ERDC SR-01-3

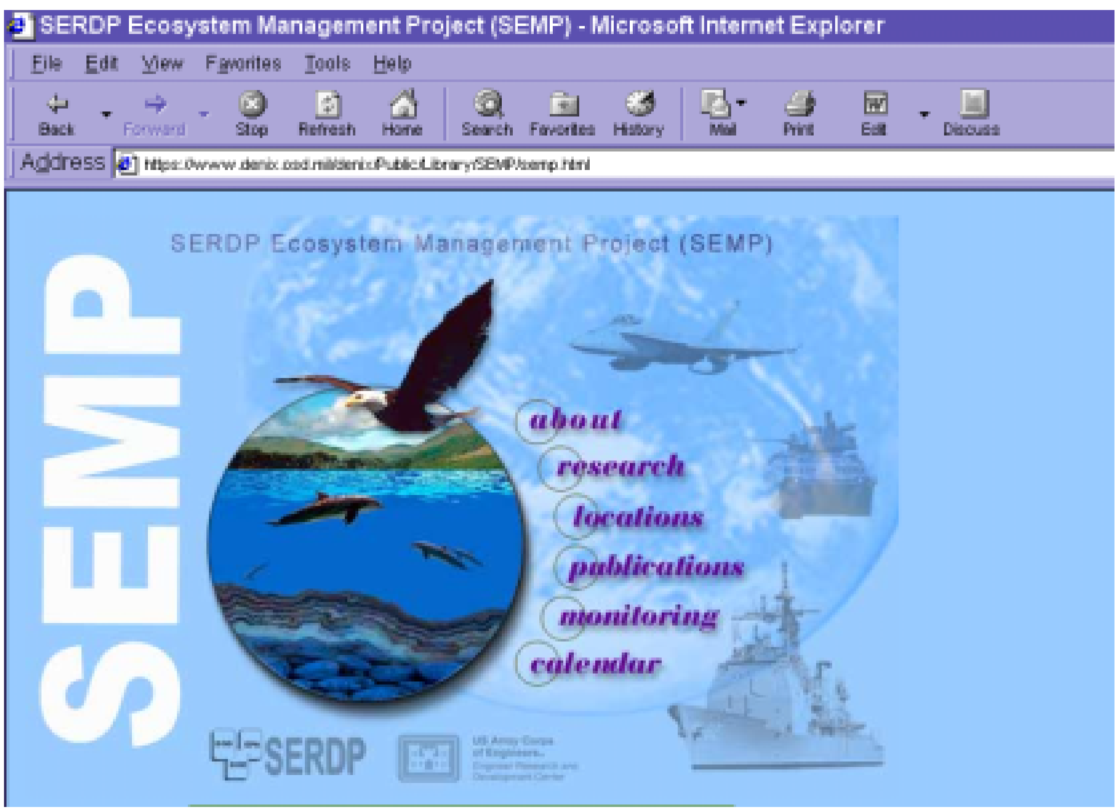
Engineer Research and Development Center

US Army Corps of Engineers

Strategic Environmental Research and Development Program (SERDP) Ecosystem Management Project (SEMP) FY00 Annual Report

Harold E. Balbach, William D. Goran, Teresa Aden, David L. Price, M. Rose Kress, William F. DeBusk, Anthony J. Krzysik, Virginia H. Dale, Chuck Garten, and Beverly Collins

September 2001



REPORT DOCUMENTATION PAGE

Form Approved OMB No. 0704-0188

1. REPORT DATE (DD-MM-YYYY)	2. REPORT TYPE	3. DATES COVERED (FROM - TO)
01-09-2001	Final	xx-xx-2000 to xx-xx-2001

4. TITLE AND SUBTITLE
Strategic Environmetal Research and Development Program (SERDP) Ecosystem Management Project (SEMP) FY00 Annual Report
Unclassified

5a. CONTRACT NUMBER
5b. GRANT NUMBER
5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
Lin, Mike C.J. ;
Taha, Yezin E. ;

5d. PROJECT NUMBER
5e. TASK NUMBER
5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME AND ADDRESS
U.S. Army Engineer Research and Development Center
Construction Engineering Research Laboratory
PO Box 9005
Champaign, IL61826-9005

