installation management, such restoration will be accomplished only where it is ecologically appropriate. The underlying theme of the management goal is to maintain a diversity of alliance vegetation types appropriate to the physiognomic, soil, hydrologic, and microclimate diversity present at Fort Benning.

> *Goal 4. Manage hardwoods using an ecosystem approach: conserve hardwoods where they are ecologically appropriate and contribute to overall biological diversity; conversely, control hardwoods where they are detrimental to management goals and objectives, including restoration of the longleaf pine ecosystem.*

Objective c. Develop management criteria for hardwoods, with an emphasis on either conservation or control, that reflect the historical occurrence data of hardwood communities and the longleaf pine ecosystem, current condition of the physical and biological environment, and the needs of listed species and overall biological diversity.

Objective d. Conserve ecotones between pine and hardwood communities in upland, slope, and bottomland sites by using fire and other silvicultural activities as the primary management tools.

Objective e. Do not purposely burn bottomland hardwood communities. Use an adaptive management approach to introduce fire to other hardwood communities that depend on fire for their maintenance.

Relevance to the SEMP Integrated Framework. The preceding goal and its associated objectives are an expansion of the general implications of Goal 3 insofar as hardwood communities are concerned. Because hardwood control is an explicit part of the management actions needed to restore a longleaf pine ecosystem, installation managers felt that it was important to also capture the importance of conserving hardwood communities where appropriate to ensure the proper management balance.

> *Goal 5. Manage aquatic and wetland ecosystems to restore and maintain their ecological integrity.*

Objective b. Develop management strategies to restore and maintain the ecological integrity of Fort Benning's aquatic and wetland ecosystems.

Objective d. Use silviculture and fire to restore and/or maintain natural ecotones between wetlands and uplands.

Relevance to the SEMP Integrated Framework. A significant proportion of the installation's aquatic resources are degraded relative to their historic biotic potential because of excessive sedimentation and other adverse impacts. With some exceptions, the aquatic systems (both biodiversity elements and ecological processes) tend to be poorly characterized. The Ecosystem Characterization and Monitoring Initiative, as well as SEMP research projects, provide important baseline characterization information that can be used to plan future restoration actions or at least help to identify appropriate management actions that can mitigate the extent of additional degradation. The direct consequence of aquatic system condition to SEMP research may be that the suite of potential biotic indicators already is reduced from what may have been available historically.

Goal 6. Develop a strategy for management of designated unique ecological areas.

Objective a. Characterize the physical and biological features of currently identified Unique Ecological Areas, characterize new areas as they become identified, establish appropriate boundaries (including buffer zones) for each area, and delineate the boundaries of each area in a geospatial format.

Objective b. Develop for each Unique Ecological Area a set of management guidelines to include the types of military training that can take place without adversely affecting the ecological integrity of each area.

Objective e. Identify those Unique Ecological Areas, or portions thereof, that require little or no active management to maintain their condition and, as a result, can serve as reference sites for the biodiversity and ecological processes associated with natural communities.

Relevance to the SEMP Integrated Framework. A number of the installation's Unique Ecological Areas (see Chapter 5 of the INRMP for descriptions) potentially could serve as reference sites for SEMP research activities that are focusing on areas of the installation experiencing different degrees of military training intensity. Although many of the Unique Ecological Areas experience some military training, the associated impact levels (today and historically) could be

qualitatively different from the levels experienced in more intensively used areas.

> *Goal 7. Use forest management as part of an adaptive management approach that focuses on the ecological integrity of the landscape as its primary end state.*

Objective a. Use modeling to help predict future stand composition, structure, and age under different harvesting and reforestation scenarios. Use the modeling to assist in planning longleaf pine restoration and to ensure that future stand conditions favor the continued viability of red-cockaded woodpeckers at Fort Benning.

Objective b. Use an uneven-aged management approach for pine and mixed pine/hardwood stands.

Objective c. Use silvicultural prescriptions, including the use of fire, such that their primary emphases are to maintain a realistic training environment and to support the habitat needs of listed and other species of conservation concern.

Objective d. Use thinning, single-tree selection, and small group cuts as the primary silvicultural prescriptions.

Objective g. Adjust methods of site preparation to account for the presence of desirable native species that may be sensitive to ground disturbance or the presence of residual pesticides.

Objective h. Optimize the use of appropriate seed and seedling stock and planting techniques to best ensure the viability of longleaf pine seedlings and eventual natural stand structure of the plantings.

Objective i. Use prescribed fire at the frequencies, timing, and intensities appropriate to restore and maintain longleaf pine communities, to enhance overall plant community diversity, and to support habitat management needs of the red-cockaded woodpecker.

Objective k. Use existing natural and previously constructed, human-made firebreaks as much as possible; if new firebreaks are needed, avoid placing them in ecotones. Let fire determine the characteristics of ecotones, except when detrimental to listed plant species or native plant communities.

Relevance to the SEMP Integrated Framework. The preceding goal and its associated management objectives indicate the specific management approaches for pine and mixed pine/hardwood stands that the installation, through the use of appropriate silvicultural prescriptions, intends to implement. Although silvilcultural prescriptions, including the use of prescribed fire, may represent a form of anthropogenic disturbance, they also represent management actions that are applied to restore fire-suppressed and otherwise altered areas (for example, areas converted to off-site pine plantations) to the composition, structure, and functional attributes of a "mature" longleaf pine ecosystem. As a consequence, SEMP research that is concerned with investigating disturbance regimes and/or desired sustainability end states must account for the role of silvicultural practices as both a possible source of disturbance and as the primary suite of mechanisms that are used by the installation to achieve desired future ecosystem conditions. It is the desired future ecosystem conditions against which the impacts of other anthropogenic disturbances, such as military training, on ecological sustainability must be tested.

> *Goal 10. Manage species of conservation concern using an ecosystem approach to maintain the ecological integrity of the landscape while still contributing to species recovery or maintenance.*

Objective f. Manage for red-cockaded woodpeckers by: meeting the requirements of the Reasonable and Prudent Alternatives from the September 22, 1994 Biological Opinion of the U.S. Fish and Wildlife Service, following the 1996 "Management Guidelines for the Red-cockaded Woodpecker on Army Installations," and continuing to recover the population toward the Regional Recovery Goal.

Relevance to the SEMP Integrated Framework. Requirements of the Endangered Species Act, insofar as they affect the ability to fully implement the ecosystem approach today, still largely dictate management approaches whenever federally listed species are present. The challenge for Fort Benning natural resource managers is to meet the habitat requirements of listed species while at the same time doing so in a manner that is beneficial, and not adverse, to the maintenance of overall biodiversity. Still, as an example, some management prescriptions are specific to the habitat needs of the red-cockaded woodpecker. Whether such management has any adverse consequences, short- or long-term, on overall biodiversity is unknown. (The consequence for SEMP research and its technical outcomes is the recognition that listed species recovery may or may not add some degree of artificiality to what is considered the ecological Desired Future Condition (DFC) that may not have otherwise existed if the species in question was not listed.) The current approach is to look at the ecosystem as a whole and turn

from past thinking of species-specific management. The DFCs were developed with this in mind.

> *Goal 12. Manage problematic species to eliminate or minimize adverse impacts to natural resources.*

Objective d. Develop and implement a management strategy that attempts to eradicate, or contain to the extent attainable, kudzu.

Objective e. Develop and implement a management strategy to contain, to the extent attainable, other undesirable plants with an emphasis on those invasive plant species that potentially affect listed species, undermine ecological integrity, or degrade military training activities. Use an appropriate ranking methodology, scientific literature, or expert opinion to identify those invasive species that should receive the priority for control measures.

Objective f. Develop and implement a management strategy for the aggressive containment of insects and disease organisms that adversely affect the timber resources of the installation, while accounting for the potentially adverse ecological impacts caused by specific containment methods.

Objective g. Develop and implement a management strategy that attempts to eradicate, or contain to the extent attainable, feral swine.

Objective h. Develop and implement a management strategy to contain, to the extent attainable on mission lands, other undesirable animals with an emphasis on those non-native animal species that potentially impact listed species, undermine ecological integrity, or degrade military training activities.

Relevance to the SEMP Integrated Framework. Besides the direct loss of habitat, invasive species (those non-native species whose introduction may cause ecological disruption) represent the next most important threat to the maintenance of biodiversity. The presence and relative abundance of invasive species can be a direct indication of the ecological condition of a particular plant community or ecosystem. Plant communities or ecosystems that are otherwise disturbed are more susceptible to invasion by non-native species. At Fort Benning a number of invasive species, such as kudzu (*Pueraria lobata* [= *montana*]) and feral swine (*Sus scrofa*), directly or indirectly impact listed species and native plant communities adversely and are targeted for control measures (see Appendix B11 of the INRMP). With over 150 non-native plant species that occur within its boundaries, Fort Benning can attempt focused control measures on only the handful of invasive species that pose the most threat to listed species and native plant

communities. Moreover, given the installation's current forest management focus on longleaf pine ecosystem restoration, a potential byproduct of the associated silvicultural practices could be changes in floral composition attributed to species-specific negative or positive effects on upland-associated non-native species. Consequently, during the lifetime of SEMP, the interaction of natural resources management, military training, and the relative persistence of native and non-native species will be dynamic. Cause and effect may be hard to determine in some cases.

> *Goal 14. Develop and implement a comprehensive, ecosystem-based monitoring strategy that tracks indicators of ecological change, enables the determination and use of ecological thresholds, facilitates adaptive management, and leads to a sustainable training environment by providing a basis for effective land-management decisions.*

Objective a. Conduct baseline monitoring of the installation's physical, chemical, and biological environment via the Ecosystem Characterization and Monitoring Initiative to support: SERDP ecosystem science research objectives, regional ecosystem management initiatives, and installation-specific ecosystem management initiatives.

Objective d. Determine those environmental metrics that best meet the management goals for monitoring over the long-term, based on the results of the ECMI, SERDP research, and other available data.

Objective e. Ensure all monitoring data collected are appropriate to the management objectives they are designed to support and are repeatable, statistically analyzable, and scientifically rigorous.

Relevance to the SEMP Integrated Framework. The preceding goal and its associated objectives state the broad expectations Fort Benning has in regard to the outcomes of SEMP research and the ECMI.

Desired Future Ecosystem Conditions in the Context of a Military Training Environment

A desired future ecosystem condition "is an attempt to envision all aspects of an ecosystem in the future, including human organizations and needs, in measurable terms" (Leslie et al. 1996). A clear picture of current ecosystem conditions, as well as desired future conditions, which is tempered by an understanding of

the inherent uncertainties and limitations associated with predicting the behaviors of natural and altered ecosystems and human social systems, is fundamental to ecosystem management (Leslie et al. 1996). Uncertainty is addressed by using an adaptive approach to management.

Although the desired conditions expressed herein for Fort Benning (and its surrounding environs) are stated in the context of a military training environment, specific human uses of the land and their distribution across the landscape are not specified (for example, the amount of cantonment or urbanized area is not specified). That is left for a separate process; however, the desired future ecosystem conditions stated here provide a framework against which future human uses of the land can be planned and executed in a sustainable manner.

The specific desired future ecosystem conditions selected gain cohesiveness when they are organized around a central theme. The organizing theme for Fort Benning is the promotion of the ecological integrity of the Fort Benning landscape. As a result, all desired future ecosystem conditions should be consistent with the promotion of ecological integrity. Additionally, however, they should also reflect conditions that are indeed achievable.

Ideally, desired ecosystem conditions should be defined on the basis of a natural (or attainable) range of variation in composition, structure, and function for a particular ecosystem (Leslie et al. 1996). For many ecosystems, especially those that have been largely altered since human settlement, defining a natural or historical range of ecosystem variation based on empirical data is not always feasible. An understanding of current ecosystem conditions and how they may have come about may provide at least a baseline of information for defining acceptable variation in altered ecosystems. Additionally, no matter what the state of knowledge is about a particular ecosystem, not all desired conditions will have easily measured attributes (Leslie et al. 1996). As a result, many desired ecosystem conditions may need to be stated in non-quantitative terms. A key challenge for SEMP research is choosing a suite of measurable indicators of ecosystem condition, perhaps even in situations when the condition itself can be described only qualitatively.

An initial set of, desired future ecosystem conditions for Fort Benning are identified on the following pages. Although they are mostly qualitative in nature, they still reflect a comprehensive vision of ecological integrity for the Fort Benning landscape. A similar set of ecosystem conditions, used to define ecological integrity for the sandhill ecosystems at Eglin Air Force Base in Florida, was used as an initial template for identifying ecosystem conditions at Fort Benning

(The Eglin conditions are identified in Leslie et al. [1996:126].). Fort Benning's desired future ecosystem conditions are:

1. Indicator and/or keystone species are present, approach in abundance the carrying capacity of the ecosystem for that species, and are not declining across the landscape; age distributions in populations primarily reflect random fluxes in demography and environmental conditions; regeneration and reproduction of selected species are evident, and populations fluctuate within a desired range. Appropriate indicator and/or keystone species for Fort Benning include:
   - longleaf pine [*Pinus palustris*]
   - red-cockaded woodpecker [*Picoides borealis*]
   - gopher tortoise [*Gopherus polyphemus*]
   - fox squirrel [*Sciurus niger*]
   - native pyrophytic grasses, including sandhill dropseed (*Sporobolus junceus*), arrowfeather three-awn (*Aristida purpurascens*), little bluestem (*Schizachyrium scoparium* [= *Andropogon scoparius*]), Elliot's bluestem (*Andropogon gyrans*), splitbeard bluestem (*Andropogon ternarius*), and yellow Indiangrass (*Sorghastrum nutans*).

2. The red-cockaded woodpecker population is recovered (at least 250 effective breeding pairs within managed areas), genetically diverse, and well-distributed across the landscape (the population is distributed not only within both the Alabama and Georgia portions of the installation, but breeding pairs also are present on lands that occur near Fort Benning).

3. Local extirpations are buffered by recolonization from nearby populations. Example species that may be subject to local extirpations include:
   - relict trillium (*Trillium reliquum*)
   - sweet pitcherplant (*Sarracenia rubra*)
   - gopher frog (*Rana capito*)
   - eastern diamondback rattlesnake (*Crotalus adamanteus*).

4. Landscape-level native species richness (number of species) and evenness (measure of how equally abundant the species are) are maintained over time.

5. Invasive species are controlled to the extent that they have a minimal impact on the integrity of native plant and animal communities; kudzu's (*Pueraria lobata* [= *montana*]) distribution and abundance is reduced to 10 percent or less of its peak historic values; feral swine (*Sus scrofa*) are no longer intentionally introduced and their distribution and population levels do not pose a significant threat to ecological integrity.

6. At least 90,000 acres on Fort Benning are managed as pine (*Pinus*) and mixed pine/hardwood.

7. Longleaf pine is the dominant upland pine species; longleaf pine stands have an open architecture and multi-aged distribution, with many trees more than 200 years old, a few shrubs, a suppressed midstory of mixed hardwoods, a sparse to abundant understory dominated by mixed grasses and forbs (the composition and relative abundance of which reflect the different soil conditions present at Fort Benning), and a few standing dead trees (snags); longleaf pine stands are regenerated naturally and are manipulated silviculturally using low-impact harvest methods and single-tree selection prescriptions.
8. Other stands in which a pine species other than longleaf pine is the dominant species, such as those stands in which loblolly pine (*P. taeda*) is dominant, occur on slopes and within floodplains in accordance with their natural distribution.
9. Fire-adapted native communities burn every 1 to 5 years, at various times of year, and at different patch sizes; the timing and intensity of fire at any particular location is different from burn to burn.
10. Hardwood community diversity includes viable representations of all alliance vegetation types characteristic of the area; hardwood communities are found primarily within the Chattahoochee River and stream floodplains, on steep slopes (especially north- and east-facing slopes), on fire-sheltered upland sites, and associated with non-riparian wetlands.
11. Ecotones are the result of dynamic ecosystem processes (including the use of prescribed fire) and edaphic conditions rather than anthropogenic disturbance.
12. Riparian areas are forested and are buffered from upland disturbances by one or more ecotonal communities (for example, upland mixed hardwood and mixed hardwood/pine slope forests) rather than by anthropogenic fire breaks.
13. Riparian areas, wetlands, ephemeral ponds, and streams are characterized by intact ecological processes, provide their full range of ecosystem services, and have most, if not all, of their historic complement of native species.
14. Hydrologic regimes and erosion rates reflect natural rates as evidenced by stream morphology and extant natural communities.
15. Roads are limited to the number needed to support military training and natural resource management activities.
16. Point and non-point source pollution is minimal or absent.
17. Site- and landscape-level productivity remain relatively constant; the combination of natural mortality and annual forest product output at the landscape scale is in a dynamic equilibrium with rates of replacement or net primary productivity. Annual forest product output is dictated by the management goal of maintaining landscape ecological integrity and not by economic considerations.

18. Landscape-level patch dynamics remain relatively constant, but individual patches may transition among several community types depending on chance disturbance events or levels of human intervention.
19. Landscapes are of sufficient size for natural recolonization following disturbances at various scales; viable populations of species with large home ranges and representing all trophic levels exist and can become reestablished following disturbance.
20. The landscape surrounding Fort Benning and its management do not adversely impact and in many cases contributes to the landscape ecological integrity of Fort Benning.

Consequences of Installation Natural Resources Management Direction for SEMP's Technical Outcomes

To be useful to land managers, research meant to inform the practices of adaptive management should be framed within the contexts of human land use (past, present, and planned), present ecosystem condition, and desired future ecosystem conditions. Because of past land-use practices within the area of interest, as well as the practices past, present, and planned within a surrounding landscape that ecologically influences the area of interest, desired future conditions may need to account for changes from the historic potential of the land and its resources to achieve a particular state. To accomplish the transition to desired future ecosystem conditions, land managers may take advantage of both intact ecological processes or management techniques that attempt to mimic disrupted ecological processes. To make their research relevant, researchers interested in (1) understanding ecosystem change, (2) identifying the indicators of that change, and (3) directing change toward a desired end state should account for the influences of land use, ecosystem condition and how it changes under relatively undisturbed conditions, and natural resource management actions. The following paragraphs provide additional considerations related to the consequences of management direction for SEMP's technical outcomes. Considerations specifically for Fort Benning are explored first; this is followed by a brief look at the consequences for the Department of Defense complex as a whole.

Fort Benning Considerations

Because of its location, Fort Benning is at an ecological crossroads. The fall line that meanders along its northern boundary represents the transition zone between Piedmont and Coastal Plain. Within the installation itself the coarse soils of the sandhills interface with the finer textured soils of the loam hills; the latter

occur roughly as a conical-shaped lens jutting eastward across the southern portion of the installation. The topography is heavily dissected by numerous creeks. As an Army training facility, the land is subjected to a variety of land uses (as well as management practices) that range from low impact to potentially highly disruptive to the viability of native flora and fauna and the persistence of ecological processes. The imprints of past land use (that is, prior to the military's use of the land) are still pervasive across the landscape. As a result, Fort Benning has both ecological and land-use complexity.

It is within the preceding context that Fort Benning land managers attempt to manage the installation's natural resources to meet desired goals, objectives, and future conditions. Moreover, Fort Benning land managers are not just trying to maintain the status quo. Past land uses and management practices, fire suppression and the disruption of other ecological processes, and the introduction of non-native species have resulted in an altered environment. In response to these altered conditions, natural resources management at Fort Benning has become in large measure a long-term restoration project. The desired future ecosystem conditions reflect the long-term vision for restoration.

The technical outcomes from SEMP must account for the above considerations. Choosing an appropriate set of ecological indicators useful to land managers, identifying relevant thresholds of change, and determining what is and what is not sustainable are contingent not only on an understanding of past and present ecosystem conditions but also on an appreciation of the management trajectories that Fort Benning is attempting to achieve.

Considerations Applicable Across the Department of Defense Complex

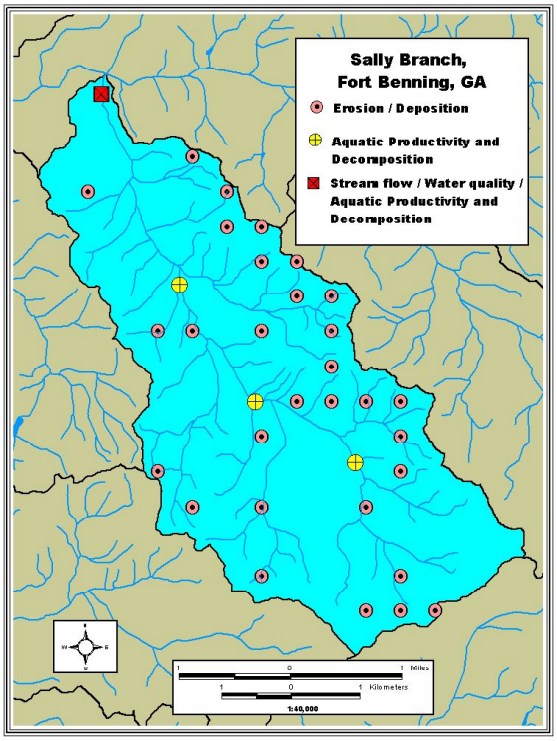
The process outlined in the sections above that uses an installation's natural resource management goals and objectives and desired future ecosystem conditions as a framework for relating the technical outcomes from ecosystem research to management action can be applied to any DoD installation. Although many site-specific situations may arise that affect individual goals, objectives, and desired conditions at an installation, the process itself is general. The process is premised on the assumption that an understanding of the management context is prerequisite to making research outcomes relevant to management needs.