8. PERFORMING ORGANIZATION REPORT NUMBER
ERDC SR-01-3

9. SPONSORING/MONITORING AGENCY NAME AND ADDRESS
,

10. SPONSOR/MONITOR'S ACRONYM(S)
11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
APUBLIC RELEASE
,

13. SUPPLEMENTARY NOTES

14. ABSTRACT
This report is an annual summary of the research activities and findings and the accomplishments for SEMP.

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19. NAME OF RESPONSIBLE PERSON
			Same as Report (SAR)	84	Balbach, Harold E. Hal.E.Balbach@erdc.usace.army.mil
a. REPORT	b. ABSTRACT	c. THIS PAGE			19b. TELEPHONE NUMBER
Unclassified	Unclassified	Unclassified			International Area Code Area Code Telephone Number DSN

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39.18

Foreword

This study was conducted for the Strategic Environmental Research and Development Program (SERDP) Office under SERDP Work Unit CS-1114, "SERDP Ecosystem Management Project." The technical monitor was Dr. Robert Holst, Program Manager.

The work was performed under the direction of the Ecological Processes Branch (CN-N) of the Installations Division (CN), Construction Engineering Research Laboratory (CERL). The CERL Principal Investigator was Dr. Harold E. Balbach. William D. Goran and Teresa Aden are from CERL. David Price and Rose Kress are from the Environmental Lab, Engineer Research and Development Center. Dr. William F. DeBusk is from the University of Florida, Gainsville. Dr. Anthony J. Krzysik is from Embry-Riddle Aeronautical University. Dr. Virginia H. Dale and Chuck Garten, are from Oak Ridge National Laboratory, and Dr. Beverly Collins is from the Savannah River Ecology Laboratory. The technical editor was Gloria J. Wienke, Information Technology Laboratory. Stephen E. Hodapp is Chief, CEERD-CN-N, and Dr. John T. Bandy is Chief, CEERD-CN. The associated Technical Director was Dr. William D. Severinghaus, CEERD-CV-T. The Acting Director of CERL is Dr. Alan W. Moore.

CERL is an element of the U.S. Army Engineer Research and Development Center (ERDC), U.S. Army Corps of Engineers. The Commander and Executive Director of ERDC is COL John Morris III, EN and the Director of ERDC is Dr. James R. Houston.

Contents

List of Figures and Tables

Figures

Tables

1 Introduction

Background

The U.S. Department of Defense (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.

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, the ecological relationship of military lands to their surrounding lands, and the interactions between mission activities and ecological processes. In response to these expressed needs, the Strategic Environmental Research and Development Program (SERDP) sponsored a workshop, in June 1997, entitled *The Management-Scale Ecosystem Research Workshop*. Workshop participants 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, the SERDP Ecosystem Management Project (SEMP) was created as a new SERDP project to pursue ecosystem research relevant to DoD ecosystem management concerns (including the research themes from the 1997 SERDP Workshop).

Objective

The overall program objective for SEMP is to plan, coordinate, execute, and manage, on behalf of the 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 Research 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.

Approach

The approach was to issue Statements of Need (SONs) and fund independent research projects responding to the themes from the workshop. At this time, five projects have been funded. Their individual approaches are discussed in Chapter 3.

Mode of Technology Transfer

The transfer of the information gained will be through the development of adaptive environmental management relationships. Each of these relationships will integrate the background information, knowledge of ecosystem processes, and installation ecosystem management objectives in such a manner that installation environmental managers may implement management changes to meet the installation goals.

This report will be made accessible through the World Wide Web (WWW) at URL:

http://www.cecer.army.mil

Units of Weight and Measure

U.S. standard units of measure are used throughout this report. A table of conversion factors for Standard International (SI) units is provided below.

SI conversion factors		
1 in.	=	2.54 cm
1 ft	=	0.305 m
1 yd	=	0.9144 m
1 sq in.	=	6.452 cm^2
1 sq ft	=	0.093 m^2
1 sq yd	=	0.836 m^2
1 cu in.	=	16.39 cm^3
1 cu ft	=	0.028 m^3
1 cu yd	=	0.764 m^3
1 acre	=	0.4047 ha
1 gal	=	3.78 L
1 lb	=	0.453 kg
1 mile	=	1.6 km
°F	=	(°C x 1.8) + 32

2 SEMP Organization and Activities

SEMP is organized with a Program Manager, a Technical Advisory Committee (TAC), an Environmental Characterization and Monitoring Initiative Team (ECMI), Host Site(s) Points of Contact, and Research Teams. The Program Manager works with the TAC and the SERDP Program Office to develop Statements of Need (SONs) 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. Individual members of the research teams are listed in Chapter 3 (Research Projects).