The specific technical outcomes from SEMP, couched as they will be in Fort Benning's management framework, may still have some general applicability. As an outcome of basic scientific research, they will improve our understanding of ecosystem processes and function. The general principles that may be derivable from such understanding perhaps can be used to improve management practices

in ecosystems quite different from those that exist at Fort Benning. The technical outcomes from SEMP also may be broadly applicable to the various DoD installations that are within the sandhills ecological subsection (Keys et al. 1995) that runs coastward along the fall line from Fort Benning to Fort Bragg. Other scales are possible at which the outcomes may have applicability; however, as ecosystem differences become more pronounced, applicability likely diminishes accordingly.

5 SEMP Data Acquisition

Ecosystem Characterization and Monitoring Initiative



The SEMP ECMI supports SERDP's ecosystem management research investment, which focuses on ecological indicators, disturbance regimes and ecological thresholds, and adaptive management. The ECMI compliments this research through design, development, and demonstration of an ecological baseline monitoring program.

Objective

The objective of the ECMI is to characterize the long-term spatial and temporal dynamics of key ecosystem properties and processes — hydrologic, biological, productivity, biogeochemical cycling, decomposition, and maintenance of biological diversity — in support of ecological research on sustainable management of DoD lands and installation objectives. The resulting monitoring concepts and protocols will have applications on subsequent SEMP research sites beyond Fort Benning.

Design Requirements and Specifications

There are four major principles upon which the ECMI is designed, beyond the parameters set by SEMP's major research themes. These are:

1. Consider elements of ecosystem management.
2. Incorporate monitoring within an ecosystem management protocol.
3. Link science, land management, and data/information requirements.
4. Incorporate adaptation into the monitoring system.

Consider elements of ecosystem management

A science-based approach to 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 composition, 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). This goal 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 (Christensen et al. 1996). Specifically, the variables should:

1. Focus on monitoring key ecosystem processes to detect changes in their sustainability over the long-term rather than on system outputs in the short term, including monitoring those forces that enhance the ability of the system to maintain resiliency in the face of disturbance.
2. Be based on measurable goals defined in terms of key ecosystem processes as they relate to sustainability.
3. Use sound ecological models to define system understanding and as a basis for selecting measurement data at all levels of organization.
4. Include measures of system complexity and connectedness.
5. Characterize the dynamics of the ecosystem under study.
6. Define the context and scale in terms of both mission and stewardship goals and activities.
7. Incorporate mission use and stewardship as primary factors affecting ecosystem dynamics beyond natural disturbance regimes.
8. 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 by the SEMP, is the overall need to integrate the monitoring effort into a recognized ecosystem management process or protocol. 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. 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.

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 the 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. One important aspect of this link is integration of the monitoring variables themselves, with co-location of samples, thematic and locational compatibility of ECMI and SEMP sampling, and roll-up of data from individual areas of study.

Incorporate 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. 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.

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 to maintain the integrity of the database for the long term.

Additional design considerations

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. Hierarchical design across space will be necessary to capture information at all scales.

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

1. Avoid intruding on the military mission and burdening land management activities.
2. Ensure rapid acquisition, handling, storage, synthesis, and display and visualization of monitoring results.
3. Enhance efficiency of quality assurance/quality control (QA/QC) protocols.

This will include reliance on state of the art remote sensing (RS), global positioning systems (GPS), GIS, 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 ECMI does not interfere with the military mission or create an unwanted burden for installation land managers. These considerations highlight the requirement for use of remote and other unobtrusive data collection and acquisition technologies to the extent appropriate. The ECMI needs to tie into other existing and planned monitoring activities to the extent appropriate, in order to ensure proper leveraging and coordination. 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 responses 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 active ecosystem monitoring program over a long time period may be inversely proportional to its complexity and cost.

ECMI Program Structure and Timeline

The ecosystem characterization and monitoring plan developed for Fort Benning, is structured in three phases covering a minimum timeline of 10 years. The phases are identified in Table 3 along with a description of the activities in each phase. Phase I (FY99-FY01) is an extended design and implementation phase. During Phase I the program moves from initial background investigations and design to baseline ecological characterization of the installation followed by on-site implementation with an initial 1-year evaluation of the monitoring activities. This initial year includes calibration, evaluation, and integration of ECMI ground measurements with various remotely sensed data, data provided from the focused research projects, and Fort Benning's ongoing land management activities. Phase II (FY02-05) provides the opportunity for adjustments to the monitoring design based on the analysis of 2 years of ECMI data, results of the SEMP focused research projects (indicators, disturbance thresholds, adaptive management), and the experience of Fort Benning land managers in field testing results of the SEMP research. Phase III (FY06- and beyond) is dedicated to the long-term continuation of the monitoring program and the implementation of periodic technology upgrades.

Table 3. The ECMI general program structure and timeline.

PHASE I 1999-2001 **DESIGN**	PHASE II 2002-2005 **ADAPT**	PHASE III 2006-and beyond **MAINTAIN**
Extended design, implementation and documentation	Adaptation based on: a) initial monitoring results b) SEMP research results c) land management experience with indicators	Long-term maintenance and technology upgrades

ECMI Characterization Plan

The characterization component of the ECMI included four primary activities. These were to:

1. Identify baseline data requirements needed to support the design and implementation phases of the long-term ecosystem monitoring program;
2. Inventory and document existing data;
3. Identify data gaps; and
4. Develop plan to fill data gaps.

These activities are discussed in the following paragraphs.

Identify data to support design and implementation. This activity was accomplished in three parts. The first was a review of existing monitoring programs. Table 4 provides a list of the most relevant on-going monitoring programs reviewed as background to the characterization task ("Inventory of Fort Benning" 1999). The second part was a workshop of subject area experts from the research community, which identified an exhaustive list of data considered relevant to the design of the monitoring plan and fundamental to the characterization of ecosystem ("Report of Land Managers and Trainers Workshop" 1999). The third part was a workshop conducted with Fort Benning land managers and trainers that partially addressed the data needs in support of the draft goals and objectives of the installation INRMP ("Report of Land Managers and Trainers Workshop" 1999).

Inventory and document existing data. An inventory of available data was initiated in October 1998. The inventory addressed installation-wide data, regional data, spatial and non-spatial data, natural resource data, management activity data, and training activity data. The bulk of the data located during the inventory are listed in the "Inventory of Fort Benning, GA," 1999, Appendix D). Most of the geospatial data held by the installation have been documented using the Federal Geographic Data Committee (FGDC) metadata standard and distributed to the study partners.

Identify data gaps and develop plan to fill the gaps. The combined results of the background reviews, workshops, and data inventory allowed the identification of data gaps. Table 5 briefly describes the identified data gaps. Each of these gaps have either been addressed or a plan is in place to address this specific data requirement. Table 5 also indicates the method of resolution or the status of resolution for each identified data gap. Note that these gaps are those considered

fundamental background characterization to the successful design and implementation of the monitoring plan, not the elements of the monitoring plan itself.

Table 4. On-going monitoring programs reviewed as background to the characterization task.

Program Abbreviation		Program Name	Leading Agency
1	GAP	Gap Analysis Program	USGS
2	EMAP	Environmental Monitoring and Assessment Program	EPA
3	FHM	Forest Health Monitoring	EPA/USDA
4	FIA	Forest Inventory and Analysis	USDS – FS
5	NAMS/SLAMS	National Air Monitoring Stations/ State and Local Monitoring Stations	EPA
6	NSGN	National Stream Gaging Network	USGS
7	NAWQA	National Water Quality Assessment Program	USGS
8	NRI	National Resources Inventory	USDA – NRCS
9	Forest Service Experimental	Forest Service Experimental and Rangeland Sites	USDA
10	LMER	Land Margin Ecosystem Research	NSF
11	LTER	Long Term Ecological Research	NSF
12	NASQAN	National Stream Quality Accounting Network	USGS
13	NERP	National Environmental Research Parks	DOE
14	NPEMP	National Park Ecosystem Monitoring Program	NPS
15	USGS WEBB	Water, Energy, and Biogeochemical Budgets	USGS
16	RNA	Research Natural Areas	USDA – PS
17	LTEM	Long Term Ecological Monitoring	NPS
18	ARS	Agricultural Research Service Experimental Watersheds	USDA
19	BEST	Bio-monitoring of Environmental Status and Trends	USGS
20	MAB/SAMAB	Man and the Biosphere Reserve Program/Southern Appalachian Man and Biosphere Cooperative	Interagency / SAMB Coordinating Office

Table 5. Data gaps identified in the Fort Benning data holdings considered important to design and implementation of an ecosystem monitoring plan.

Data Gap	Status
Digital elevation model (regional)	Completed by ECMI
1:24,000 scale surface hydrology (regional)	Completed by ECMI
Watershed delineation and ordering (regional)	Completed by ECMI
Watershed-based potential management unit delineation	Completed jointly by Fort Benning and ECMI
Detailed vegetation map (alliance and association level)	Cooperative product by Fort Benning and TNC; completed 2001
Training intensity distribution map	On-going; joint investigation by Fort Benning and ECMI;
Burn/fire history	On-going; contracted by Fort Benning to ITAM regional GIS support center

6 SEMP Data Repository

The SEMP/ECMI Data Repository is operational and located on the Internet at http://206.166.205.173/. Figure 6 shows the Repository's home page.

Access to the repository is currently password protected. Passwords are issued only to individuals that have been verified to be working with/for one of the six SEMP research groups; Fort Benning staff; and SERDP staff. Currently 36 accounts have been opened. A User's Guide and an Administrator's Guide are available on the web site and have been emailed to registered users. The repository resides on an NT server connected to the Internet via a T1 line and a commercial Internet Service Provider (ISP).

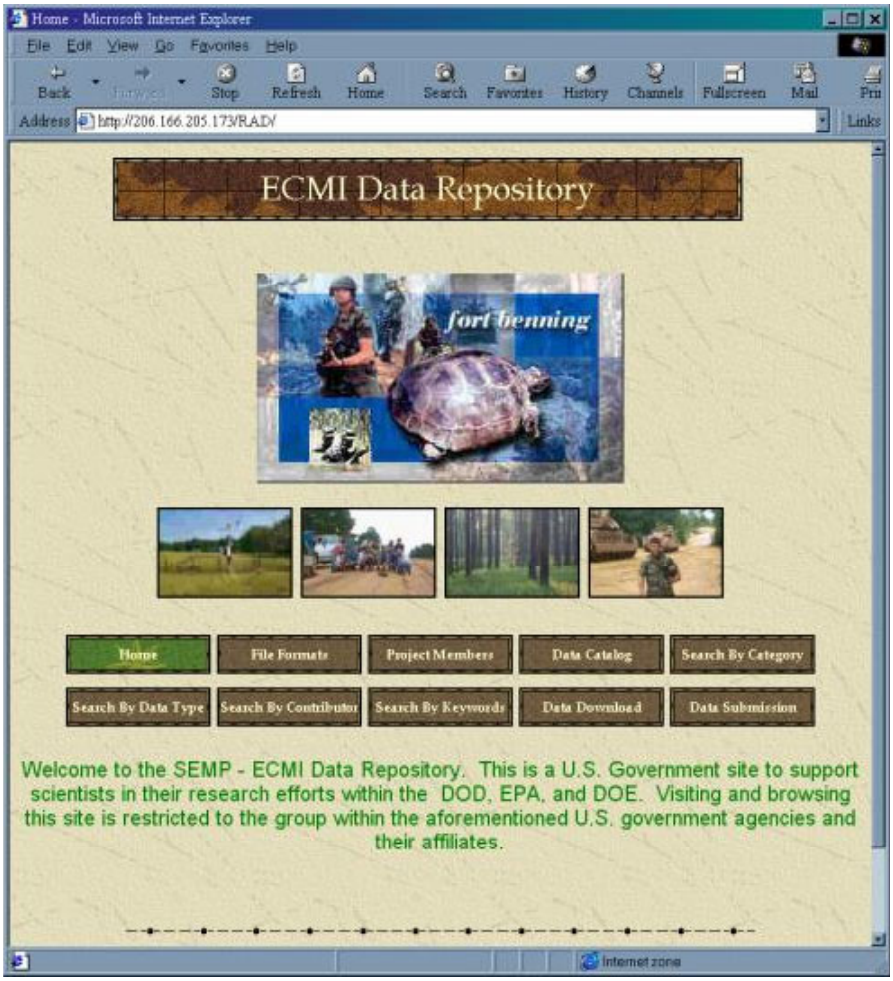


Figure 6. SEMP/ECMI Data Repository home page.

Repository Conceptual Design

The conceptual design for the SEMP repository is simple and functional. It is designed specifically to provide data access and exchange among the SEMP study partners and serve as a stable, long-term data archive mechanism to protect the SERDP investment. The approach was to build a simple, functional, well-documented repository that has low long-term maintenance requirements. The SEMP repository is designed to operate as a stand-alone archive and to be directly or remotely accessed by other more complicated systems and data archives as a "node" or "object." It is a file-based repository, organized using a directory structure based on the Spatial Data Standards for Facilities, Infrastructure and Environment (SDS/FIE) entity set.

Several important design decisions guided the development of the SEMP/ECMI repository. These decisions were made early in the program to ensure early availability of the repository and to remain within the projected budget. The most important of these design considerations were: (1) the SEMP repository does not function as a graphic map product server; (2) the SEMP repository does not function as an enterprise-level geospatial data warehouse for operational use at Fort Benning; and (3) the SEMP repository is file-based rather than Relational Database Management System (RDBMS)-based.

The four main design components of the ECMI data repository are illustrated in Figure 7. These components are Data Storage, The Repository Index/Data Catalog, The User-Web Interface, and the User Profile Information.

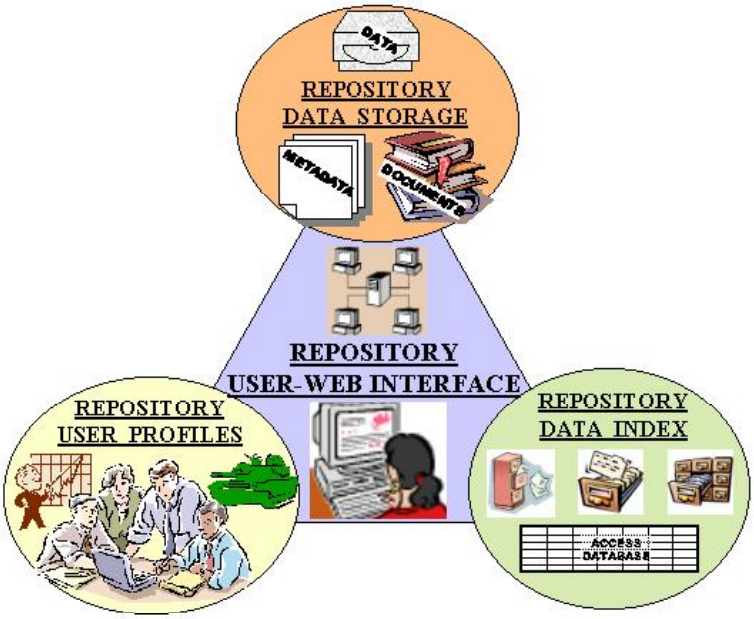


Figure 7. ECMI conceptual design components.

Data Storage Component

All data storage and retrieval in the SEMP repository is file based. The system is designed to organize, store, index, catalog, and retrieve electronic files rather than individual data values. The fundamental organization of the repository content is a directory structure based on the entity set as defined in the SDS/FIE (version 1.95, 1999). See Figure 8 to view the directory structure of the repository.

Repository Index/Catalog Component

The Index component is the key to maintaining and accessing the data repository. Each file submitted to the repository is described and indexed using a standard procedure. The Index component provides the mechanism for tracking the name, location, and description of each file, which allows for efficient searching of the repository's contents. All searches of the repository are executed on records in the Index. Physically, the Index is a Microsoft Access database containing 23 standard index fields. Each file in the repository has one unique INDEX record. Table 6 shows the Index items. Most Index items can be used as search fields. The repository is not searchable by geographic coordinate.

Table 6. ECMI Data Repository standard index fields.

Title	Description	Language
Creator	Publisher	Relation
Subject (category)	Contributor	Coverage
Keyword 1	Date	Rights
Keyword 2	Type	Rights
Keyword 3	Format	Comments
Keyword 4	Identifier	File Name
Keyword 5	Source	Metadata File Name

User-Web Interface Component

Patrons interact with the repository by using a modern Web browser. Either Microsoft Internet Explorer 5.0 or Netscape Navigator 4.75 may be used.

User Profile Component

Data submissions and retrievals are password protected. Each user issued a password must provide standard profile information for system administration purposes. Each file submitted is indexed by the contributing patron.

Repository Contents

Currently the repository contains important geospatial data for the Fort Benning military installation and the surrounding region, as well as initial data collected under the ECMI. All existing data were bulk loaded and documented as the initial starting point for the repository. The repository design is flexible and can be expanded to include data from additional installations when the SEMP is expanded. Figure 8 indicates the SDS/FIE entity sets that contain data.

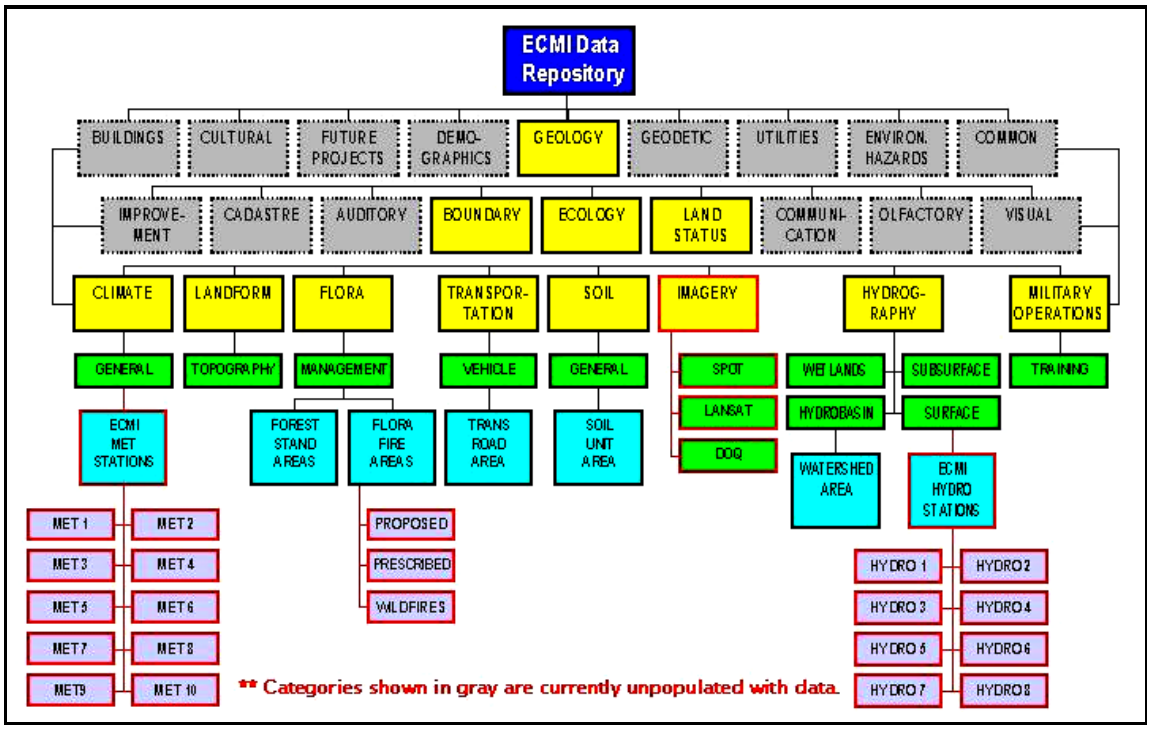


Figure 8. ECMI Data Repository directory structure.

The repository contents fall into the general classes of:

1. Baseline GIS data of Fort Benning and the surrounding area (e.g., Forest Stands, Burn Areas, Training Compartments, Wetlands, Geology, Watersheds, Soils, etc.);
2. Digital imagery of Fort Benning and surrounding area (e.g., digital orthoquads, satellite imagery, etc.)
3. ECMI monitoring data (e.g., ECMI meteorological weather station data and hydrologic surface water data, etc.) and
4. SEMP research project data. As the individual SEMP research projects continue, contributions to the repository will include their field data, analysis results, and model output from the research teams.