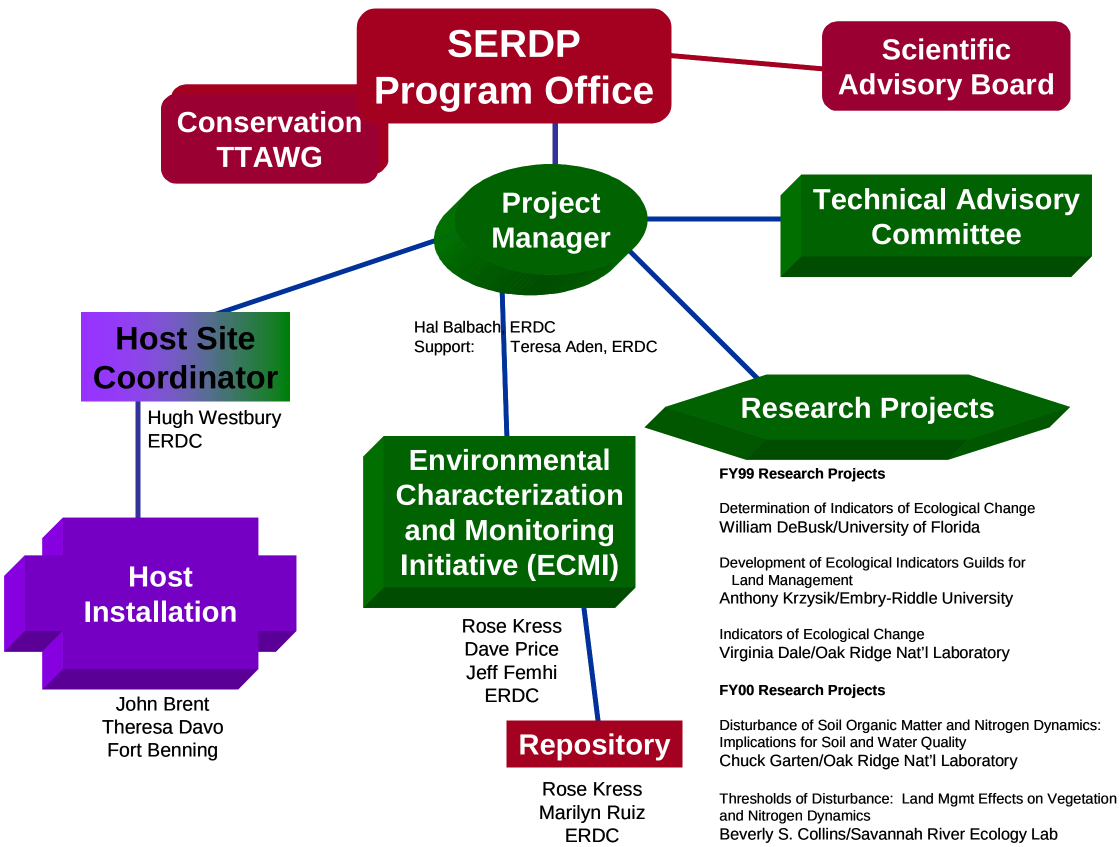


Figure 1. SEMP Organization Chart.

The 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 flows into the common data repository, shared by all teams and the installation managers.

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

The Technical Advisory Committee (TAC) for SEMP was established with input from the SERDP Program Office, the SERDP Conservation Technology Thrust Area Working Group (TTAWG), the SEMP Working Group, and the defense services. The purpose of this group is to provide technical review and oversight of SEMP activities and plans, linkages to related research activities and findings, continuity across the diverse research efforts, and assistance in transfer of SEMP findings and outcomes to the scientific and defense land management communities.

Current Membership

Current participants include (involvement with other SERDP-related committees are noted in parentheses):

- Dr. Mary Barber (SERDP Scientific Advisory Board [SAB]), Ecological Society of America
- Mr. Peter Boice (Conservation TTAWG), Director of Conservation Programs, Deputy Undersecretary for Defense, Environmental Security
- Dr. Neil Burns, Environmental Protection Agency, Region 4
- Mr. George Carellus, Army Environmental Center, Southern Regional Environmental Office

- Dr. Roger Dahlman (Conservation TTAWG), Program Manager, U.S. Department of Energy
- Dr. Mark Fenn, U.S. Department of Agriculture, Forest Service
- Dr. Penny Firth, National Science Foundation
- Dr. J. Whitfield Gibbons, Savannah River Ecology Laboratory and University of Georgia
- Dr. John Hall, The Nature Conservancy
- Mr. Richard McWhite, Natural Resources Chief, Eglin Air Force Base, FL
- Dr. Doug Ripley (Conservation TTAWG), Headquarters, Air Force National Guard
- Dr. James Spotila, Drexel University
- Ex Officio Members from SERDP, ERDC, and Fort Benning

Information Access

SEMP information is being provided through the SEMP website (https://www.denix.osd.mil/denix/Public/Library/SEMP/semp.html). All documents, briefings, and meeting minutes are being posted at this site, located under the Defense Environmental Network Information eXchange (DENIX). This website is open to all interested parties. Figure 2 shows the SEMP public website.

There is also a password-protected DoD site that can be accessed through DENIX, by selecting the DoD menu, under the main menu, then selecting Work Groups, then selecting SERDP Ecosystem Management Program (SEMP). The title of the webpage is “SEMP Working Group.” A password for DENIX can be obtained through on-line registration, by selecting “Registration” on the DENIX main menu (https://www.denix.osd.mil/SEMP/), or by contacting Cal Corbin, commercial 217-373-6731, FAX 217-373-7222. There are a variety of listserve and discussion forums available through the SEMP public and working group websites. There is also an events calendar.