Metadata

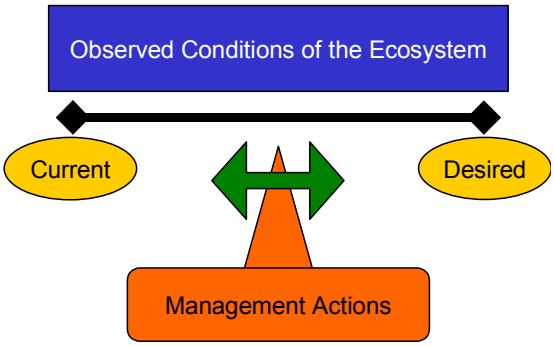
Most data files are documented by separately maintained files, which contain the metadata. Geospatial data are accompanied by metadata meeting the FGDC Content Standards for Digital Geospatial Metadata (CSDGM). Tabular data (e.g., weather data) are accompanied by a customized version of the FGDC/CSDGM suitable for tabular data having no graphic component. Documents are accompanied by bibliographic citations (and sometimes abstracts) in a text file. All metadata documentations are stored in Acrobat .pdf files or ascii .txt files. Metadata can be downloaded or viewed online.

Mechanism for Data Access

Data are uploaded, searched, and downloaded via web pages designed for this purpose. Repository contents are accessed by three methods: direct ftp, search and download; browse data-catalog and download.

7 Integration of SEMP Activities: An Ecosystem Management Framework

Framework-Group Discussion



The concept of developing a "framework" for SEMP emerged from several SEMP meetings and presentations. A decision was made, after the August 1999 TAC meeting, to include a "framework development process" in the FY2000 plan for SEMP. A workshop was held in November at Columbus Georgia to gather researchers and interested TAC members and installation participants in an effort to begin this process. This discussion provided an opportunity for feedback and direction on the planned process. Figure 9 is a picture of the workshop participants. This picture was taken at the workshop site in downtown Columbus, Georgia.

Figure 9. Participants in the November 1999 Framework Workshop.

Integrating Framework Desired Outcomes

At this workshop, the desired outcomes from the integrating framework were defined as follows:

- Linking SEMP into specific processes of DoD installations, to better focus how SEMP is structured and how SEMP outcomes will be brought into installation business processes.
- Pulling the diverse elements of SEMP together into related and complementary components (e.g., providing a flowing context of relationships between research activities, monitoring activities, repository activities, and technology transition to host and other installations).
- Improving the mechanism to evaluate both current and future investments for SEMP, and more broadly for the SERDP and service conservation research investments, and to highlight and prioritize future investment opportunities (e.g., to help provide an investment roadmap).
- Providing a means to create linkages to ecosystem management approaches and processes being used outside DoD and to create useful dialogue across scientific and agency forums.

Installation Business Process Linkages

The workshop also served to identify the primary DoD installation process for integrating SEMP outcomes with the INRMP. The INRMP is required by law (through the Sikes Act) and regulations for all DoD installations. One of the key concepts for INRMP is for installations to have an approach that identifies goals for installation resource management programs, and to integrate all of the component plans into a complementary and coordinated plan that helps achieve these goals. Thus, the INRMP represents some degree of articulation of the installation's desired future conditions. SEMP can provide input into these INRMPs, especially when the plans contain clear goals and progress can be tracked towards achieving these goals.

Fort Benning has made progress in INRMP development, and the INRMP does help define many installation goals and objectives. Eglin Air Force Base, Florida, represented at the framework workshop by Tim Christianson, also uses the INRMP to define goals; the base even identified goals for monitoring and inventory updates within their INRMP. Both installations concurred that INRMP represents an excellent context for linkage between installation processes and SEMP outcomes.

How Do the Components of SEMP Fit Together?

Overall, the SEMP is focused on improving the synchronization between *observations, goals* and *actions* related to military managed ecosystems. To accomplish these linkages, SEMP is developing and implementing an observation protocol and investing in research projects that help frame this protocol based on "understanding" how observed phenomena relate to ecological structure, function, and composition. Investments will also be designed to improve understanding of the critical links between management actions and ecosystem responses. Especially important are the feedback loops that provide continuous adjustments and improvements in the relationships between management observations, goals, and actions.

Figure 10 provides a graphic depiction of the current and future SEMP components. On the lower portion of the figure, the installation fits within a landscape ecosystem and impacts the ecological system (symbolized by the arrows emerging from the installation) directly through resource use and management actions and indirectly through setting goals and making plans. The installation's resource management becomes *adaptive management* when these management actions are interwoven through feedback loops between *observed conditions* and *desired conditions*.

The term "management action" is used here to mean any actions intended to achieve specific ecological responses. Fort Benning is intensively used and managed. In this context, management actions might be a shift in mission use patterns or an adjustment in ongoing management practices (e.g., burning, invasive species removal, replanting, forest management, species or habitat protection) or the initiation of a new management practice.

In adaptive management, management actions are prescribed and modified based on information about the state of the ecological system and its tendency toward desired future conditions. Three primary questions, posed in the blue ovals in Figure 10, relate SEMP activities to adaptive management at Fort Benning. These are: (1) What ecological phenomena should be observed, when, where, and how? (2) When should an observation trigger a management response (which may be an action)? and (3) What will be the likely impacts, under various conditions and timeframes, of specific management actions? The SEMP investments are designed to address these three primary questions.

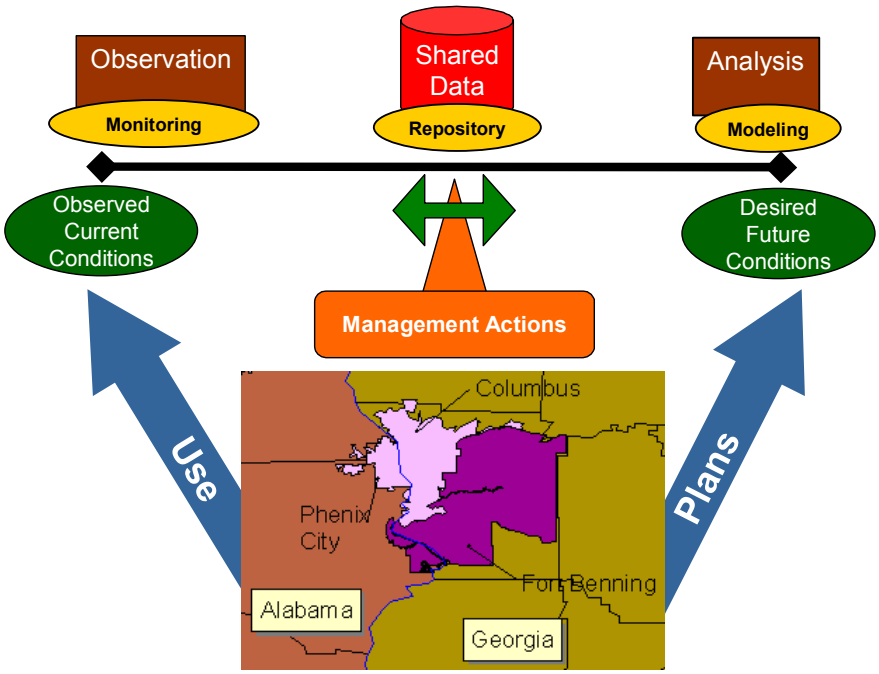


Figure 10. Overall concept for SEMP.

Figure 11, taken from a briefing that Virginia Dale gave to the SERDP Scientific Advisory Board (SAB) in October 1999 (Dale and Beyeler 1999), shows ecological components — composition, structure, and function — with nested triangles to represent scaling over ecological levels from individuals to the landscape. The triangle shape and nesting imply linkages among the ecological components and ecological levels.

The Indicators (defined in the FY99 Statement of Need; see Figure 10 and Appendix A) are focused on identifying ecosystem elements that provide both an understanding of the ecological system and feasible measures for ongoing ecological monitoring. Essentially, these efforts are focused on the question, "What should be observed, when, where, and how?" Indicators can be measures of ecological components or linkages. They can be "mapped" into the multi-scale ecosystem framework (Figure 11), to better understand how each fits our understanding of ecosystems operations and scales, and to assess which scales and processes are being observed through any selected suite of indicators. This and similar analyses will help determine if the indicator suites are representative of the key ecological conditions. Potentially useful indicators are considered as phenomena to be monitored in the SEMP "observation protocol" (the what, when, where, and how questions). The monitoring data can be published, analyzed, and stored in the SEMP repository for analysis and sharing.

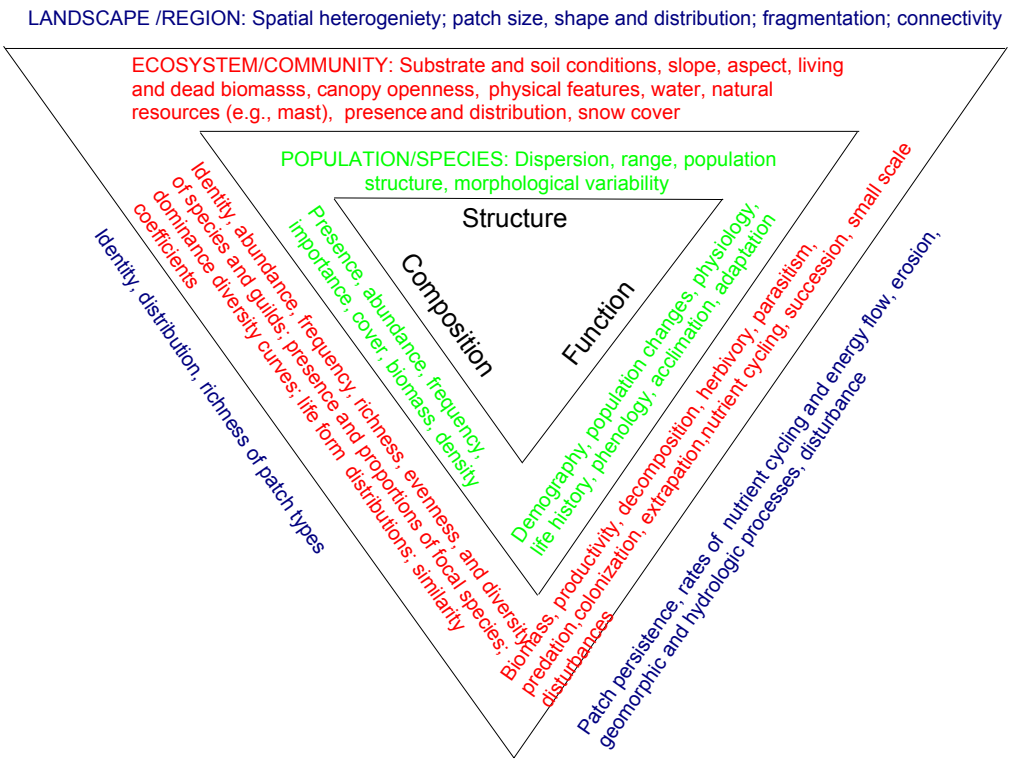


Figure 11. Representation of the complexity of the ecosystem from multiple scales and perspectives.

Several SEMP research efforts are aimed at identifying useful indicators. Some of these indicators may be very valuable in terms of understanding, but too expensive, difficult to collect, or too widely variable to contribute to a standard ecosystem monitoring protocol. Indicators will be measured against the Criteria for Acceptance, shown in Table 7 (Dale and Beyeler 2001) before they become part of the observation protocol. Those that fit well into an installation-monitoring program will be added to the installation baseline monitoring program, and the Observation Protocol, which has application for adaptation at locations beyond the host site.

Table 7. Criteria for indicators.

Criteria for Indicators
Are easily measurable
Are sensitive to stresses of system
Respond to stress in a predictable manner
Signify an impending change in key characteristics of the ecological system
Experience changes that can be averted by management actions
Together with the full suite of indicators, provide a measure of coverage of the key gradients across the ecological systems (e.g., soils, vegetation types, temperature, etc.)
Have a known response to natural disturbances and changes over time
Have low variability in response

The Thresholds (defined in the FY2000 Statement of Need, see Appendix A) research efforts address the question of when and how to react (Figure 10). Disturbances, whether natural or due to management actions, alter ecosystem components and break linkages. An ecosystem's trajectory over time is influenced by the type, intensity, and frequency of disturbance. At some threshold of combined disturbance effects, the ecosystem diverges from a trajectory toward desired future condition (Figure 12). In other words, the ecosystem cannot sustain the disturbance. This management-defined "ecosystem response threshold" can be identified by considering "individual thresholds" for the suite of measures, such as indicators, that characterize ecosystem state and dynamics.

The threshold research projects relate primarily to mission use (soil impacts) and forestry management actions (e.g., burning, thinning). For example, Figure 12 shows the relationship of upland pine-hardwood forest to the forest management thinning and burning regime. After the desired future condition of a site has been defined and the management actions are imposed, measures characteristic of pine and hardwood communities (e.g., species composition, canopy openness, vegetation structure, and soil nutrient cycling) can be used to determine ecosystem response thresholds of the site's trajectory.

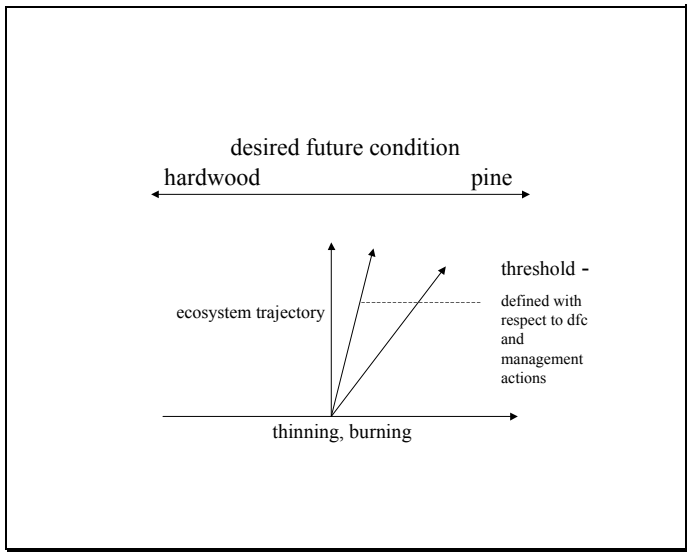


Figure 12. Trajectory of upland pine-hardwood forest with respect to forest management actions.

Data Management and Analysis

All of the information from observing conditions (either through research projects or through the implementation of the observation protocol) is contributed to a central data Repository. This repository provides organization of and access to all the data resulting from SEMP investments and from other research investments relevant to the host site and region.

To ensure that feedback loops are developed between observations, goals, and actions, a suite of analysis and predictive modeling functions will be performed on the data. Ultimately, these will be represented in an analysis protocol. This protocol will draw from the data repository to identify and develop observation trends and provide techniques for comparing these trends to current and desired conditions. This is identified in Figure 10 as a "future" capability for SEMP, but will be an important complement to the extensive data gathering and data management activities that comprise the current SEMP investment. An analysis protocol will help ensure that adequate value is obtained from this SEMP investment. Another "future" requirement identified is a predictive capability for understanding the potential impacts of management actions. To accomplish this improved predictive capability, a database of management actions and outcomes will be needed from not only the host site but also from other comparable locations. This database will help inform a predictive/decision aid for management use.

Our current investment in pursuing multiple indicators suggests that a balanced scorecard is appropriate for understanding ecosystem condition. We need to know about weather, how much impermeable surface is in the watershed, how many fauna types inhabit our surface streams, how significant is the fluctuation in the water table, breeding success rates of tortoises and teals, and the number of mission miles driven and hiked last year. These observations together give us a window of understanding about the condition of the ecological system and this understanding can be reviewed against this same set of observations from the past and projected into the future. Presumably, no one single observation is sufficiently integrative to fully represent all ecological conditions, but the goal is to have a small set of indicators that represents significant understanding of the system.

Given this approach, we can then either use multiple observations, each in isolation from the other, as "points for comparison" and create a scorecard by comparing each observation with itself over time, or we generate methods to combine multiple observations into indices that themselves provide a mechanism for comparison. To simplify input into easily understood and managed information,

it may be useful to generate from multiple observed phenomena an index or more than one index to give us overall condition measures.

Right now, SEMP is tackling the issue of "what should we observe and how and what do these observations tell us about function and status?" The next question will be "what suite of observations can be combined how to give us good management parameters to know "how we're doing" and compare across time and space (and management regimes).

Just what comparisons will be made is uncertain. One likely comparison is over time. That is, Fort Benning in 2000 versus Fort Benning in 2020 or in 1980. What's the trend in ecological condition, given a set of measures that are common throughout that timeframe and are expressed against one another (as separate measures and perhaps as rolled into an index)? Developing these indices will be one outcome of an analysis protocol.

With these various capabilities used in an integrated framework, resource managers should have an improved ability to understand and synchronize their processes to define goals, observe trends, and understand the likely impacts of management actions. This capability should also be constantly improving, as observed trends provide data on the impact of management actions and as the historic records (and modeling capabilities) grow, to allow continuously improving hindcasting and forecasting functions.

8 Research Projects

FY99 Research Projects

The objective of the FY99 Statement of Need entitled, "Determination of Indicators of Ecological Change" (Appendix A) is to identify indicators that signal ecological change in intensively and/or lightly used ecological systems on military installations. Table 8 lists the research teams selected to support the FY99 SON.

Table 8. Research Projects supporting the FY99 SON.

Title	Number	Lead PI	Lead Organization
Determination of Indicators of Ecological Change	CS-1114A-99	Dr. W. F. DeBusk	University of Florida
Development of Ecological Indicators Guilds for Land Management	CS-1114B-99	Dr. Anthony J. Krzysik	U.S. Army Engineer Research and Development Center (ERDC), CERL
Indicators of Ecological Change	CS-1114C-99	Dr. Virginia H. Dale	Oak Ridge National Laboratory

Determination of Indicators of Ecological Change

The principal investigator for this proposal is Dr. William F. DeBusk from the University of Florida, Gainesville. Other team members and the task/topic they will be working on are listed in Table 9.

Table 9. Research team members for "Determination of Indicators of Ecological Change."

Name	Task/Topic	Institution
K. R. Reddy	Soil Sediment/Water Quality	University of Florida
A. V. Ogram	Microbial Diversity	University of Florida
D. L. Miller	Vegetation	University of Florida
G. W. Tanner	Vegetation	University of Florida
J. Jacobs	Hydrology	University of Florida
P. S. Rao	Hydrology	Purdue University
W. Graham	Synthesis and Analysis	University of Florida

Background

The concept of ecosystem integrity, or "health," in the context of the military installation, encompasses not only the sustainability of the "natural" biota in the system, but also the sustainability of human activities at the installation — namely the military mission. Thus, changes in ecological condition are of great concern to both resource managers and military trainers. A suite of variables is needed to measure changes in ecological condition. Two types of indicators that may be useful are: (1) variables that inform managers about ecosystem status and (2) variables that signal impending change threshold implications.

Objective

The goal of this research is to determine suitable indicators of ecosystem integrity and impending ecological change resulting from both natural variation and anthropogenic activities. The research will identify physical, chemical and biological properties and processes that reflect ecological condition and change in intensively and lightly used ecosystems on the Fort Benning military installation.

Approach

This research project is employing a multiscale approach, which will result in robust techniques for ecosystem monitoring and evaluation. It is proposed to evaluate a suite of parameters related to properties and processes in the soil, understory vegetation, and surface hydrology as potentially sensitive indicators of ecosystem integrity and ecological response to natural and anthropogenic factors (Figure 13). In general, the soil hydrologic and biogeochemical parameters to be examined relate to changes in soil physical and chemical characteristics, and the response of soil microbial population and plant communities. Quantitative relationships will be developed between environmental change, due to both natural variability and anthropogenic perturbation, and soil and vegetation responses, primarily as they relate to nutrient storage, nutrient turnover and population dynamics.

Relationships between ecological indicators and environmental and anthropogenic stressors will be evaluated simultaneously over a broad area encompassing a wide range of environmental conditions (low-intensity sampling) and in localized areas of relatively homogeneous environmental conditions (high-intensity sampling). This approach will give us the ability to apply and test indicator-based algorithms across multiple spatial scales, a major consideration in assessing the utility of the indicators for evaluating ecological change.

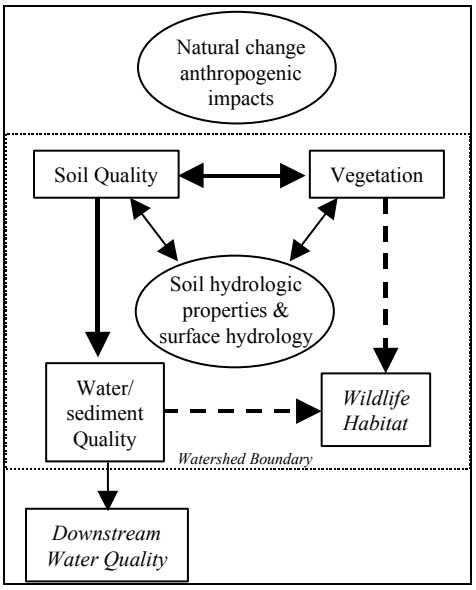


Figure 13. Approach for "Determination of Indicators of Ecological Change."

Development of Ecological Indicator Guilds for Land Management

The lead principal investigator is Anthony J. Krzysik. He has moved to the Embry-Riddle Aeronautical Institute, located in Prescott, AZ, but retains his role as the person directing the thrust of the research team. Harold Balbach, ERDC/CERL, assumed the financial POC position. Other team members are as listed in Table 10.

Table 10. Research team members for "Development of Ecological Indicator Guilds for Land Management."

Name	Task/Topic	Institution
John M. Emlen	Theoretical Ecology Mathematic Modeling Developmental Instability	U.S. Geological Survey
D. Carl Freeman	Plant Ecology and Physiology Developmental Instability	Wayne State University
John H. Graham	Population Genetics and Ecology Developmental Instability	Berry College
David A. Kovacic	Ecosystem Ecology Riparian & Wetlands Ecology	University of Illinois
Lawson M. Smith	Geomorphology Geology	Geotechnical and Structures Lab, ERDC
John C. Zak	Soil and Microbial Ecology	Texas Tech University

Background

Military training and testing lands must be efficiently and cost-effectively monitored to assess conditions and trends in natural resources relevant to training sustainability, ecosystem maintenance, and the timing and success of restoration efforts. A suite of indicators for early-warning detection of ecological changes related to training and testing missions and multiple land use will be an important land management tool.

Objective

The objective of this research is to develop Ecological Indicator Guilds based on ecosystem relevant design criteria and multi-scale performance and stress-response criteria, for the purpose of monitoring ecological changes directly relevant to biological viability, long-term productivity, and ecological sustainability of military training and testing lands. Three important capabilities of developed ecological indicators are: (1) the ability to assess and monitor multi-scale ecosystem stressor effects independent of natural environmental variability and disturbance regimes, (2) their direct applicability to ecoregional contexts, and (3) the developed approaches, analysis, and modeling capabilities could be extended to any global ecoregion.

Approach

Classifications (Guilds) of ecological indicators will be developed to assess and monitor ecological changes and thresholds relevant to land use management decisions. These Guilds will be developed from responses to five different indicator systems measured along ecosystem disturbance gradients in three spatially delineated watershed ecosystems: uplands, riparian, and aquatic-lotic. These indicator systems are:

- ecological test systems;
- ecological multi-scale metrics;
- geoindicators;
- ecofunction groups; and
- indicator taxa (and possibly communities).

Indicators of Ecological Change

The principal investigator is Dr. Virginia Dale from Oak Ridge National Laboratory (ORNL), Oak Ridge, TN. Other team members are as listed in Table 11.

Table 11. Research team members for "Indicators of Ecological Change."

Name	Task/Topic	Institution
Suzanne Beyeler	Terrestrial Indicators	Miami University, Ohio
Theresa Davo	Impact Experiments and T2	Fort Benning, Environmental Mgmt Division
Jack Feminella	Macroinvertebrates	Auburn University
Thomas Foster	Historic Land Cover	Penn State University
Ken Fritz	Macroinvertebrates	Auburn University
Danny Johns		Auburn University
Kelly Maloney		Auburn University
Sarah McNaughton	Soil Microbiology	University of Tennessee
Pat Mulholland	Aquatic Ecology	Oak Ridge National Lab
Lisa Olsen	Landscape Metrics	Oak Ridge National Lab
Aaron Peacock		University of Tennessee
David White	Soil Microbiology	University of Tennessee

Background

This project was selected to help identify indicators of ecosystem change focusing on the test site of Fort Benning, GA, but with the intent that the ideas would be applicable across the diversity of DoD lands.

Objective

This effort will identify indicators that signal ecological change in intensely and lightly used ecological systems. The goal is that these indicators improve managers' ability to manage activities that are likely to be damaging and to prevent long-term, negative effects. Therefore, a suite of variables is needed to measure changes in ecological conditions. The suite to be examined includes measures of terrestrial biological integrity, stream chemistry and aquatic biological integrity, and soil microorganisms as a measure of belowground integrity of the ecosystem.

Approach

The identification of indicators will encompass five steps: (1) analyzing historical trends in environmental changes to identify potential indicators; (2) collecting supplemental data relating to indicators (this will of course build upon existing data already available at Fort Benning); (3) performing experiments to

examine how disturbances at Fort Benning might affect these indicators; (4) analyzing the resulting set of indicators for the appropriateness, usefulness, and ease of taking the measure; and (5) developing and implementing a technology transfer plan.

FY00 Research Projects

The objective of the FY00 SON entitled, "Ecological Disturbance in the Context of Military Landscapes" (Appendix A) is to develop the knowledge required to implement adaptive ecosystem management approaches for military lands and waters, as well as other federal facility lands and waters. Table 12 lists the two research teams selected to support the FY00 SON.

Table 12. Research projects supporting the FY00 SON.

Title	Number	Lead PI	Lead Organization
Disturbance of Soil Organic Matter and Nitrogen Dynamics: Implications for Soil and Water Quality	CS-1114D-00	Charles Garten, Jr.	Oak Ridge National Laboratory
Thresholds of Disturbance: Land Management Effects on Vegetation and Nitrogen Dynamics	CS-1114E-00	Dr. Beverly S. Collins	Savannah River Ecology Laboratory

Disturbance of Soil Organic Matter and Nitrogen Dynamics: Implications for Soil and Water Quality

The principal investigator is Charles Garten, Jr., from ORNL. Table 13 lists other team members.

Table 13. Research team members for "Disturbance of Soil Organic Matter and Nitrogen Dynamics: Implications for Soil and Water Quality."

Name	Task/Topic	Institution
T. Ashwood	GIS	Oak Ridge National Laboratory
B. Lu	Laboratory Technician	Oak Ridge National Laboratory

Background

The deterioration of soil quality can lead to dramatic and long-term changes in terrestrial ecosystems, but little is currently known about what thresholds may exist that prolong or prohibit the recovery of soil quality following ecosystem disturbance. This project will evaluate the short- and long-term effects of land use change and terrestrial ecosystem disturbance on two key measures of soil quality: soil organic matter and soil nitrogen dynamics.

Objective

The overall objectives of this project are to: (1) describe how soil carbon and nitrogen dynamics are affected by current land use activities and disturbance regimes, (2) evaluate the potential for short- and long-term recovery of soil quality in disturbed environments, (3) use existing GIS resources for analysis of spatial patterns of soil carbon and nitrogen, and (4) predict the effect of site disturbance and/or land use change on nonpoint sources of nitrogen pollution.

Approach

The research project will assess the potential impact of military activities, ecosystem disturbance, fire, and land use change on soil quality and terrestrial nonpoint sources of nitrogen to surface receiving waters. Soil organic matter and soil nitrogen dynamics will be compared at sites with different disturbance histories. We will measure soil carbon and nitrogen stocks in ecosystems along gradients of disturbance and land use change and map the data using a geographic information system. Short- and long-term studies of soil carbon and nitrogen dynamics will be undertaken at field sites. Where possible, we will use models of soil carbon and nitrogen dynamics to predict the potential recovery of soil organic matter, soil carbon sequestration, and potential terrestrial sources of nitrogen to aquatic ecosystems following soil disturbance.

Thresholds of Disturbance: Land Management Effects on Vegetation and Nitrogen Dynamics

The principal investigator is Dr. Beverly S. Collins from Savannah River Ecology Laboratory, Aiken, SC. Table 14 lists other team members.

Table 14. Research team members for "Thresholds of Disturbance: Land Management Effects on Vegetation and Nitrogen Dynamics."

Name	Task/Topic	Institution
R. Sharitz	Plant Ecology	Savannah River Ecology Laboratory (SREL)
J. McArthur	Microbial Ecology	SREL
C. Romanek	Geochemistry	SREL
J. Seaman	Soil Chemistry	SREL
M. Cadenasso	Landscape-level Consequences of Disturbance	Institute of Ecosystem Studies (IES)
D. Imm	Botany	U.S. Forest Service Savannah River Institute (SRI)
P. White	Disturbance Ecology	University of North Carolina

Background

Disturbances shape diversity and dynamics of vegetation, and can be key to ecosystem management. Current land use for military training at Fort Benning ranges from light disturbance by foot and light vehicle traffic through heavy disturbance by repeated heavy vehicle traffic; site-specific management of uplands for the endangered red-cockaded woodpecker (*Picoides borealis*) entails thinning and burning to promote longleaf pine (*Pinus palustris*) savanna. At some intensity and frequency, disturbances due to land use may no longer be sustainable. That is, the ecosystem may lose nutrients, become dominated by early successional or invasive species, or fail to regenerate key species. Identification of thresholds beyond which ecosystems cannot sustain a disturbance can guide land management practices.

Objective

The broad objective of the research is to evaluate the ecological effects of military training and forest management for longleaf pine at Fort Benning, to determine if there are thresholds beyond which upland ecosystems cannot sustain the combined effects of thinning, burning, and military traffic disturbances.

Approach

We hypothesize that the underlying soil type partly determines nutrient cycling, species diversity, and vegetation dynamics on a site, and influences thresholds for sustainability of land use disturbances. We take an experimental approach, in which we will compare cycling of a key element, nitrogen, as well as species diversity and vegetation dynamics of sites on clayey and sandy soils subjected to different forest management scenarios (burned on a 2-year cycle, burned on a 4-year cycle, thinned, unthinned) and to either heavier (open to vehicles) or lighter (primarily infantry) military use.

Other Research Efforts

Riparian Ecosystem Management at Military Installations: Determination of Impacts and Restoration and Enhancement Strategies

The DoD recognizes the critical importance of riparian ecosystems as controls on adjacent aquatic ecosystems, including maintenance of water quality of streams and rivers draining military installations. Riparian ecosystems at many military installations are stressed to an unknown degree by singular and interactive effects of training activities involving mechanized vehicles and other disruptive activities such as prescribed fires for forest management efforts to reduce fuel loads. This research project is designed to evaluate these impacts on riparian ecosystems and investigate an intensive study at Fort Benning, GA, where riparian disturbances are significant and typical of those experienced at other military installations. The two major objectives of this project are to: (1) identify the impacts of upland and riparian disturbances resulting from military training and prescribed fire to riparian ecosystem function, and (2) evaluate two riparian restoration strategies (woody debris additions and revegetation). Phase 1 involves assessing the current impacts. Phase 2 will involve evaluation of riparian restoration techniques.

Point of Contact for this effort is Dr. Pat Mulholland (mulhollandpj@ornl.gov) phone: 865-574-7304.

Regional Data Sources Study

In 1998, ERDC/CERL awarded a contract to Clark Atlanta University of Atlanta, GA, to conduct a study of data sources and environmental monitoring activities in the Fort Benning region (region being defined as both the ecoregion area in which Fort Benning is situated and a 10-county area ecoregion area in

which Fort Benning is situated and a 5-county area around Fort Benning). This effort relates to a partnering initiative between ERDC/CERL and Clark Atlanta University, and was funded primarily from sources other than SERDP. This study was designed as a supplement to the SEMP initiative at Fort Benning. The specific goal of this study was to provide broad regional information complementing the environmental characterization work conducted by ERDC as part of the SEMP ECMI effort. A report was delivered to ERDC/CERL from Clark Atlanta University in August 1999 (Adeyemi et al. 1999).

Phase II of this effort was awarded to Hunter College through a competitive (limited to only Historically Black and Minority Colleges and Universities) solicitation. This effort focused in the Fall Line Sand Hills region, gathering environmental and ecological data, land ownership, and other data for this region, which extends from Fort Benning along the fall line up into North Carolina and even farther north. Besides gathering this data, this effort also focused on statistical and spatial methods to interpolate and infer conditions across the region from specific and limited sample sites.

Point of Contact for both of these efforts is Robert Lozar, ERDC/CERL, (Robert.C.Lozar@erdc.usace.army.mil) phone 217-373-6367.

Auburn University Center for Forest Sustainability

Auburn University's Center for Forest Sustainability within the School of Forests and Wildlife Sciences has implemented a new initiative focused on sustainable forestry management practices. Several of the key members of this center have connections with Fort Benning (e.g., serve as advisors to Fort Benning staff and/or have conducted research at Fort Benning) and they plan to conduct some of the center-funded research at Fort Benning. Auburn University has committed to supporting efforts over a 5-year period for studies performed by this center, but is anticipating some matching funds from Fort Benning, National Science Foundation, the forestry industry or others. A 10 August 1999 Strategic Plan describes this initiative. Discussions are underway between Auburn faculty, Fort Benning staff, and SEMP managers about how this work will be coordinated with other SEMP research activities, contribute to the SEMP data repository, etc.

Point of Contact for Auburn is Dr. Graeme Lockaby (lockaby@forestry.auburn.edu).

Spatially Explicit, Individual Based, Object-oriented Simulation of the Population Dynamics of the RCW

This military land management research project developed an environmental spatial simulation model to support Army land managers and examine population trends, effects of habitat changes, military impacts, management practices, and effectiveness of recovery plan for TES. To explore these objectives, the project prototyped a simulation based on the RCW and leveraged funding from Fort Benning to field and customize the simulation to Fort Benning data and management practices. The RCW population dynamics model provides Army RCW biologists and land managers with a way to experiment with the landscape, in terms of locations of RCW nesting cluster locations, to see how changes may affect the trends of the RCW population over time.

The point of contact for this project is Dr. Chris Rewerts, ERDC/CERL, Chris.C.Rewerts@erdc.usace.army.mil, phone 217-352-6511 x7324.

9 Infusion of SEMP Technical Outcomes Into Installation Business Practices

It is the intent that SEMP outcomes be infused into military installation natural resources management practices. To understand how SEMP outcomes can contribute to installations, specific business processes at military installations need to be evaluated. Fort Benning is the primary development site for SEMP technologies; therefore, evaluation of the business process will focus on this installation's organizational structure and processes. However, the processes identified at Fort Benning are generally consistent across all installations in the DoD, although installations within different service branches may have differing office designations, and/or process requirements.

Figure 14 shows the Fort Benning offices and organizations that have an active stake in the natural resources decision and management process.

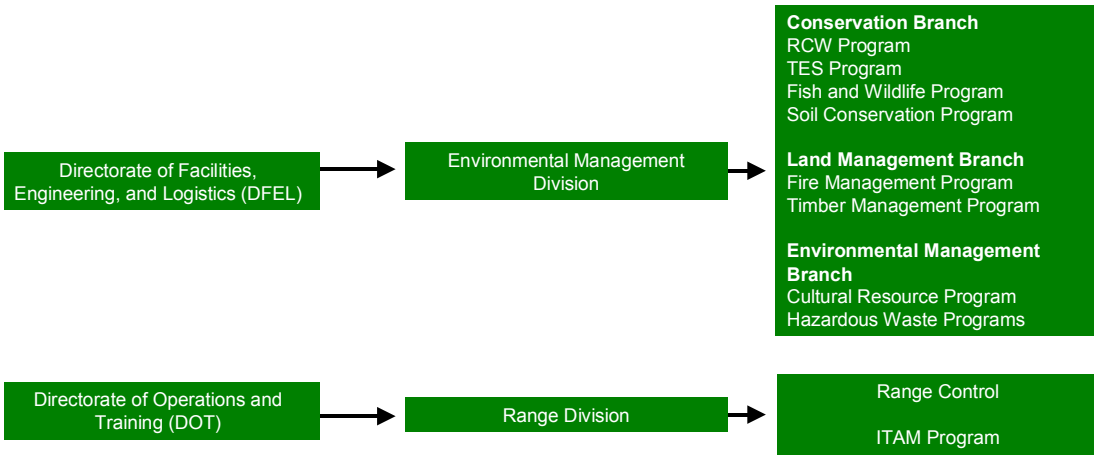


Figure 14. Fort Benning organizational and office structures.

Figure 15 shows the general processes identified across both the Directorate of Operations and Training (DOT) and the Directorate of Facilities, Engineering, and Logistics (DFEL) organizations at Fort Benning. The processes or tasks are

consistent across all installations in the DoD, but there are variations in the programs developed to accomplish these tasks from service to service. For example, only the Army has an ITAM program, which includes subcomponents for monitoring land condition and trend (Land Condition Trend Analysis — LCTA), for land repair and management (Land Rehabilitation and Maintenance — LRAM) and for assessing appropriate use levels (Army Training and Testing Area Carrying Capacity Model — ATTACC) (Department of the Army 1995). All services have compliance assessment programs, but the Air Force calls their program ECAMP (Environmental Compliance Assessment and Management Program) and the Army calls their program ECAS (Environmental Compliance Assessment System). Since the initial host site for SEMP is Fort Benning, this discussion will focus on programs and processes in place at the host site. Understanding these counterpart processes at other DoD installations should facilitate technology transfer of these outcomes beyond the host site.

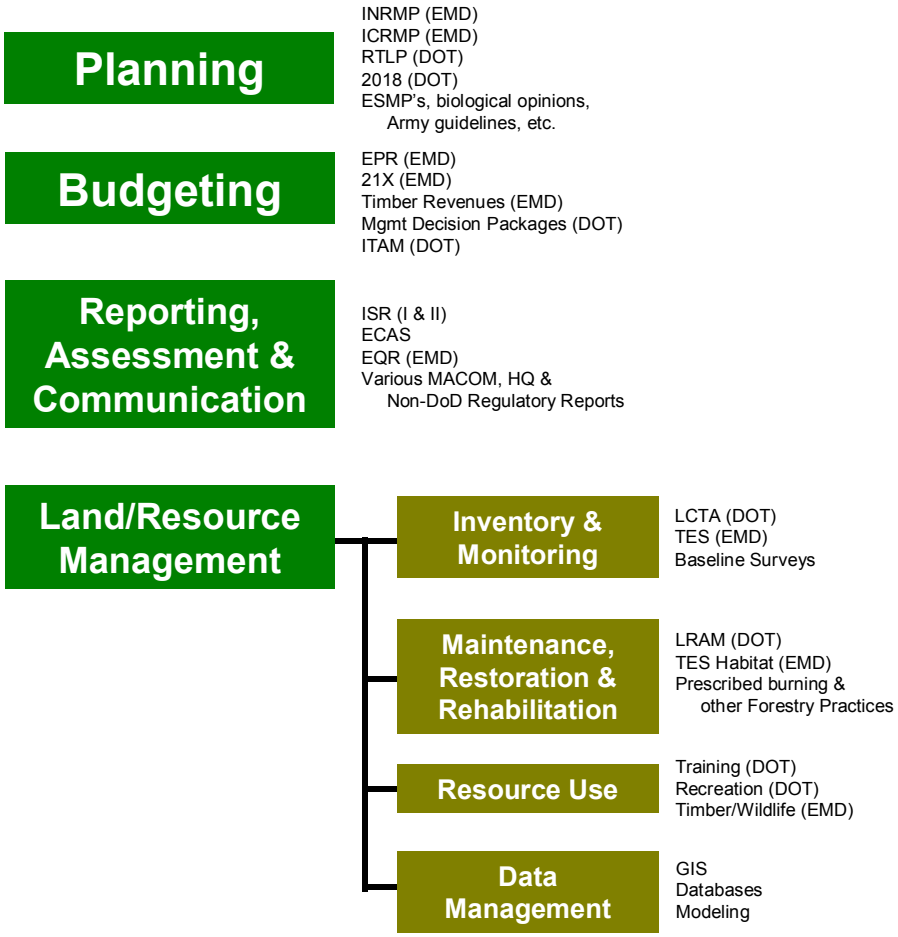


Figure 15. General processes identified across both the Directorate of Operations and Training and the Directorate of Facilities, Engineering, and Logistics.

The processes outlined in Figure 15 are described in detail below. Although described separately, the individual processes are quite dynamic and interface with each other at many levels. Input from reporting mechanisms such as the Installation Status Report (ISR) can directly affect the budgeting and planning processes, which in turn affect Land Management execution which affects the ISR reporting status. In addition, the processes do not occur in a linear fashion; planning can occur through the yearly cycle, as well as data calls, land management execution, etc.

Planning

There are many requirements for military installations to develop plans for each program and to integrate across these plans. The keystone Army natural resource plan, designated by the Sykes Act of 1996, is the Integrated Natural Resources Management Plan; completion of this plan is a DoD (and service) measure of merit (MOM). AR 200-3 (1995) requires that INRMPs be completed and provides guidance for developing INRMPs. The Integrated Cultural Resource Management Plan, required under AR-200-4 (1998), is the INRMP equivalent for installation cultural resources. INRMPs are one of the most important "targets" for SEMP outcomes to be expressed, in that INRMPs are the likely context in which desired future conditions would be articulated. These desired future conditions represent important targets towards which installations manage.