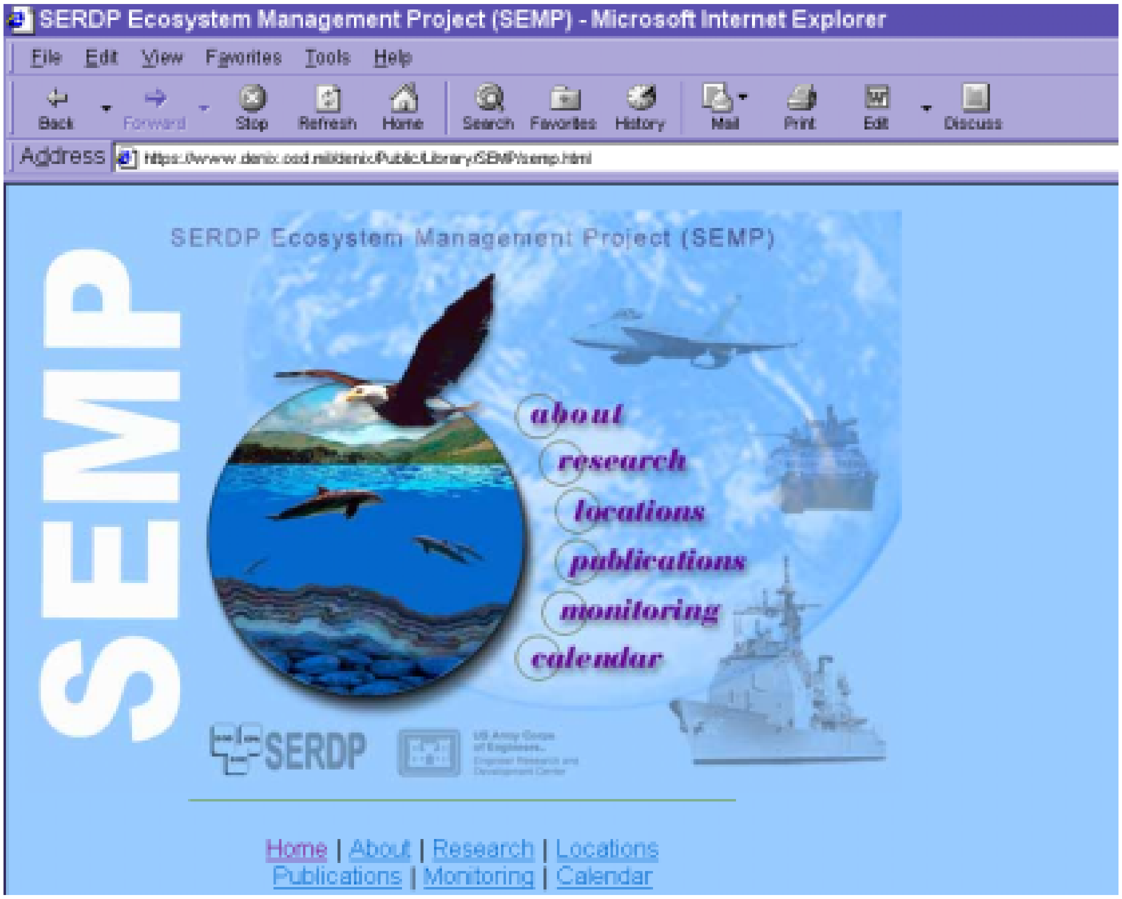


Figure 2. SEMP public website homepage.

3 Research Projects

Indicator Projects

The objective of the Fiscal Year 1999 (FY99) Statement of Need (SON) entitled “Determination of Indicators of Ecological Change,” is to identify indicators that signal ecological change in intensively and/or lightly used ecological systems on military installations. Three research projects were selected to support this SON (Table 1).

Table 1. Research projects supporting the SON for indicator projects.

Title	SERDP Number	Lead Principal Investigator	Lead Organization
Determination of Indicators of Ecological Change	CS-1114A-99	Dr. W. F. DeBusk	University of Florida
Development of Ecological Indicators for Land Management	CS-1114B-99	Dr. Anthony J. Krzysik	Embry-Riddle Aeronautical University
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 are working on are listed in Table 2.

Table 2. Research team members for “Determination of Indicators of Ecological Change.”

Name	Task/Topic	Institution
K. R. Reddy	Soil Biogeochemistry	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 reflect trends or signal impending change in ecosystem status. In many cases, these indicators may be the same. Both types 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, may be especially valuable.

Objectives

The research and monitoring plan will address the following objectives:

- Identify physical, chemical, and biological variables (properties and processes) associated with soil, surface hydrology, and vegetation that may be used as indicators of ecological change.
- Evaluate potential ecological indicators based on sensitivity, selectivity, ease of measurement, and cost effectiveness.
- Select indicators that most effectively (1) show a high correlation with a certain state in a specific ecosystem, (2) provide early warning of impending change, and (3) differentiate between natural ecological variation and anthropogenic negative impacts.
- Determine the likely range of natural variation for indicator variables and compare with the range of values under anthropogenic, especially mission-related influences.

Approach

Researchers for this project are employing a multidisciplinary and multiscale approach, which will result in robust techniques for ecosystem monitoring and evaluation. They are evaluating a suite of parameters related to properties and processes in the soil, understory vegetation, and surface/subsurface hydrology as potentially sensitive indicators of ecosystem integrity and ecological response to natural and anthropogenic factors. 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 variability, 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.

Progress to Date

Phase I results and summary

The Phase I objectives were to: (1) characterize the distributions (range, central tendency) of indicator variables at a regional scale, (2) determine the response of variables to impacts related to military training and other land uses and management practices, and (3) narrow the list of indicators (Table 3) based on sensitivity to ecological variability.

Phase I sampling and monitoring was conducted within 6 watersheds (of the 3rd or 4th order) at Fort Benning, GA, that had been proposed and/or selected as ECMI long-term monitoring units (Figure 3). These watersheds, associated with Sally Branch and Bonham, Halloca, Randall, Wolf, and Shell Creeks, represent a wide range of military and nonmilitary land uses and anthropogenic disturbance regimes (type and intensity of disturbance).

Table 3. Proposed soil biogeochemical indicators and their potential ecological significance.

Category/Indicator	Ecological Role	Controls	Ecosystem Impacts
Geochemical indicators – uplands and wetlands			
Soil organic matter (OM) **Total C, N and P**	OM storage/turnover Ecosystem stability	Soil type Soil moisture Vegetation Hydrology Geomorphology	Productivity Species composition Water quality Hydrology
Mineralizable N **Extractable inorganic N & P** **HCl extractable Ca, Mg, Fe and Al** **pH**	Nutrient bioavailability Nutrient mobility		
Microbial indicators – uplands and wetlands			
Nitrifying bacteria (rRNA) **Enzyme activities** **Microbial biomass C, N & P** **Microbial respiration** **Organic N mineralization**	OM storage/turnover Nutrient bioavailability Nutrient storage/mobility	Vegetation Soil type Soil moisture Temperature	
Geochemical indicators – wetlands and stream sediment			
Dissolved organic C, N, P **Oxalate extractable Fe, Al** **Soil/sediment oxygen demand** **Phosphate sorption coefficient**	Nutrient bioavailability Nutrient mobility	Hydroperiod Vegetation Geomorphology	Eutrophication Water quality Species composition
Microbial indicators – wetlands and stream sediment			
Denitrification **Sulfate reduction** **Methanogenesis**	OM storage/turnover Nutrient bioavailability	Hydroperiod Geochemistry Temperature	

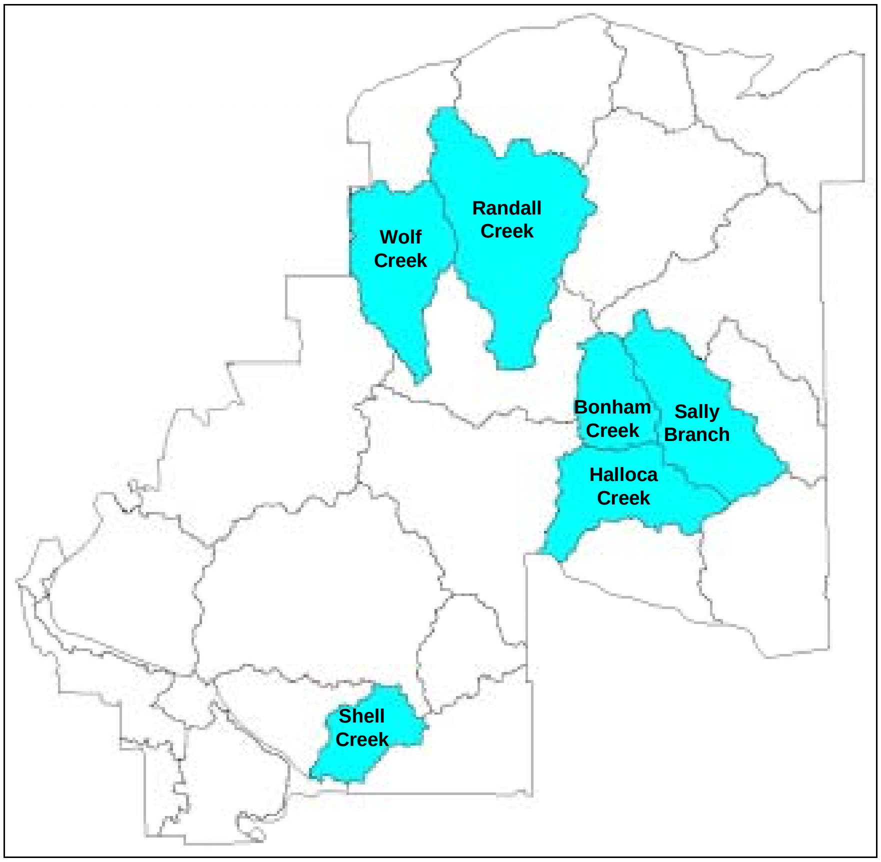


Figure 3. Watersheds representing the Phase I monitoring domain at Fort Benning, GA.

Descriptions of tasks completed and accomplishments for Phase I (FY00) are presented below for soil biogeochemistry, vegetation, surface hydrology, and soil hydrologic properties.

Soil biogeochemistry

Soil sampling sites in the experimental watersheds were located on or near transects normal to the direction of flow of the main stream. Samples were obtained at approximately 50 locations in each watershed, for a total of 300 sites (Figure 4). Each sample point consisted of a 1-m^2 square plot, within which five individual samples were taken in a diagonal pattern. The individual samples were then composited for analysis as a single sample. Soil was sampled to a depth of 20 cm, using a soil push probe with an inside diameter of 1 inch. Triplicate samples were taken at approximately 20 percent of the sites. At the triplicated sites, the two additional sampling points were located to either side of the primary sample point, at a distance of 5 m from the center of the primary point.