Natural resource planning and guidance are often influenced by legal and stewardship factors. These factors may include compliance with the Clear Air Act, the Clean Water Act, or the Threatened and Endangered Species Act. Documents and plans developed in cooperation with various state and Federal agencies to meet legal and stewardship standards play a key role in defining the planning requirements of an installation. Fort Benning's planning process is guided by the 1994 Jeopardy Biological Opinion (Red Cockaded Woodpecker [RCW]), and the 1994 Army Wide Guidelines for Management of Red Cockaded Woodpeckers (Department of the Army 1996), along with several draft cooperative agreements with state and Federal agencies and endangered species management plans for five species (RCW, Bald Eagle, Wood Stork, American Alligator, and Relict Trillium).

The military training interests of installation training land management, represented by the Range Division of the DOT at Fort Benning, is responsible for planning and executing all activities related to the preparedness and use of training land and ranges; including scheduling and maintenance. The training counterpart to the INRMP is the Range and Training Land Program and Range

Development Plan, required under AR 210-21 (1997). These are the major processes for planning and meeting installation needs for training facilities. Additionally, other planning documents, such as the 2018, a GIS map depicting desired training land and range configurations by the year 2018, influence the planning process.

Budgeting

The budgeting processes for both the natural resources/environmental and training sides of the house are a combination of direct programmatic funding, and funding through installation programs such as timber, sport fish and game, and ITAM. Natural resource funding is received through a number of mechanisms depending on the activity. Many of the activities carried out in the Conservation and Environmental branches of the Environmental Management Division (DFEL) are funded through the Environmental Program Requirements (EPR) Report (Department of the Army 1998), in the past referred to as the 1383 process. These activities include soil conservation, TES, and cultural activities. Additionally, fish and game programs as well as timber management and agricultural out lease programs are funded through revenues brought in by the respective program.

Similar to natural resource programs, DOT activities are funded through a combination of mechanisms. Most range activities are funded through the Management Decision Package. Budgeted dollars come down from headquarters levels through the MACOM. Programs such as ITAM are funded through individual program proponents. ITAM is funded through the Deputy Chief of Staff for Operations and Plans (DSCOPS).

Reporting, Assessment, and Communication

Reporting, assessment, and communication processes are driven by the need to exchange installation information regarding compliance, installation status, funding needs, and similar factors with MACOM and higher level Army/DoD headquarters organizations, and with non-DoD government regulatory agencies. These processes included the ISR (parts I and II, Department of the Army, Final Draft), ECAS, and the Environmental Quality Report (EQR), all of which are mechanisms for reporting to headquarters organizations. Additional reporting requirements are required by MACOM offices; in Fort Benning's case this is TRADOC. MACOM-level reports have several formats including planning-level

survey status reports on TES, ESMPs, and the status of range and training lands (TRADOC Status Report [TSR]).

Land Resource Management

The Land Resource Management process represents activities undertaken to execute the physical activities needed to maintain and improve the training lands as planned and budgeted for under the other processes. This process includes a wide variety of programs and tasks and for the purpose of this report has been divided into the following subprocesses: Inventory and Monitoring; Maintenance, Restoration, and Rehabilitation; Resource Use; and Data Management.

Inventory and Monitoring

Inventory and Monitoring processes represent those activities designed to quantify and describe the natural resource and training assets of the installation. On the natural resource/environmental side of the house these activities include baseline inventories of vegetation, soils, and similar features, as well as ongoing surveys of TES populations, habitat, and timber assets, etc. Activities carried out by the training side of the house include similar baseline information on the existence and status of range and training facilities. In addition, it includes the LCTA program, designed to characterize the condition of training lands.

Maintenance, Restoration, and Rehabilitation

Maintenance, Restoration, and Rehabilitation processes represent all activities designed to restore training lands after use, as well as programs focused on rehabilitating TES and other natural habitats. The processes include activities such as LRAM, the ITAM components for training land rehabilitation and maintenance under the DOT, and various conservation projects designed to provide better RCW habitat.

Resource Use

Resource Use processes cover all the management and physical activities associated with utilization of the training lands and natural resources of an installation. These include training and recreational scheduling of lands, and activities such as timber harvesting/management and fish and game programs.

Data Management

Data management crosscuts all levels of the business processes defined above. It includes processes and tasks that involve developing, storing, and using data in decision making. Specific data management activities include GIS use, natural resource databases (such as those used in LCTA and TES programs), and modeling activities for both research and management decisions.

Anticipated SEMP Outcomes: Infusion into the Installation Business Process

SEMP research activities have been organized to support DoD requirements for ecosystem management and to develop/identify the knowledge, tools, and protocols needed to use ecosystem-based practices to manage sustainable military training lands. To date, two Statements of Need have been initiated to provide mechanisms to identify ecological indicators of ecosystem health and to link these indicators to activities and management strategies occurring on military lands. Additionally, SEMP has identified, funded, and/or leveraged against several other research initiatives to provide the knowledge, data requirements, and perspectives needed to successfully engage in ecosystem management approaches. The individual areas of emphasis, as well as expected payoffs, are outlined in Table 15.

Table 15. SEMP initiatives and expected outcomes.

SEMP Initiatives*	Expected Outcome
SON 99 Research Areas: Determination of Indicators of Ecological Change	Identified indicators of ecological change at multiple spatial and temporal scales, relationship between indicators and land use.
SON 00 Research Areas: Ecological Disturbance in the Context of Military Landscapes	A developed knowledge to implement ecosystem management approaches for military lands.
Ecological Characterization and Monitoring Initiative (ECMI): Base Line Monitoring Program	Techniques and tools for baseline ecosystem monitoring programs.
Enterprise Repository Database Design and Test	Techniques and protocols designed for efficient data storage, use, and sharing for land management decision support.
Regional Data Sources Study	Identification and development of ecoregion-wide data sources (Fall Line Sandhills region) and techniques to interpolate region ecosystem trends and status.
Auburn University Center for Forest Sustainability Cooperative Effort	Increased knowledge for sustainable forestland management practices.

* Refer to Chapter 8, **Research Projects** for project details.

The SEMP efforts outlined in Table 15, were planned to directly infuse needed knowledge and technologies into the installation Land/Resource Management processes (Figure 16). ECMI efforts provide for baseline characterization data for installation monitoring plans, as well as, long-term data for assessment of relationships between land use and management and ecosystem sustainability. This effort ties directly to current installation inventory and monitoring programs, such as LCTA, and offers the ability to expand program emphasis to a multi-scale ecosystem level. Research under SON 00 and the cooperative efforts with Auburn University provide information and resources needed to manage ecosystem health and sustainability by identifying the relationships between land use and ecosystem impacts. These efforts have direct utility for installation Land/Resource Management and Repair and Rehabilitation processes and provide the keystone for ecosystem management implementation. The Enterprise Data Repository and Regional Data Source Studies interface with the installation Data Management processes. These efforts will provide needed protocols and technologies for efficient data storage, use, management, and sharing, including tools for data analysis and GIS applications. SON 99 research will identify appropriate ecological indicators of ecosystem health and develop the protocols needed to use these indicators to monitor land use and management practices. This effort crosscuts other areas of SEMP focus, as it provides data at differing levels needed to improve our understanding of ecosystem processes for inventory, monitoring, and management. The effort also broadens available data resources for inter-agency and regional ecosystem planning.

In addition to the direct applicability of SEMP products for improving the installation Land/Resource Management processes, the infusion of SEMP technologies offers installation land managers the opportunity to incorporate improved ecosystem information and data sources into their planning and management cycles, thus allowing for an increased ability to maintain sustainable training lands while meeting compliance and stewardship goals.

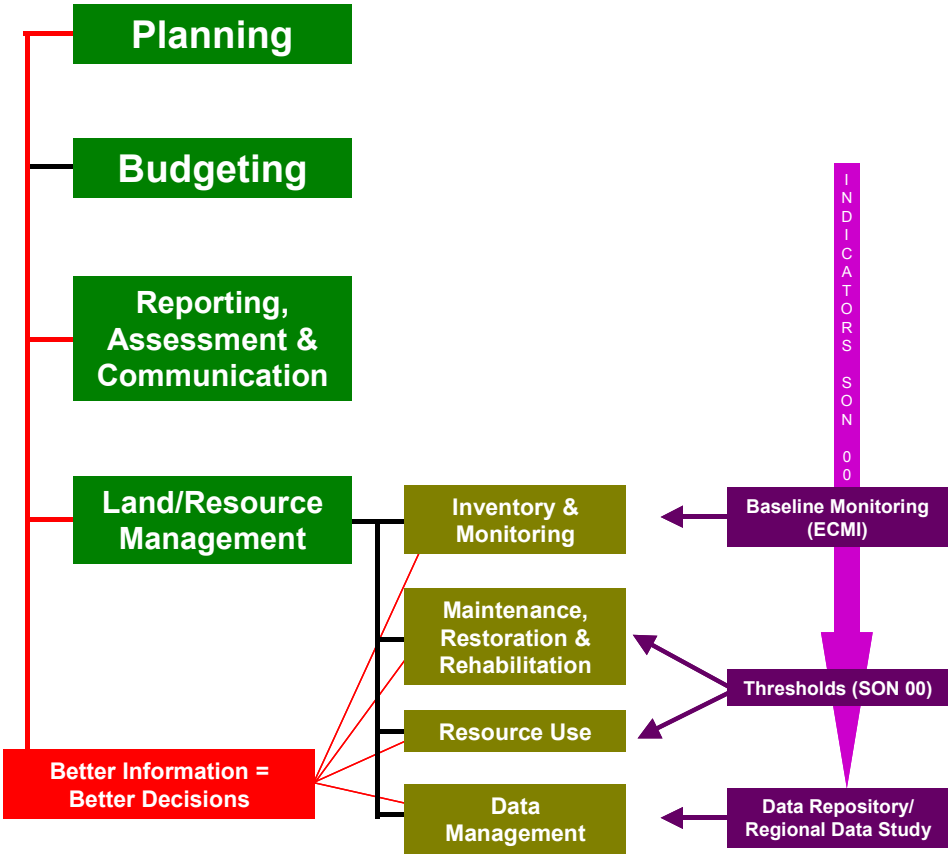


Figure 16. Military installation processes or tasks related to use and management of landscape resources.

10 Future Plans

Analysis Framework and Protocol

In the coming year, SEMP will initiate a focus on data analysis and report generation. The research teams, SEMP managers, SEMP TAC, and host site staff will dedicate resources to analyze, synthesize, and integrate the data being collected into our understanding of and planning for ecosystem management. Reports will provide insight on data collection, synthesis, management, and other issues "upstream" from these reports. Extensive resources have been committed to data collection and analysis, using our best hypotheses and state-of-the-art approaches. Generating useful reports from these data will help identify any adjustments or refocusing that might be needed, and will, ultimately, allow data to be better aligned to the needs of installation land managers.

Data analysis and reporting is critical input from SEMP for our host site. Within the current SEMP efforts, there is not any funded effort to perform data analysis, except those efforts limited to specific research teams pursuing their specific hypothesis. These hypotheses are primarily limited to "what is a good indicator of change, and what do these potential good indicators tell us" and "what are the 'thresholds' of degradation that we need to manage to avoid in our resource use and management program?" These are very useful outcomes, but they are presently independent of any specific management concern, action, or program conducted by the SEMP host site or other DoD installations. The outcomes of the SEMP investment need to be incorporated into the host site business processes, then packaged towards transition to other installations' business processes.

Data analysis and reporting are also important in helping with SEMP technology transfer. SEMP represents a major Research and Development (R&D) investment for SERDP and DoD (over $2.5 million/year) and clear product outcomes from SEMP should be targeted to emerge from the program sooner rather than later. Data analysis reports, custom tailored to meet host site requirements, not only represent payback from the SEMP investment for the host site, but can also translate to other facilities.

The overall plan for SEMP originally proposed that research would progress from "what should be observed?" to "what do the observations mean?" to "what management action do we take?" to "how do we know we're achieving our desired end states?" The analysis reports are critical links between each of these stages.

SEMP needs some analysis to explain the observations and to evaluate when observations should generate concerns and actions. Also, reports are needed to help check the results of the management actions and "close the loop" on the process, even back to redetermining what should be observed. Analysis reports are an essential glue to draw the different investments together into a whole.

Assessing Trends in Monitoring Data

Selected parameters will be monitored through the developing ECMI system, and will be transferred to Fort Benning for long-term, potentially perennial, operation at the conclusion of the formal SEMP activities. Since, by definition, any one year's data for any parameter are almost impossible to interpret in a vacuum, one of the products of the SEMP "turnover protocol" must be sufficient temporal depth so that managers may interpret trends. This is one of the primary reasons why the minimum stated term of monitoring will be 10 years. Frankly, even this may represent only a short-term point of view, and the SEMP/ECMI data will be supplemented with longer-term information from other available studies in the southeastern United States. For many elements, it will be hard to determine if any trend at all is evident within the ECMI timeline, but the basis will be laid for future extrapolation and prediction through application of assessment tools developed by the SEMP process.

Building a Framework of Analysis Capabilities

Beyond the explicit tasking to acquire data that relates to the installation environment, it is expected that interpretation of these data as they relate to installation needs and goals will lead to creation of predictive capability. Tools will be developed that will allow installation managers to "model" the possible results of management actions, and will allow those actions to be tailored to effect the results proposed in the "Desired Future Conditions" section of the Fort Benning INRMP.

Goals, Plans, and Progress Measures: Linking Outcomes of Analysis to Management Goals

In the long run, monitoring any number of environmental parameters, even if required at some future date for compliance reasons, will not actively help the installation to manage its environment unless there is a clear linkage between actions and results. Upon closer examination of the goals and objectives in the INRMP, it has become apparent that, for many, if not a majority, of the specific objectives, no assured course of action may now be specified that will result in the desired future condition proposed. This is not to say that there is not a general understanding of what course of action is likely to create a desirable result. Overall, the developers of the INRMP feel they know at least some of the required changes in policies and actions. A principal objective of SEMP is to create more specific linkages among management actions, parameters which may be monitored, and desired future conditions. It may be noted here that the existence of a set of desired future conditions within the INRMP sets the host installation apart from many other military installations, and that the belief that these will be implementable has led, in turn, to a high level of support for SEMP.

An Analysis Protocol

What is an "Analysis Protocol"? As used in relation to SEMP, we will define it as an example (or a set) of linkages among a measurable parameter, an indicator of some condition(s), one or more management actions, and an end state for some environmental element. Some might call these protocols models, or equations, or cause and effect relationships, or by any of a series of terms. With the host installation, we share the belief that it will be possible to develop such relationships, sooner or later, so that a manager may implement a site-specific action with the expectation that, in the future, the result(s) will be of a certain nature and fall within certain expected measures. Among the best models we have for this sort of relationship in a natural resources context are those for crop fertilization. If crop X is being grown on soil type Y in a particular county under known irrigation, then the addition of a specific quantity of a certain mix of nutrients may fairly reliably be anticipated to result in a given growth response and a certain anticipated yield from that field. However, even these linkages, although tested for decades under relatively controlled conditions, are far less than perfectly predictive. The task when dealing with largely natural systems, where controls cannot be so specific nor predictive capability so developed, is considerably more challenging. In many cases, we will likely have to be satisfied that we may reliably predict the direction in which the desired parameter will be moved, even if the rate and degree remain, for now, only imperfectly predictable.

Technology Transfer: Beyond Fort Benning and Beyond the Fall Line

What is Transferable from SEMP?

SEMP was initiated to examine the complex relationships of natural systems exposed to military use, and to increase our understanding of military installation management practices in the context of dynamic ecosystems impacted by other human and nonhuman factors. Elements of this "increased understanding" will help us manage other installation throughout the region, other installations in other regions, and installations within the context of their regional neighborhoods. But much of the knowledge gained from SEMP will be specific to the ecosystem of the host installation(s).

Besides knowledge about ecosystem dynamics, SEMP has also nurtured some approaches that themselves can be transitioned to ecosystems beyond the host site. These approaches include: (1) the monitoring protocol, (2) the research data repository, (3) mechanisms for linkages between research results and the host site's INRMP, (4) analysis tools and approaches that sift through research and monitoring data to identify, compare, and quantify ecosystem trends and conditions and the impacts of mission use and management actions.

Building SEMP Approaches Into Installation Operations

The key to transferring SEMP outcomes begins with linking these outcomes to host installation management practices. Those indicators that provide valuable insight to the ecosystem need to be tested for validity (perhaps at multiple sites) and then transferred into the monitoring effort, so that SEMP begins to gather a longer term timeline of the "indicator" variables. Data from the monitoring program then needs to be structured into an analysis protocol that yields valuable information related to ecosystem trends, which is also important feedback to how these trends relate to management objectives and actions. The SEMP design involves observing and analyzing these trends across multiple temporal and spatial scales. Once linkages are made to the host installation management practices, then elements of the approach can be transferred to other sites.

For other installations along the fall line, the test bed program should expand the number of host installations, and similar transfer approaches can be designed. However, to accomplish transitioning of SEMP approaches to other fall line locations will require "simplified" monitoring and analysis protocols that are adapted to the varying scale, mission use, and budgetary circumstances of each location. Likely, also, there will be some necessary adjustments and linkages to

the plans for each of these locations — so that clear linkages are made between management objectives, plans, actions, and ecosystem observations and analysis.

These same adjustments will be required to transition SEMP to locations throughout the southeastern United States. In every case, implementing approaches from SEMP extends beyond just selecting ecosystem parameters to observe and analyze. Linkages must be made to management objectives and actions, or the value of these observations and subsequent analysis will be limited.

The original characterization and monitoring program (ECMI) and the research data repository can be adapted for use at other sites, without these linkages to the entire SEMP program. To facilitate the use of these approaches, both efforts will be detailed in reports and presented at workshops.

Forums for Technology Sharing and Infusion

SEMP approaches and outcomes have been and will be aggressive presented at numerous scientific, agency, and regional forums. Besides the SERDP annual Symposium, SEMP papers and sessions have been and will be planned for many scientific forums (e.g., Ecological Society of America, American Society of Agronomy, American Society of Foresters, International Society for Landscape Ecology, North American Fish and Wildlife Association) and numerous DoD forums (e.g., National Defense Industrial Association, DoD sessions of professional societies, and agency meetings). Sharing in scientific forums is critical to nurture a critical dialogue about SEMP approaches and to share these approaches with others who might continue to adapt and evolve SEMP.

In addition to society and agency forums, SEMP will also be presented in regional forums, such as the Long Leaf Alliance, and the Southeast Natural Resources Leaders Conference. These forums are important from multiple perspectives — sharing across Federal, regional, and state agencies; establishing regional linkages and ecosystem partnerships; and the joint pursuit of ecosystem management approaches within a larger ecoregion.

SEMP also has a web presence which serves several functions:

1. A reference site for information, contacts, and publications related to SEMP.
2. Linkages to other web sites with relevant information and programs (such as SERDP, host installation, National Science Foundation's Long Term Ecosystem Research [LTER] Program, etc).
3. Calendar of upcoming activities (field work, meetings) related to SEMP.

4. Forums, when needed, for discussion and sharing by groups within and beyond the SEMP "community."
5. Posting of SEMP reports.

Ecoregional Analysis and Monitoring Sites and other DoD Settings

An important extension of SEMP is the aspect of the larger scale — both temporal and spatial. Most of the current SEMP activities are within the installation fence line; but one of the concerns in understanding ecosystem dynamics involves an improved understanding of how the installation contributes to and is impacted by the dynamics in the larger ecoregion. To this end, these are several new efforts underway; some funded by SERDP and some through other programs, that extend the "scope" of study to the issue of across the fence line dynamics. Some of these efforts are already underway, and others will begin in 2002. These efforts will involve the installation and surrounding communities, and begin to address questions such as goals for the entire region (e.g., protected species habitat), air and water quality conditions and impacts across the fence line, and the impacts of urban dynamics on installation operations. These larger spatial- and temporal-scale efforts will provide critical data for joint planning between military installations and communities, and will help inform the efforts of multiple locations to shape regional goals and monitor regional progress towards these goals. These regional efforts will also provide a "connect" with the regional efforts of other agencies (e.g., Environmental Protection Agency and the Southeastern Framework) and this will help transition the outcomes of SEMP investments into a broader regional context.

Other DoD Settings

Will SEMP extend beyond the southeast? The current activities at Fort Benning were, to a limited degree, modeled after the LTER program of the National Science Foundation. LTER sites, which are located in selected managed areas across the United States, include some long-term monitoring, a variety of short- and long-term research efforts, and use a repository approach to manage, share, and archive data.

The establishment of one host site for SEMP was always perceived as a "beginning" of ecosystem research for SERDP. After the initial site selection of Fort Benning, the TAC recommended that expansion of SEMP be first focused within the southeast, especially along the Fall Line region.