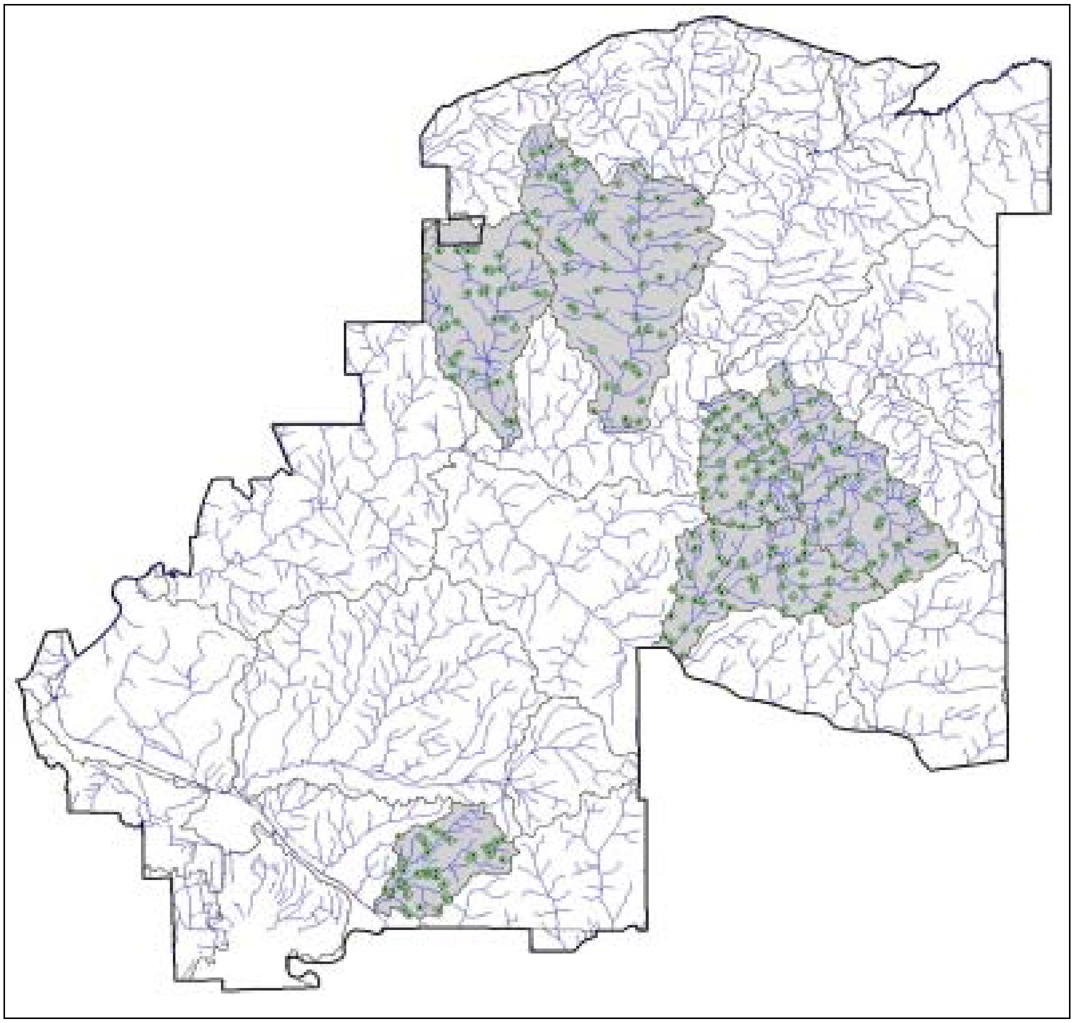


Figure 4. Phase I sampling sites for soil biogeochemistry and vegetation.

The Phase I soil sampling scheme was designed to capture the full range of spatial variability of soil properties within each monitoring unit. Sites along each transect were stratified according to landscape position, such that approximately equal numbers of sites were selected for bottomlands (wetlands), uplands (hilltops and ridges), and side-slopes. This stratified sampling scheme will enable us to account for the “natural” variability related to differences among community or ecosystem types associated with landscape position. Future sampling (Phase II) will be designed to characterize both ecological and anthropogenic impact gradients on a smaller scale, and at a greater spatial resolution. Soil samples were analyzed for a comprehensive set of geochemical and microbial properties and processes related to carbon, nitrogen, and phosphorus cycling.