However, the issue of other ecoregions and other LTER-like sites for DoD is still under consideration. One of the goals of a transferable package for monitoring and analysis protocol is to provide a scalable methodology for establishing other SEMP locations in regions relevant to DoD operations. Current plans call for the evaluation of SEMP expansion costs and value to another ecoregion in the 2004 timeframe.

Along the Fall Line – Benning Area as Part of a Larger Ecoregion

Ecoregional Analysis

If the official DoD and Army policy guidance requiring management of ecosystems rather than of individual species is ever to be effectively implemented, each installation's land management personnel must be aware of the nature and boundaries of the ecosystem(s) within which the installation functions. Some locations are clearly definable. Others, especially larger installations, and including Fort Benning, have affiliation with more than one system or alliance. Depending on the definitions applicable, this location is in the transition area between the Fall Line of the Piedmont and the Upper Coastal Plain of the southeast. The Fall Line Sandhills, which are well represented on Fort Benning, are especially interesting because of the number of military installations located there. Forts Benning, Gordon, Jackson, and Bragg are all sited in whole or in part in this system, as are Shaw and Robbins Air Force Bases. All share, to a greater or lesser degree, land management challenges that are based on a common heritage of forest clearance, followed by agricultural exploitation and associated loss of the sandy topsoil. Thus, principles learned at Fort Benning should be capable of extrapolation to several military installations as well as being of general use to other land managers in the region.

As just one example, the challenges of managing and enhancing the longleaf pine habitat for the endangered RCW is a shared problem across wide areas, including all these DoD facilities. This is a problem that has much wider extent than just the fall line sandhills, but the sandhills are believed to exemplify the habitat needs of the woodpecker, and significant effort is being expended to address these needs, in both sandhills and coastal plain habitats. In a similar manner, we believe, with some confidence, that many ecosystem relationships identified through SEMP at Fort Benning will be applicable to wide areas of both ecosystems. In the final context, however, these linkages must be tested and validated across the range of their potential application before their usefulness across this range may be assumed.

The southeast has also been the recent focus of efforts by the Environmental Protection Agency regional office, in Atlanta, to develop programs that may be applied to ecosystem change analysis. ERDC personnel associated with SEMP have assisted the EPA in developing and testing this procedure. The protocol has been, and will be, applied to SEMP-sponsored studies at Fort Benning as well as to other sites which may become a part of the initiative.

Testbed Program

As one approach to the technical transfer of potential indicators and other findings from SEMP, a variety of small tests will be performed at locations along the fall line sandhills (or upper coastal plain) outside Fort Benning. Starting in FY 2002, the SEMP research teams will propose significant tests or experiments that they believe require validation beyond the original sites on Fort Benning before they may be considered "finalists" in the indicator selection process. A small amount of additional funding is proposed to be allocated for this purpose. The term "testbed" has been used to describe the identification of processes and locations that will be so tested. Possible locations include other military installations in this system, as discussed above, as well as holdings of other Federal and state agencies, and possibly cooperating private landowners if a site is especially well-suited to SEMP needs. No funding of the other landholders is proposed, although it would be hoped that the data acquired through the testbed studies will be of value to the land mangers of those properties.

Building Alliances Along the Fall Line

The Fall Line Sandhills workshop held in March 2001 at the Savannah River Ecological Laboratory brought together managers and researchers representing more than a dozen agencies. Issues discussed included many areas where it was believed that common interests should be pursued. Among these were endangered species, ecosystem restoration, forest management, controlled burning practices, and relations with adjacent landholders. The numerous military installations located within this association form one natural potential working group. The U.S. Forest Service and associated research organizations represent another focus of need for development of environmental analysis and predictive management protocols. Any formal or informal groupings developed should continue to relate to the existing Southeast Natural Resources Leaders Group, and continue liaison with efforts that they have originated.

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Acronyms

AFCEE	Air Force Center for Environmental Excellence
AFI	Air Force Instruction
AFPD	Air Force Policy Directive
AFRES	Air Force Reserve
ANG	Air National Guard
AR	Army Regulation
ASN(I&E)	Assistant Secretary of the Navy (Installations and Environment)
ATTACC	Army Training and Testing Area Carrying Capacity Model
CEMML	Center for Environmental Management of Military Lands
CERL	Construction Engineering Research Laboratory
CEQ	Council on Environmental Quality
CFR	Code of Federal Regulations
CNO	Chief of Naval Operations
CSDGM	Content Standards for Digital Geospatial Metadata
DA	Department of the Army
DASA (ESOH)	Deputy Assistant Secretary of the Army for Environment, Safety, and Occupational Health
DCNO	Deputy Chief of Naval Operations
DCSOPS	Deputy Chief of Staff for Operations and Plans
DDRE	Director, Defense Research and Engineering
DEM	Digital Elevation Model
DFEL	Directorate of Facilities, Engineering, and Logistics
DoD	Department of Defense
DoDI	Department of Defense Instruction
DOE	Department of Energy

DOI	Department of the Interior
DOT	Director of Training OR Directorate of Operations and Training
DPW	Department/Directorate of Public Works
DUSD(ES)	Deputy Under Secretary of Defense (Environmental Security)
EA	Environmental Assessment
ECAMP	Environmental Compliance Assessment and Management Program
ECAS	Environmental Compliance Assessment System
ECMI	Ecosystem Characterization and Monitoring Initiative
EIS	Environmental Impact Statement
EL	Environmental Laboratory
EPA	Environmental Protection Agency
EPR	Environmental Program Requirements (Report)
EQR	Environmental Quality Report
ERDC	Engineer Research and Development Center
ES	Environmental Security
ESOH	Environmental Safety and Occupational Health
FGDC	Federal Geographic Data Committee
FOA	Field Operating Agency
FONSI	Finding of No Significant Impact
FORSCOM	U.S. Army Forces Command
FY	Fiscal Year
GIS	Geographic Information Systems
GPS	Global Positioning Systems
HUC	Hydrologic Unit Code
IES	Institute of Ecosystem Studies
INRMP	Integrated Natural Resources Management Plan
ISP	Internet Service Provider
ISR	Installation Status Report
ITAM	Integrated Training Area Management

LCTA	Land Condition Trend Analysis
LMB	Land Management Branch
LMS	Land Managements System
LRAM	Land Rehabilitation and Maintenance
LTER	Long Term Ecosystem Research
MACOM	Major Command (Army)
MAJCOM	Major Command (Air Force)
MOA	Memorandum of Agreement
MOM	Measure of Merit
MOU	Memorandum of Understanding
NASA	National Aeronautics and Space Administration
NEPA	National Environmental Policy Act
NGO	Nongovernmental Organization
NIH	National Institutes of Health
NIST	National Institute of Standards and Technology
NOAA	National Oceanic and Atmospheric Administration
NPR	National Performance Review
NRCS	Natural Resources Conservation Service
NRM	Natural Resources Management
OPNAVINST	Office of the Chief of Naval Operations Instruction
PM	Project Manager
QA/QC	Quality Assurance/Quality Control
R&D	Research and Development
RCW	Red-cockaded Woodpecker
RDBMS	Relational Database Management System
RS	Remote Sensing
SAB	Scientific Advisory Board
SAF/MI	Secretary of the Air Force for Manpower, Reserve Affairs, Installations and Environment
SDS/FIE	Spatial Data Standards for Facilities, Infrastructure and Environment

SEMP	SERDP Ecosystem Management Program
SERDP	Strategic Environmental Research and Development Program
SON	Statement of Need
SREL	Savannah River Ecology Laboratory
SRI	Savannah River Institute
TAC	Technical Advisory Committee
TES	Threatened and Endangered Species
TRADOC	U.S. Army Training and Doctrine Command
TSR	TRADOC Status Report
TTAWG	Technology Thrust Area Working Group
USDA	U.S. Department of Agriculture
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey

Glossary

The following definitions are based on the definitions contained in Callicott, Crowder, and Mumford (1999) and the reference sources for these definitions contained therein. When appropriate, the original reference cited is provided. Some of the definitions, such as the definition for ecosystem management, may be modified to fit the Fort Benning context. Occasionally, a simple definition may be accompanied by a complex, perhaps more technical, definition. Additional clarifications may accompany each definition.

Adaptive management

Treating management goals and techniques as hypotheses that are confirmed or falsified by success or failure (Walters 1986).

Biological diversity (biodiversity)

The variety of life at every hierarchical level and spatial scale of biological organization: genes within populations, populations within species, species within communities, communities within landscapes, landscapes within biomes, biomes within the biosphere (Wilson 1992). Often limited to native biodiversity, not diversity per se (Noss and Cooperrider 1994).

Ecological (biological) integrity

Native species populations in their historic variety and numbers naturally interacting in naturally structured biotic communities (Angermeier and Karr 1994). According to Angermeier and Karr (1994), diversity describes only the elements of the biota; and biological integrity more inclusively comprises ecological processes. Moreover, as indicated in the preceding sentence, these authors use the term biological integrity; however, because ecological processes are involved, ecological integrity is a more descriptive term.

Ecological restoration

Process of returning, as nearly as possible, a biotic community to a condition of ecological integrity (Society for Ecological Restoration 1997). According to Angermeier and Karr (1994), the goal of ecological restoration is to produce a self-sustaining system as similar as possible to the native biota (or more broadly, natural communities with intact ecological processes); however, because of the pervasive effects of human actions, often it is difficult to characterize naturally evolved conditions. Because of the inability to define "naturalness" in an absolute sense, Anderson (1991) proposes assessing degrees of naturalness using criteria that can be quantitatively measured across a continuum. These criteria look essentially at the differences between biotic communities in the presence and absence of humans and their culture. A plausible conclusion from such an assessment (as far as selecting appropriate restoration targets is concerned) is that prior to European settlement relatively stable ecological interactions between native and "naturalized" species, among them resident humans, were established in the Americas. As a result, the pre-European settlement conditions represent appropriate targets for restoration.

Determining what is native and non-native (introduced, exotic, or alien) also can be problematic. When can an introduced species, whether by means of natural or cultural means, be considered naturalized? Callicott, Crowder, and Mumford (1999) suggest an ecological criterion: "To what extent is the species in question a good citizen of its new biotic community? Does it displace or adversely affect its native and naturalized neighbors?"

Ecosystem health

Occurrence of normal ecosystem processes and functions (Costanza, Norton, and Haskell 1992). "Normal" ecosystem function means ecological processes, such as primary production of biomass, nutrient recruitment, retention, and cycling, and disturbance regimes, occurring as they have occurred historically. Wilderness areas potentially provide the historic benchmarks (Leopold 1941). According to Leopold (1941), a science of ecosystem health would determine the ecological parameters within which land may be humanly occupied without making it dysfunctional. Ecosystem health also may be characterized by its "counteractive capacity": the capacity to absorb external perturbations and rapidly resume normal activities after being substantially assaulted (Rapport 1995). In summary, the concept of ecosystem health, defined as it is in terms of the occurrence of normal ecosystem processes, can be specified only by reference to natural areas in terms of which the concept of biological integrity is understood.

Ecosystem management

Managing, where appropriate and at the appropriate geographic scales, either for ecological integrity or for ecosystem health and managing human exploitation of natural resources such that the primary goal is the ecosystem health of exploited areas.

The definition of ecosystem management is controversial. Grumbine (1994) originally defined ecosystem management in terms of biological integrity as:

> [A process that] integrates scientific knowledge of ecological relationships within a complex sociopolitical and values framework toward the general goal of protecting native ecosystem integrity over the long term.

Stanley (1995), however, points out that biological integrity is not an explicit goal of ecosystem management as envisioned by numerous Federal agencies that have embraced the concept. Callicott, Crowder, and Mumford (1999) used a revised definition by Grumbine (1997) to suggest a middle path: "Managing ecosystems with the primary goal of maintaining their health and relegating commodity extraction to a subordinate goal." Although from the standpoint of commodity production this definition seems to fit Fort Benning well, the installation's primary mission of military training also may be viewed within the same context. In other words, military training cannot occur in the absence of healthy ecosystems.

As true as the last statement above is, the regional importance of Fort Benning's biotic resources make managing strictly for ecosystem health insufficient. Callicott, Crowder, and Mumford (1999) seem to assume that the world can be divided neatly into nature reserves (where ecological integrity is the management goal) and human inhabited and exploited areas (where ecosystem health is the management goal). Depending on the perspective chosen, Fort Benning can function in either way. The choice is in part scale dependent. Accordingly, for its practical application at Fort Benning, ecosystem management is defined herein more broadly.

Ecological sustainability

Meeting human needs without compromising the health of ecosystems (Callicott and Mumford 1997). An ecologically sustainable project or activity does not compromise ecosystem health.

Ecological rehabilitation

Process of returning, as nearly as possible, an ecosystem to a state of health (Michigan Department of Natural Resources 1994). Meffe (1995) defines ecological rehabilitation as incomplete restoration: "A partial movement along the trajectory from degraded to the original state is termed 'rehabilitation.' " "Original state" is probably the same thing Anderson (1991) means by a "pre-settlement" biotic community (Callicott, Crowder, and Mumford 1999).

Appendix A: Statements of Need

The SONs in this appendix are copies of the texts that were initially published for FY99 (in the Fall of 1997) and FY00 (in November 1998).

FY99 STATEMENT OF NEED
FOR
STRATEGIC ENVIRONMENTAL RESEARCH AND DEVELOPMENT PROGRAM ECOSYSTEM MANAGEMENT PROJECT (SEMP)

TITLE: DETERMINATION OF INDICATORS OF ECOLOGICAL CHANGE

1. OBJECTIVE OF PROPOSED WORK

Description: The main objective of this statement of need (SON) is to identify indicators that signal ecological change in intensively and/ or lightly used ecological systems on military installations.

Research Emphasis: Land and water resources are affected by military training and testing activities, but it is difficult to predict ecological responses (changes) outside the range of natural variation, especially under different ecological circumstances (such as: different ecosystems, different moisture conditions, different seasons of the year, different intensities of competitive or mutualistic interactions, etc.). A combination of human- induced and natural factors may yield changes that appear to be negative impacts of military or other human activities. Thus, it would be beneficial to understand and employ ecological indicators that identify differences between natural variation and anthropogenic negative impacts.

It is accepted that some changes are natural and characteristic of ecosystems. It is understood that ecosystem change also results from human activities and that changes sometime occur after a time lag. Military activities, i.e., training and testing, as well as other land management practices on installations, can cause change. Early indications of change, and an understanding of the likely cause(s), will improve managers' ability to manage activities that are shown to be damaging, and prevent long- term, negative effects.

To this end, a suite of variables is required to measure changes in ecological condition. There are two types of indicators that may be useful: 1) variables that inform managers about ecosystem status and 2) variables that that signal impending change. In many cases these indicators may be the same. Both types of indicators are needed, but variables that serve as early warnings of impending changes outside the natural range of variation, and variables that are shown to be related to activities affecting the military mission, would be especially valuable.

Specific Product Parameters: The results of research under this SON should accomplish one or more of the following objectives: 1) identify measurable variables that are highly correlated with a certain state in a specific ecosystem, and 2) determine the likely range of natural variation for such variables, and how those values compare with the range of values under anthropogenic (especially mission- related) influences.

Research may focus on one or more variable at any ecological level, i.e., biogeochemical processes, natural disturbance processes, plant or animal communities, populations dynamics, landscape change, etc. Research may focus on responses related to composition, structural or functional characteristics of the focal variable(s).

It is important to develop and test the efficiency, reliability, and accuracy of a set of easily measured physical and biological variables that predict trends in ecosystem change.

These questions are relevant to any ecosystem on any DoD installation. To initiate this effort within the available funding, a specific region (the Southeastern United States) and installation (Fort Benning, GA) have been selected as a target for research to be conducted under this SON. Ongoing ecological research projects and ecosystem management efforts on Fort Benning and throughout the region will provide useful supplementation, and perhaps a foundation, for funded work see Appendix for a list of current data and recent projects available on Fort Benning). Nonetheless, proposed work should be developed with the intent to transfer results to installations across an appropriate portion of the southeastern region.

It is possible that measuring change could make use of advanced technologies. Change might be detected and analyzed using a suite of field monitoring capabilities, which would include remote sensing, geographic information systems (GIS) and image analysis tools.

Specific Objectives: Research effort to be funded under this SON should address one or more of the following objectives for the selected installation and for one or more specified ecosystem(s):

1) Identify specific indicators of ecological change and the historic range of variation of the selected ecosystem indicators, possibly under more than one ecological circumstance.

2) Develop tools and methodologies for distinguishing change indicators. Differentiation should be made between anthropogenic effects, natural variation and natural rates of ecological change.

2. EXPECTED PAYOFF OF PROPOSED WORK

Results of this project will:

1) Provide a foundation for distinguishing negative impacts related to military training and testing activities from other sources of ecological variation.

2) Provide an improved knowledge base for evaluation of ecosystem health.

3. BACKGROUND

Introduction: This statement of need (SON) is the first in a series of SONs that comprise a major SERDP initiative to support DoD installations in accomplishing ecosystem management objectives, while maintaining lands and waters to accomplish military training and testing missions. The series of SONs is part of a major programmatic effort titled the Strategic Environmental Research and Development Program Ecosystem Management Project (SEMP). The overall intent of SEMP is to develop the knowledge required to assess the interaction between military activities and ecological resources, monitor those interactions, and identify adaptive, ecosystem management approaches for management of military lands and waters.

The strategic plan for the series of SONs is 1) to determine indicators of environmental change, 2) identify critical thresholds (either natural or anthropogenic) of ecological change, and 3) examine the types, intensities, and frequencies of natural and anthropogenic disturbances that can be sustained by an ecosystem. The focus will be on the role of military activities, combined with natural processes, as the generator of change. Later SONs will focus on application of such knowledge into adaptive, ecosystem management approaches for management of military lands and waters. The series of SONs to support SEMP will be

advertised over a period of the next several years, pending early results of this initial SON.

This effort will support and adopt the guiding principles of the 1994 memorandum from the office of the Deputy Secretary of Defense for Environmental Security (DUSD[ES]/EQ-CO memo, "Implementation of Ecosystem Management in the DoD", 8 August 1994). These principles are:

1. Maintain and improve sustainability and native biodiversity of ecosystems.
2. Administer in accordance with ecological units and timeframes.
3. Support sustainable human activities.
4. Develop a vision of ecosystem health.
5. Develop priorities and reconcile conflicts.
6. Develop coordinated approaches to working toward ecosystem health.
7. Rely on the best science available.
8. Use benchmarks to monitor and evaluate.
9. Use adaptive management.
10. Implement through installation plans and programs.

Current Efforts: Research on indicators of ecological change is intended to refine concepts and develop and test new approaches to instrumentation and monitoring in support of ecosystem management. This SON has a close relationship to the following SERDP efforts. These efforts may provide some foundation for proposals in this area: *[Editor's Note: Several project numbers and titles have changed since original publication of the SON.]*

SERDP Project #244 "Ecological Biomarkers: Monitoring Wild Fauna at DoD Installations"

SERDP Project #246 "Genetic Diversity Monitoring in Plants and Wildlife"

SERDP Project #507 "Threatened, Endangered and Sensitive Resources"

SERDP Project #1054 "Training and Testing Risk Assessment Framework"

SERDP Project #1055 "Analysis and Assessment of Military and non-Military Impacts on Biodiversity"

SERDP Project #752 "Terrain Modeling and Soil Erosion Simulation"

SERDP Project #1102 “Improved Units of Measure for Training and Testing Activity Impacts on the Environment”

SERDP Project # 758 “Ecological Modeling for Military Land Use Decision Support"

SERDP Project #1096 “Error and Uncertainty Analysis”

SERDP Project #1098 “Emerging and Contemporary Technologies in Remote Sensing for Ecosystem Assessment and Change Detection on Military Reservations”

Modeling/Simulation and Advanced Remote Sensing Technologies: As appropriate, effort should be made to use or apply modern modeling and simulation tools and techniques. In addition, advanced remote sensing and GIS technologies should be proposed for use if they would provide obvious advances in technologies.

4. USER REQUIREMENTS TO BE ADDRESSED BY PROPOSED WORK

DoD/Tri-Service User Requirements:

Army 4.2.a Land Capability/Characterization (High)

4.3.a Mitigating Army-Unique Impacts(High)

4.3.f Development of an Ecosystem Approach to Training Area Management (High)

4.4.o Ecological Importance of Wetland Buffer Zones and Riparian (High)

4.6.a Impacts to Threatened and Endangered Species (TES). (High)

DoD

Department of Defense (DoD) guidance for implementation of an Ecosystem Management approach to military land management (DUSD[ES]/ EQ-CO memo, 8 August 1994, and DoD Instruction 4715.3, “Environmental Conservation Program”, 8 May 1996) includes the following two guiding principles: 1) “Develop a vision of ecosystem health”: Ecological health is a complex concept that relies on social and ecological values related to the state of the land. Since it is impossible to comprehensively measure ecosystem health, managers must substitute individual elements of the ecosystem for evaluation, and those variables become the

indicators of the state of the whole system. This SON reflects the need for greater understanding in selection and application of such variables. 2) "Use benchmarks to monitor and evaluate outcomes: Accountability measurements are vital to effective ecosystem management. Implementation strategies should include specific, measurable objectives and criteria with which to evaluate activities in the ecosystem."

DOE Requirements: Theoretical and empirical research is already being conducted at DOE National Laboratory locations, and some of the results have broad application to DOE and DoD site and installation issues of impact assessment, land management and rehabilitation.

EPA Requirements: EPA is conducting indicator development research, monitoring approaches, (network design, etc.), and regional vulnerability studies as tools designed to enable regional risk assessments. EPA's research program will benefit from enhanced activities in this area. EPA's management-related needs to refine current assessment and regulatory approaches are also well served by the data and tools projected from this research.

Users: Users of this technology will be DoD installation and land managers responsible for the long-term sustainability of ecological resources, for whatever purpose.

Working Groups and Consortia: The Army has convened at least two user groups to influence R&D funding decisions and the direction of project execution. The land rehabilitation and maintenance and carrying capacity user advisory group is available to help direct relevant R&D toward these user requirements. Issues related to threatened and endangered species of Army concern should be coordinated with the Army Threatened and Endangered Species User Group.

5. ESTIMATED COST AND DURATION OF PROPOSED WORK

The government estimate of the cost and time to meet the requirements of this SON is an annual investment not to exceed $400K per year for 5 to 6 years' duration. Proposers should not consider this estimate to be a required maximum; it is provided only as an estimate around which reasonable proposals may be developed. It should be understood, also, that the government reserves the right to fund more than one proposal either to meet this requirement fully or to pursue more than one innovative approach; the reasonable total cost of which might be more or less than the government estimate. The government will consider and encourages proposals that offer technical or cost advantages but only meet partial technical requirements in this SON.

6. POINT OF CONTACT: Inquiries can be made to Joyce Roberts, Contract Specialist, by phone at (217)352-6511, extension 7568, or by email at j-roberts@cecer.army.mil; or to Deloras Adamson, Contracting Officer, by phone at (217)373-7297, or by email at d-adamson@cecer.army.mil.

19 Nov 1998

SON Number: CSSON-00-03

STATEMENT OF NEED FOR FY00 SERDP CONSERVATION NEW STARTS

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

ECOLOGICAL DISTURBANCE IN THE CONTEXT OF MILITARY LANDSCAPES

The Defense Department is directed to use an ecosystem approach to manage their lands. The SERDP Ecosystem Management Project (SEMP) was initiated to address Defense Environmental Quality mission requirements and research and development opportunities in ecosystem management identified by the June 1997, SERDP-Sponsored, Management-Scale Ecosystem Research Workshop. They include: 1) establishment of a long-term research site (or sites) on DoD lands for Defense relevant ecosystem research; 2) conducting ecosystem research and development and monitoring activities relevant to the highest priority Defense mission activities such as training and testing; and 3) facilitating integration of the results and findings into DoD ecosystem management practices.

1. OBJECTIVE OF PROPOSED WORK

The overall intent of this statement of need (SON) is to develop the knowledge required to implement adaptive ecosystem management approaches for military lands and waters, as well as other federal facility lands and waters. Proposed efforts should address one or more of the following objectives:

1. Identify the historical range of variation in types, spatial extent, intensities and frequencies of natural disturbances across the landscape associated with specific ecological and/or land use conditions.
2. Describe how current DoD activities within the ecosystem compare to past disturbance regimes, in terms of affecting specific ecological and/or land use conditions.
3. Determine whether there are thresholds in spatial extent, intensity or frequency above and/or below which the natural system cannot sustain identified ecological and/or land use disturbances.

Research must be directed at supporting and improving installation land management goals. Funded work should elucidate the data necessary to promote the management of ecosystem processes as a basis for meeting specific management goals, objectives and practices at military installations.

Fort Benning GA has been selected as the site for research to be conducted under this SON. Fort Benning has been chosen as the research site because of existing and supplemental long-term ecosystem monitoring program. This monitoring program will consist of fundamental environmental data gathering across and adjacent to the installation as well as some site-intensive monitoring. This data will be available to the project investigator. The complete suite of parameters to be monitored has not been identified, however, this information will be available prior to the preparation of full proposals. In addition, as this work will be part of a series of ecosystem projects at Fort Benning, any additional environmental monitoring information gathered as a result of this proposed work will be made available on a near- real-time basis to other researchers working under this Program. All fieldwork with will performed at Fort Benning. Nonetheless, proposed work should be developed with the intent to transfer results and findings to DoD installations across the southeastern region of the United States and to other Federal land managers (i.e., DOE, BLM, National Parks, etc.).

2. EXPECTED PAYOFF OF PROPOSED WORK

The results from this research would provide an:

1. Improved long-term perspective about the relationship between DoD land use activities and the ecosystems that sustain all land uses.
2. Improved understanding about the spatial and temporal scales at which the ecosystem and land management actions can sustain long-term multiple land uses.
3. Improved decision rules for appropriate responses to the changes caused by DoD activities, at multiple spatial and temporal scales.
4. Improved compliance with DoD environmental stewardship responsibilities while minimizing any negative effects that such compliance may have on the military mission.

3. BACKGROUND

A SERDP sponsored a workshop on Management Scale Ecosystem Research (June 1997) which identified a number of opportunities and needs for improving scientific foundations for ecosystem management. This workshop lead to the development of the SERDP Ecosystem Management Project (SEMP). The goal of

SEMP is to conduct research to support DoD installations in accomplishing ecosystem management objectives, while maintaining land and water resources to accomplish military training and testing missions. The objectives of SEMP will focus on research to (i) determine indicators of environmental change, (ii) to identify critical thresholds (either natural or anthropogenic) of ecological change, and (iii) examine types, intensities and frequencies of natural and anthropogenic disturbances that can be sustained by an ecosystem. This SON is part of a series of SONs designed to implement the SERDP SEMP initiative. The focus here is on the role of military activities within the long-term dynamics of the ecological landscape. Other SONs will focus on application of such knowledge into adaptive, ecosystem management approaches for management of military lands and waters.

The continual environmental monitoring of Fort Benning has been termed the SEMP Ecosystem Characterization and Monitoring Initiative (ECMI). The goal of the ECMI is to design, develop and demonstrate an ecosystem monitoring protocol in support of SEMP objectives. The protocol will be demonstrated at Fort Benning. Over the course of the next 12 months, the effort will:

1. Inventory available ecological data and information relevant to Fort Benning and the surrounding ecological region.
2. Develop an adaptive monitoring program based on documented data and information needs of researchers and range and land managers.
3. Make the data and information accessible to researchers and land managers via a data and information repository.

Monitoring needs of individual research projects at the demonstration site will be accommodated to the extent possible.

It is understood that certain types, intensities and frequencies of disturbance are desirable and play important roles in the functioning of ecosystems. From a management point of view, it is important to understand how human activities compare to natural disturbances in effect and extent and frequency, and it is important to respond in a way that promotes or detracts from desired conditions through time and space. Improved understanding leads to more appropriate ecosystem or management response; for example, it may be determined that disturbances in certain locations or at certain times require aggressive response whereas disturbances in other locations or at other times are acceptable without intervention. It is likely that the effect of a given disturbance only can be evaluated within the context of other ecological conditions and disturbance across the landscape. Such perspective should assist DoD and other federal agency land

managers in compliance with Federal laws and regulations and with efforts to maintain sustainable conditions for military and non-military land uses.

An understanding of the ecological context of disturbance is gained through scientific inquiry into the characteristics of natural and anthropogenic disturbance regimes that have influenced long-term plant and animal community dynamics and physical conditions on the landscape. Characteristics whose study is likely to improve management options include the historical range of variation in spatial extent, intensity and frequency of the disturbance across the landscape, as well as the effects that these processes have had on physical conditions, plants, animals, and their ecological inter-relationships. Knowledge gained about causal relationships that led to persistence of certain species or a healthy soil ecosystem, for example, should provide concrete guidelines for future management options, ideally within an adaptive framework.

Among the common disturbances experienced on military installations are those that are imposed by human activity and those by environmental situations. The human activity includes off-road military maneuvers employing heavy tracked or wheeled vehicle, explosive impacts from munitions, and trench emplacements for strategic and logistic purposes. Environmental situations include violent storms (hurricanes, tornadoes, floods), drought, and fire, whether they be naturally imposed or carelessly started. In each case, it is important to continue learning about disturbance processes and their biological and physical effects. Increased knowledge should refine management recommendations, should determine appropriate management response over large spaces and over long time periods, and should allow a comparison between "natural" disturbances and the effects of specific activities as they relate to the goals of specific management objectives

Related SERDP Projects

The following SERDP projects are related to this Statement of Need and information concerning these projects may found in an appendix at the end of this SON.

Assessment and Management of Risks to Biodiversity and Habitat (CS-241)

Strategic Natural Resource Management Methodology (CS-373)

Threatened, Endangered, and Sensitive Species (CS-507)

Ecological Modeling for Military Land Use Decision Support (CS-758)

Risk Assessment Framework for Natural and Cultural Resources on Military Training and Testing Lands (CS-1054)

Analysis and Assessment of Military and non-Military Impacts on Biodiversity: A Framework for Environmental Management on DoD Lands Using the Mojave Desert as a Regional Case (CS-1055)

Error and Uncertainty for Ecological Modeling & Simulation (CS-1096)

Ecological Modeling and Simulation Using Error and Uncertainty Analysis Methods (CS-1097)

Emerging and Contemporary Technologies in Remote Sensing for Ecosystem Assessment and Change Detection on Military Reservations (CS-1098)

Predicting the Effects of Ecosystem Fragmentation and Restoration: Management Models for Animal Populations (CS-1100)

Improved Units of Measure for Training and Testing Area Carrying Capacity (CS-1102)

Identify Resilient Plant Characteristics and Develop Wear Resistant Plant Cultivars for Use on Military Training Lands (CS-1103)

Modeling/Simulation and Advanced Remote Sensing Technologies: As appropriate, effort should be made to use or apply modern modeling and simulation tools and techniques. In addition, advanced remote sensing and GIS technologies should be proposed for use if they would provide obvious advances in technologies.

Working Groups and Consortia: The Army has at least two user groups that influence R&D funding decisions and the direction of project execution of conservation research. The Integrated Training Area Management (ITAM) Installation Steering Committee (IISC) reviews land rehabilitation and maintenance and carrying capacity efforts to help direct R&D toward relevant user requirements. Issues related to threatened and endangered species of Army concern are reviewed by the Army Threatened and Endangered Species User Advisory Group.

4. ESTIMATED COST AND DURATION OF PROPOSED WORK

Notional SERDP projects have an annual investment ranging from $100,000 to $400,000 per year and have a duration ranging from 1 to 4 years. These ranges

are provided only as estimates around which reasonable proposals may be developed. Proposers may submit smaller proposals that only address one or more portions of the statement of need. Proposers with innovative approaches to the SON which entail high technical risk and/or have minimal supporting data may submit a proposal for a limited amount of funding (less than $100,000) for a single year to develop the data necessary to provide for risk reduction and/or a proof of concept. The government reserves the right to fund more than one proposal either to meet this requirement fully or to pursue more than one innovative approach.

5. POINT OF CONTACT

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Appendix B: SEMP Reports and Websites

Reports

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Balbach, Harold E., William D. Goran, Teresa Aden, David L. Price, M. Rose Kress, William F. DeBusk, Anthony J. Krzysik, Virginia H. Dale, Chuck Garten, Jr., and Beverly Collins, *Strategic Environmental Research and Development Program (SERDP) Ecosystem Management Project (SEMP) FY01 Annual Report,* ERDC SR-02-2, March 2002.

Bourne, Scott G. and Mark R. Graves, *Classification of Land-Cover Types for the Fort Benning Ecoregion Using Enhanced Thematic Mapper Data,* ERDC/EL TN-ECMI-01-01, Spetember 2001.

"Design Document for Long-Term Monitoring Program (Fort Benning, GA)," July 1999. Unpublished. Available from the SEMP Website.

Graves, Mark R. *Watershed Boundaries and Relationship Between Stream Order and Watershed Morphology at Fort Benning, Georgia,* ERDC/EL TR-01-23, September 2001.

Hahn, Charles D. *Ground Control Survey at Fort Benning Georgia,* ERDC/EL TN-ECMI-01-02, September 2001.

Hahn, Charles D., Mark R. Graves, and David L. Price. *S-Tracker Survey of Sites for Long-Term Erosion/Deposition Monitoring,* ERDC/EL TR-01-18, August 2001.

"Inventory of Fort Benning, GA Existing Data and Summary of On-Going National Monitoring Initiatives," April 1999. Unpublished. Available from the SEMP Website.

Kress, M. Rose. *Long-Term Monitoring Program, Fort Benning, GA; Ecosystem Characterization and Monitoring Initiative, Version 2.1,* ERDC/EL TR-01-15, August 2001.

Lozar, Robert C., Harold E. Balbach, William D. Goran, and Beverly Collins. *Proceedings of the "*Partners Along the Fall Line*: Sandhills Ecology and Ecosystem Management Workshop,"* ERDC/CERL SR-02-2, March 2002.

"Preliminary Variable Evaluation and Selection of Fort Benning, GA for a Long-Term Monitoring Program," April 1999. Unpublished. Available from the SEMP Website.

"Report of Research Workshop: 26-28 Jan 1999 (Vicksburg, MS)," April 1999. Unpublished. Available from the SEMP Website.

"Report of Land Managers and Trainers Workshop: 11-12 Jan 1999 (Fort Benning, GA)," February 1999. Unpublished. Available from the SEMP Website.

"US Army Infantry Center, Fort Benning, GA: Geospatial Data Package," Version 2.0, CD-ROM, Vicksburg, MS. Strategic Environmental Research and Development Program (SERDP) and the U.S. Army Corps of Engineers (USACE), December 1999.

"US Army Infantry Center, Fort Benning, GA: Digital Color Orthophotography," CD-ROM, Fort Benning, GA. Natural Resources Management Branch, December 1999.

Watts, J. W.R. Whitworth, A. Hill, G.I. Wakefield, T. Davo and L.J. O'Neil, "Vegetation Map Accuracy Assessment: Fort Benning, Georgia, August 1999.

"Web-based Data Repository for the Environmental Characterization and Monitoring Initiative (ECMI)," Huntsville, AL. JAYA Corporation, October 1999. Available from the SEMP Website.

"Work Plan: Ecosystem Characterization and Monitoring Initiative (ECMI)," (draft) December 1998. Unpublished. Available from the SEMP Website.

Websites

DENIX Homepage, http://www.denix.osd.mil/

SEMP Work Group DoD Website,
http://www.denix.osd.mil/denix.DOD/Working/SEMP/semp.html

SEMP Public Website, http://www.denix.osd.mil/SEMP

Strategic Environmental Research and Development Program (SERDP) Homepage, http://www.serdp.org/

Appendix C: Memorandum of Agreement

ARTICLE I. Purpose

To conduct research and development activities in support of the Strategic Environmental Research and Developmental Program's (SERDP) initiative called the SERDP Ecosystem Management Project (SEMP) on Fort Benning.

Background and General Information

The Strategic Environmental Research and Development Program is the corporate environmental R&D program for the Department of Defenses (DoD), planned and executed in full partnership with the Department of Energy (DOE) and the Environmental Protection Agency (EPA), with participation by numerous other federal and non-federal organizations. Within its broad areas of interest, the Program focuses on Cleanup, Compliance, Conservation, and Pollution Prevention technologies. Key objectives are to focus on high priority, mission related, defense requirements, to support technical excellence, to emphasize technology transfer and to practice sound fiscal management.

The DoD's environmental concerns may be viewed in terms of operational and/or cost impacts on the primary mission of maintaining military readiness for national defense. SERDP strives to provide research and development products which, when fielded, minimize, mitigate, or remove major negative environmental impacts on DoD's ability to conduct this mission. The current costs of environmental conservation challenges are significant. The development and fielding or applying of innovative technologies will enhance mission readiness and will reduce the costs, environmental risks and the time required to resolve environmental problems in these areas while simultaneously enhancing mission execution.

SERDP research projects should be characterized by 1) addressing emerging and predicted problems of a complex nature, 2) contributing to the solution of a major mission readiness problem, 3) supporting policy formulation and/or program-level decisions, and 4) catalyzing the initiation, organization, and/or acceleration of other essential research.

SERDP has launched an initiative called the SERDP Ecosystem Management Project (SEMP), to execute ecosystem science research in support of ecosystem management on DoD installations. The overall intent of SEMP is to develop the knowledge required to assess the interaction between military activities and ecological resources, monitor those interactions, and identify adaptive, ecosystem management approaches for management of military lands and waters. SEMP is managed for the SERDP Office by the Construction Engineering Research Laboratories (CERL). CERL has the lead responsibility, in the Army and, through service agreements, across the Department of Defense, to provide research and technology products to meet military lands conservation and stewardship requirements.

The SEMP project will support and adopt the guiding principles of the 1994 memorandum from the office of the Deputy Secretary of Defense for Environmental Security (DUSD[ES]/EQ-CO memo, "Implementation of Ecosystem Management in the DoD", 8 August 1994). These principles are:

1) Maintain and improve sustainability and native biodiversity of ecosystems.

2) Administer in accordance with ecological units and timeframes.

3) Support sustainable human activities.

4) Develop a vision of ecosystem health.

5) Develop priorities and reconcile conflicts.

6) Develop coordinated approaches to working toward ecosystem health.

7) Rely on the best science available.

8) Use benchmarks to monitor and evaluate.

9) Use adaptive management.

10) Implement through installation plans and programs.

ARTICLE II. Objectives

The objectives of this MOA are:

1) Plan for and conduct various research activities associated with better understanding of ecosystem dynamics and military mission interactions with these dynamics at Fort Benning.

2) Plan for and conduct a long-term ecological monitoring program at Fort Benning in support of these (A) ecological research activities and Fort Benning mission requirements.

3) Transition findings and results from these research and monitoring activities to interested research communities and resource managers and to facilitate the integration of research results into Fort Benning (and other installations) ecosystem management practices.

ARTICLE III. Authority

10 U.S.C. 2358; Economy Act of 1932, as amended (31 U.S.C. 1535).

ARTICLE IV. Work to be Performed

Research Coordination and Data Access

Natural Resources Data

To the extent possible, CERL and Fort Benning shall leverage their respective efforts by sharing CERL and Fort Benning natural resource data. The mechanism and format for data sharing shall be mutually agreed upon by CERL and Fort Benning. This agreement is limited to access to data available at the time of the request. Neither CERL nor Fort Benning may require the other party to collect, summarize, or analyze requested data unless mutually agreed upon, and funding or personnel resources are provided to accomplish these tasks.

Military Training

Successful accomplishment of the SEMP R&D will require close coordination with installation Director of Training (DOT) on Fort Benning. This R&D requires: (a) access to available data on the nature and extent of military training on Fort Benning, (b) access to range scheduling information, (c) measurement of military training levels at selected sites, and (d) direct observation of selected, mutually agreed upon training events. Fort Benning (DOT) has the final approval for all training-related access and information requests.

This agreement is limited to access to available data and normally scheduled training events. CERL shall not require Fort Benning to collect, summarize, or analyze requested data unless mutually agreed upon, and funding or personnel resources are available to accomplish these tasks.

There is no express or implied agreement under this MOA that Fort Benning will restrict, reschedule, or in any other way modify scheduled training and military operations due to SEMP R&D activities. Although CERL may request modification of selected training activities or schedules to meet both mission and R&D requirements, modification of training activities shall be at the sole discretion of the Fort Benning training and operations staff.

Release of Data

No shared or exchanged data under this MOA shall be released to any outside individuals or organizations by the receiving party without the written consent of both CERL and Fort Benning.

Work-plans

CERL shall submit written work plans to Fort Benning and complete a FB-144 record of consideration for proposed field research activities. Work-plans will include a vehicle recovery plan in the event vehicles are disabled in the field, coordination procedures for entry and clearance of training areas, and plans for radio or cell phone communication with the Fort Benning Natural Resources Office. Prior to initiation of field research, Fort Benning and CERL shall mutually agree upon logistical coordination requirements, training range access, and timing of site visits.

Statement of Work

If Fort Benning or TRADOC is providing funds for specific work plans, each work-plan will contain a statement of work (SOW), detailing the work items to be accomplished by each participant and the schedule for completion. The SOW will provide an estimate of cost for performing the task, including a breakdown for labor, overhead, travel, administrative charges, and other costs; require written progress reports on a quarterly basis, if not more often; delineate which party is to be responsible for rights to data, government-furnished equipment, software and intellectual property rights, and contract audits; identify the types of contracts to be used (if known); contain the Funding Agency's appropriation information and the date upon which the cited funds expire for obligation purposes; and contain such other particulars as are necessary to describe clearly the obligations of the parties with respect to the requested goods and services. A separate funding document should be attached to the work plan containing the SOW.

Installation Access

As part of the work plan (paragraph VI.B.), CERL shall indicate installation access requirements-for-proposed field studies, including a CERL Point of Contact and length of time. Fort Benning shall approve these requests contingent upon compatibility with military training requirements and safety considerations. Fort Benning shall coordinate range access requests through the appropriate channels.

Equipment and Vehicle Requirements

CERL shall be responsible for acquisition and maintenance of all equipment and vehicles necessary to accomplish SEMP research under this MOA. All equipment purchased to accomplish work under this MOA shall remain the property of the purchasing agency. Any sale, transfer, or exchange of equipment or property from one party to another shall be made in accordance with applicable law and regulation in effect at the of time of the sale, transfer, or exchange.

Safety

CERL and/or its contractors shall have sole responsibility and liability for safe conduct of all field activities conducted under this MOA. CERL and its contractors shall operate in accordance with all Fort Benning and TRADOC safety regulations. Fort Benning will provide, and all appropriate/involved contractor

personnel will attend, appropriate safety briefings prior to conducting any field activity on Fort Benning.

Interagency Coordination

The parties shall coordinate with each other prior to any coordination with other agencies concerning activities conducted pursuant to this MOA.

Points of Contact

The parties shall designate appropriate points of contact at the Division or Branch level to accomplish requirements for this MOA or individual work plans.

ARTICLE V. Primary Roles

Responsibilities of CERL

1) To provide Fort Benning SEMP POC with a copy of any research solicitations and/or proposals involving Fort Benning for review and comments.

2) To provide a SEMP POC (Both at the Lab and on site when appropriate) to Fort Benning, to act as liaison, problem solver, coordinator, etc.

3) To acquire and/or facilitate the acquisition of maintaining equipment to better define be used at Fort Benning in support of SEMP activities, and to manage this equipment.

4) To inform TRADOC and Fort Benning POC of any proposed or planned research and/or review activities to be conducted at host installation.

Both Fort Benning and CERL shall maintain SEMP POC's. Any change in these POCs (person duty, access information) shall be provided to the other party in writing at the earliest convenience.

Responsibilities of Fort Benning

1) Review of current or proposed research plans to be conducted at Fort Benning.

2) Access to lands for researchers within defined training schedules and priorities.

3) Sharing relevant GIS data layers and monitoring data.

4) Assignment of a SEMP POC (Primary and alternate POC).

5) POC will circulate proposed research plan as deemed appropriate to Fort Benning management staff.

6) Fort Benning's primary role is to provide access for required research activities, to facilitate related coordination, and to help define SEMP-related problems at the field level.

TRADOC

TRADOC's primary role is to review progress of SEMP research and provide oversight for coordination between CERL and Fort Benning, and to assist in technology transfer of results to other TRADOC installations, as appropriate.

ARTICLE VI. Funding

There is no financial obligation from Fort Benning or TRADOC to provide funding for any of the specific activities under the SEMP program. During the course of this MOA they may select to undergo research activities to meet specific requirements.

CERL, as the manager of SEMP, will provide funding for the research teams acting in direct support of the SEMP program at Fort Benning. This will include funding for the CERL POC, the research teams conducting specific activities, and for monitoring assessments and selected monitoring equipment. CERL will not be providing funding to Fort Benning for costs associated with their host installation responsibilities, such as POC functions, proposed review and review of SEMP plans, proposals and other activities.

CERL will provide a "SEMP Coordinator" at Fort Benning to coordinate activities. The SEMP Coordinator will be housed in facilities at Fort Benning and will need office space (work surface and telephone access) and a parking space. CERL (and/or sister labs) will employ the individual serving as the SEMP Coordinator. Fort Benning will not be expected to contribute towards personnel

expenses, however, it will provide office space, occasional administrative support.

If funding is to be provided by either Fort Benning or TRADOC for specific research activities the following applies:

- Subject to the availability of funds and in compliance with the Anti-Deficiency Act, funds will be provided for the work described and performed in accordance with each work-plan issued under this agreement. If the actual cost to perform the work under the work-plan is forecast to exceed the amount of funds available, the Performing Agency shall promptly notify the Funding Agency of the amount of additional funding necessary to pay for the assistance. The Funding Agency shall either provide the additional funds to the performing agency within fifteen-(15) calendar days thereafter, or limit the scope of the work to be performed, or direct termination of the WO. Should the Funding Agency not exercise any of the above options, the Performing Agency may immediately terminate work under the work plan. No work will be performed until funds are received at the performing agency.
- Final Accounting. Within 90 days of completing the work under a work plan (WP), the Performing Agency shall conduct an accounting to determine the actual costs of the work. Within 30 days of completion of this accounting, the Performing Agency shall return to the Funding Agency any funds advanced in excess of the actual costs as then known. Such an accounting shall in no way limit the Funding Agency's duty in accordance with this MOA to pay for any costs, such as contract claims or other liability, which may become known after the final accounting.

ARTICLE VII. Billing

If Fort Benning directly funds work efforts related to this agreement, costs incurred to perform each work-plan will be billed on a monthly basis or as costs are incurred to the Funding Agency. Billing will be submitted on an SF 1080, Voucher for Transfers between Appropriations and/or Funds, and the Funding Agency shall reimburse the Performing Agency within 30 days after receiving the SF 1080.

ARTICLE VIII. Contracting Out Work

1) Accordance with FAR. For the SERDP funded research efforts, CERL will identify tasks under a statement of need, which will be awarded under a

contract/s. All contracting activities shall be conducted in accordance with all applicable federal acquisition regulations.

2) Intellectual Property and Data Rights. All contracts executed pursuant to this MOA shall contain data rights and intellectual property clauses sufficient to protect the Government's interest.

3) Advance Notice. Prior to initiating any contract action, CERL shall consult with Fort Benning and TRADOC regarding the scope and requirements of the proposed contract action. CERL shall provide draft SOW at the request of the other parties. Fort Benning shall provide comments regarding the logistical requirements, access availability, and predicted impact on the training mission or other installation activities of the proposed SOW. Based on this review, the parties shall mutually agree on appropriate modifications to the proposed SOW.

ARTICLE IX. Licenses

The Installation Commander will grant an non-exclusive use of real estate License to Other Non-Department of Defense agencies to conduct environmental studies on Fort Benning IAW AR 405-80, Management of Title and Granting Use of Real Estate Property. An Installation License must be executed before an Activity/Organization can perform the studies. The request for the license will be initiated 120 days out in order to process the Report of Availability and the Request of Environmental Consideration (FB Form 144-R).

ARTICLE X. Reports

CERL will conduct an In Progress Review (IPR) with the SERDP office on an annual basis of all activities in the SEMP program. CERL will contact the Fort Benning POC when preparing this report, and will provide a completed copy of the report to the Fort Benning POC. CERL may hold an IPR at Fort Benning, CERL or other appropriate location prior to the report as deemed appropriate in consultation with Fort Benning.

ARTICLE XI. Publications and Technical Reports

1) Authorship. Publications and technical reports may be joint or independent as agreed upon, always giving due credit to the cooperative effort of the parties. In the case of multiple authorship of publications or reports, authorship and publication costs will be jointly agreed upon.

2) Review. All draft manuscripts for publication shall be submitted to the parties for review at least 90 days prior to submission for publication. In the case of failure to agree on the manner of publication or interpretation of results, manuscripts may be submitted for publication 90 days after submission to the other parties. In such cases, the party publishing the results will give appropriate credit to contributions of the other parties, but assume full responsibility for any statements on which there are differences of opinion.

3) Reports to Sponsors. CERL shall provide copies (electronically, as well as hard copies whenever possible) of all reports to Fort Benning and TRADOC and other sponsors.

ARTICLE XII. Equipment

If equipment is acquired under this agreement, it will be accounted for and maintained in accordance with the applicable law and regulations of the agency funding the acquisition. Title to property acquired under a work-plan shall be retained by the agency funding the acquisition, unless otherwise stated in the work-plan. Equipment directly provided under this MOA by either party, regardless of who uses the equipment in the performance of the work, shall remain the property of the providing party unless other disposition is mutually agreed upon in writing by the parties.

ARTICLE XIII. Dissemination of Information

Public Information. Prior to releasing information to the public through the Freedom of Information Act, 5 U.S.C. 552, or otherwise, regarding work undertaken pursuant to this MOA, the parties shall coordinate and consult with each other.

ARTICLE XIV. Applicable Laws and Regulations

This MOA, and any work performed hereunder, is subject to the laws of the United States, and the delegated authority assigned to each party. Nothing in this MOA shall be construed as obligating either agency to the expenditure of funds or for future payment of money in excess of appropriates authorized by law. Nothing herein shall limit in any way the authority or legal responsibilities of the parties. Nothing in this MOA will bind either party to perform beyond their respective authority, nor does this MOA alter the legal rights and remedies, which the parties would otherwise have.

ARTICLE XV. Dispute Resolution

1) Resolution. Should a dispute arise between the parties under this MOA, the parties shall seek in good faith to resolve the dispute through negotiation, mediation, or other forms of non-binding dispute resolution, mutually acceptable to the parties. A joint decision of the signatories to this agreement, or their designees, shall be the disposition of the dispute. In the event that a joint resolution cannot be reached, the dispute will be referred within 30 days to a mutually agreeable authority for resolution.

2) Continuation of Work. Pending the resolution of any dispute, the parties agree that performance of all obligations shall be pursued diligently as agreed by the parties.

ARTICLE XVI. Miscellaneous

1) Other Relationships or Obligations. This MOA shall not affect any pre-existing or independent relationships or obligations among the parties.

2) Survival. The provisions of Articles X, XII, XIV, and XVII of this MOA, shall remain in force notwithstanding the expiration or termination of this MOA.

3) Severability. If any provision of this MOA is determined to be invalid or unenforceable, the remaining provisions shall remain in force and unaffected to the fullest extent permitted by law and regulation.

ARTICLE XVII. Amendment

Amendments to this MOA are subject to the mutual agreement of the parties and must be signed by CERL, Fort Benning and TRADOC signatories to this MOA, or their respective representatives.

ARTICLE XVIII. Termination

1) Termination by Mutual Consent. The parties may terminate this MOA, or portions thereof, at any time by mutual consent and such notice of termination will be signed by all parties.

2) Termination by Unilateral Action. Any party may terminate this MOA by giving written notice of termination to the other party not less than 180 days in advance of the effective date of termination. Any on-going contracted action which has been awarded and initially agreed to by both CERL and Fort Benning, shall be allowed to continue for the contract's period of performance, regardless of the 180 day notification period. Typically, period of performance for contract actions will be no more than one (1) year in duration.

3) Emergency Termination. Notwithstanding any other provisions of this MOA, the installation Garrison Commander may, upon finding that activities under this MOA compromise accomplishment of the mission immediately terminate this MOA and activities thereunder.

ARTICLE XIX. Period of Performance

This MOA shall become effective from the date of the last signature and shall continue in force for a period of 10 years or until terminated under paragraph XVIII above.

ARTICLE XX. Approvals

This MOA is executed by:

_____	_____
JOHN M. MITCHELL Colonel Garrison Commander Fort Benning	DATE
_____	_____
PETER F. SUN COL, GS Assistant Deputy Chief of Staff for Base Operations Support TRADOC	DATE
_____	_____
MICHAEL J. O'CONNOR Director CERL P.O. Box 9005 Champaign, IL 61826-9005	DATE

Appendix D: Fort Benning, GA Data Inventory

ABIOTIC	Available Data	Data Access	Source Date	Type	Extent	Length of Record	Frequency/ Update
Topo							
Elevation	1:24,000 Contours	In House	1998	3	Base		
	1:24,000 Benchmarks	In House	1998	3	Base		
	DEM (1:24,000 Digital Elevation Model)	In House	1998	3	Base		
Slope	1:24,000 DEM of Slope	In House	1998	3	Base		
Aspect	1:24,000 DEM of Aspect	In House	1998	3	Base		
Hydro							
Surface Drainage	1:100,000 USGS Lakes	Online	*1993	3	Base		
	1:100,000 USGS Streams	Online	*1993	3	Base		
	1:24,000 Streams (1:24,000 USGS Quads)	In House	Varies	3	Base		
Watersheds	1:24,000 Stream Watersheds	In House	1998	3	Base		
Ground Water	USGS Groundwater Site Inventory (Active and Historical Base Wells)	In House	1953-1999	2	Regional	1953-until	Daily (broken)
Surface Water	USGS Streamflow Stations (Active and Historical Base Monitoring Stations)	In House	1969-1997	2	Base	1969-until	Daily (broken)
Water Quality	USGS National Water Quality Assessment	In House	Varies	2/3	Regional		As Needed
Climo							
Weather	National Weather Stations – Columbus Airport – (2 stations)	In House	1948-	2	Regional	Since 1948	Continuous
	Regional NEXRAD Weather Stations	Online	Varies	2	Regional		Continuous
	Lawson Airfield Weather Station (limited)	In House	1965-	2	Base	Since 1965	Continuous

	Available Data	Data Access	Source Date	Type	Extent	Length of Record	Frequency/ Update
Pedo							
Soils	USDA County Soil Surveys	In House	1995	3	Base		
Erosion	Soil Erosion Inventory in RCW active foraging areas	In House	9/97	1	Excl. Impact		
Geo							
Surface Geology	USGS (Americus) 1:100,000 Geol. Of Fort Benning Quaternary	In House	1995	3	Base		
	USGS (Americus) 1:100,000 Geol. Of Fort Benning Tertiary	In House	1995	3	Base		
	Geology of Fort Benning	In House	1995	3	Base		
BIOTIC							
Flora							
Vegetation	Floristic Survey of Fort Benning	In House	6/97	2/3/4	Base		
	Vegetation Map (via aerial photography)	In House	1996	3	Base		
	Land Continuous Trend Analysis (LCTA)	In House		2	200 Base Plots	5 Years	3-5 Yrs.
	Hay Areas (areas planted w/grass seasonally)	In House	1996	3	Base		
Forest	Forest Stands	In House		3	Base		
	Forest Compartments	In House	1993	3	Base		
	Forest Inventory Stand Characteristics	In House	1997	2/4	Base		
	Long-leaf Pine Seedlings Survival Survey			1	Base		Annual
	Long-leaf Pine Cone Checks			1	Base		Annual
Wetlands	NWI Wetlands	In House		3	Base		
	Wetlands Inventory	In House	1995	3	Base		
Other	Relict Trillium Monitoring Sites			1/ 2	Base (5 sites)	5 Years	Annual
	Kudzu Locations and treatment records	In House	1997	2/3	Base		As Needed
	Sweet Pitcher restoration and management	In House	1993-	2/4	Base	Since 1993	Annual

	Available Data	Data Access	Source Date	Type	Extent	Length of Record	Frequency/ Update
Fauna							
	Alligator Survey	In House		1	Riverbend/Pond	5 Years	Annual
	Southern Pine Beetle (trapping/inventory/spots) Survey	In House		1	Base	5 Years	Annual
	Feral Swine (Informal Survey)	In House		1	Base		Annual
	Deer check harvest data	In House		1	Base	20 Years	Annual
	Deer tracks counts	In House		1	Dirt Roads	10 Years	Annual
	Quail/Turkey Survey	In House		1	Base		Annual
	Gopher Tortoises – Effects of tracked vehicles	In House	1995	4	Base		
	Bird Communities – Resp. to Dormant vs Growning Season Presc. Burns	In House	1997	4	Base		
	Small Mammal Communities – Following Growing and Dormant Season	In House	1997	4	Base		
	Amphibian Response to season burns	In House	1997	4	Base		
	LCTA – Small Mammal Monitoring	In House		2	Base Plots	5 Years	3-5 Yrs.
	LCTA – Song Bird Monitoring	In House		2	Base Plots	5 Years	3-5 Yrs.
	LCTA – Special LRAM Plots	In House		2	LRAM Base Plots	3 Years	Annual
	LCTA – Program Summary Report 1991-1995	In House	1991-1995	4	Base	5 Years	5 Yrs.
	LCTA – Wildlife Summary Report 1991-1995	In House	1991-1995	4	Base	5 Years	5 Yrs.
	Red-Cockaded Woodpecker (RCW) Surveys	In House		2/3		5 Years	Annual
	RCW Cluster Management	In House		2	Base	Since 1994	Annual
	RCW Dead Tree Locations	In House		2	Base	Since 1994	Annual
	RCW Cluster Activity	In House		2	Base	Since 1994	Annual
	RCW Breeding	In House		2	Base	Since 1994	Annual
	RCW Next and Cavity Evaluation	In House		2	Base	Since 1994	Annual
	RCW Banding Data	In House		2	Base	Since 1994	Annual

	Available Data	Data Access	Source Date	Type	Extent	Length of Record	Frequency/ Update
	RCW Cluster Centers (point)	In House	1997	3	Base		As Needed
	RCW Recruitment Sites	In House	1997	3	Base		As Needed
	RCW Clusters	In House	1997	3	Base		As Needed
	RCW – Effects of Military Training	In House	1996	4	Base		
	RCW – Cavity Augmentation	In House	1996	4	Base		
	RCW – Population Trends	In House	1996	4	Base		
	RCW – Survey for Distribution/Status of Cavity Trees	In House	1994	3/ 4	Base		
	RCW – Effect of Growing Season Burns	In House	1994	4	Base		
	RCW – Attraction of Arthropods to RCW Cavity Trees	In House	1993	4	Base	1 Year	
	Midwinter Eagle Survey	In House		1	Base	5 Years	Annual
	FWS Threatened & Endangered Botanical Survey	In House		4	Base		TBC 7/99
	FWS Gopher Frog Monitoring <20>	In House		4	Base		TBC 7/99
	FWS Rare Species Survey <21>	In House		4	Base		TBC 10/98
	FWS Aquatic Species Survey <22>	In House		4	Base		TBC 10/98
Ecological Regions	Bailey's Ecological Regions	In House	1994	3	Regional		
Ecological Units	USFS Ecological Units of the Eastern United States	In House	1995	3	Regional		
Landcover	GA Department of Natural Resources 1:24,000 Landuse/Landcover	In House	1988-1990	3	Regional		As Needed
MLRA	NRCS Major Land Resource Areas			3	Base		As Needed

	Available Data	Data Access	Source Date	Type	Extent	Length of Record	Frequency/ Update
MANAGEMENT							
Fires							
Wildfires	Record of Wildfires	In House	1987-now	2	Base	Since 1987	Continuous
Prescribed Burns	Forest Compartments Burned	In House	1994-1997	2/3	Base	Since 1994	Continuous
	Prescribed Burning Units	In House	1996	3	Base	1 Year	
	Prescribed Burn Areas	In House	1994-1997	3	Base	Since 1994	As Needed
	Prescribed Burn Areas	In House	1987-now	2	Base	Since 1987	Continuous
Timber	Reforested Areas	In House	1997	3	Base	Since 1980	Annual
	Southern Pine Beetle Ind. Infestation Reports	In House	1986-now	1	Base	Since 1986	Annual
	Southern Pine Beetle Control Operation Summaries	In House	1986-now	2	Base	Since 1986	Annual
Training							
Use Zones	Drop Zones/Landing Zones	In House	1993	3	Base		As Needed
	Exclusion Zones	In House	1993	3	Base		As Needed
	Training Zones	In House	1993	3	Base		As Needed
	Cantonment Zones	In House	1993	3	Base		As Needed
	Surface Danger Zones	In House	1993	3	Base		As Needed
	Permanent Training Sites	In House	1993	3	Base		As Needed
	Lawson Airfield Airspace	In House	1996	3	Base		As Needed
Infrastructure							
Transportation	Roads	In House	1996	3	Base		As Needed
	Railroads	In House	1993	3	Base		As Needed
	Forest Trails	In House	1995	3	Base		As Needed
Utility Location	Utility Locations (County Scale – GA Only)	Online		3	Base		As Needed

	Available Data	Data Access	Source Date	Type	Extent	Length of Record	Frequency/ Update
Aerial Photography	Dates of Aerial Photos Range from 1949-1996 (Periodic)	In House	1949-1996		Base		
	USGS Digital Ortho Quarter Quads (DOQQ)	In House	1990's		Base		
Satellite Images							
SPOT	1990 Spot Image	In House	1990	3	Regional	1 Year	
Landsat	1992 LANDSAT Image	In House	1992	3	Regional	1 Year	

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14. ABSTRACT

The Strategic Environmental Research and Development Program (SERDP) initiated an ecosystem research and monitoring program relevant to Department of Defense (DoD) ecosystem management concerns. The program, which started in Fiscal Year 1998, is titled the SERDP Ecosystem Management Project (SEMP). This report describes the purpose and approach for this project, and the ways in which research and monitoring results will be linked to DoD installation ecosystem management practices.

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