Soil nutrient storage

Preliminary analysis of the soils dataset reveals inherent differences in biogeochemical parameters among bottomland, mid-slope, and upland areas. Variability among plant communities, landscape position, and ecosystem types will be evaluated in greater depth. Similarly, a great deal of variability exists within each major landscape category. For several of the parameters, variability was greater among wetland sites than in upland sites. Field observations confirmed that wetland (hydric) soils varied considerably within major watersheds along the length of the primary stream channel and its tributaries. Soils in riparian areas were typically saturated in areas with low stream banks and/or significant groundwater seepage (discharge), and dry in areas with high or steep stream banks. In the latter case, saturated soil conditions in the wetlands are likely restricted to high water conditions in the streams. Additional data analysis will contribute significantly to assessment of the variability across the study area, including geostatistical analysis of spatial patterns.

Preliminary data analysis for soil nutrients indicates that the wetland soils in the six experimental watersheds are typically carbon (C), nitrogen (N), and phosphorus (P) enriched relative to mid-slope and upland soils. Soil microbial biomass C and N content was found to be greater in wetland soils than in mid-slope or upland soils, but when microbial C and N values were normalized by total C and total N concentrations, respectively, the trend was reversed. The ratio of microbial C to total organic C potentially can be used as an indicator of soil organic matter stability and, consequently, of substrate C availability to soil microorganisms.

Cursory analysis of soil biogeochemical data reveal that microbial C, N, and P content are inversely proportional to severity of ecological impact, judged primarily according to vegetation and soil disturbance. Concentration of oxalate extractable P, which approximately represents iron- and aluminum-P compounds, was found to be inversely proportional to severity of impact among wetland sampling sites, but was not closely related to impact in upland areas. Conversely, Mehlich-I extractable P does not appear to be sensitive to level of impact in wetlands, but may be a useful indicator in upland areas.

Soil enzyme activity

Enzyme activity is assayed by providing a labeled substrate or, in the case of dehydrogenase, an artificial electron acceptor, which changes absorbance or fluorescent characteristics upon enzymatic transformation. Extracellular enzyme activity levels have been measured on soil samples taken from triplicated sites (about 20 percent of total sites — approximately 180 samples). Enzyme activities examined include acid phosphatase, β-glucosidase, protease, and dehydrogenase. Colorimetric assays were used initially, but due to high background absorbance from many of the Fort Benning soil samples, a more sensitive fluorometric assay that eliminates the background absorbance problem has been used on the most recent samples. Fluorometric assays have been compared to colorimetric results from previous samples to confirm that the methods give similar results.

Soil samples were homogenized and stored in the refrigerator until assayed. Subsamples of 0.25 to 5 grams were assayed for the various enzymes. In the case of fluorometric analysis, soils were ground and diluted 1/200 and aliquots were assayed. Acid phosphatase and β-glucosidase enzyme activity were assayed using a *p*-nitrophenol (pnp) conjugated substrate for absorbance based assays (Tabatabai 1994), or a methyumbelliferyl (MUF) conjugated substrate for fluorometric assays (Sinsabaugh et al. 1997). Upon enzymatic degradation, the pnp becomes colored and is measured spectrophotometrically, while MUF becomes fluorescent. In both cases, soil samples are compared to a standard curve of known concentration to determine the amount of substrate degraded. Protease was assayed using a standard protein (casein) and the degradation products were detected using the Folin reagent that reacts with tyrosine residues forming a colored product (Ladd and Butler 1972). These were compared to a standard of known tyrosine concentration. Dehydrogenase was assayed using triphenyltetrazolium chloride (TTC) as electron acceptor by the method of Thalmann (1968) as described in Alef (1995). TTC is reduced to the insoluble triphenyl formazan (TPF) and activities are reported as micrograms TPF per gram of dry soil.

Data analysis has not been completed for enzyme activity levels, but consistent trends are evident. Enzyme levels were generally highest in bottomland samples, which tend to have the highest organic content. Protease appears to be the exception, with at least one upland site showing the highest levels. Replicate samples appear to be fairly consistent, although some examples of large variance between replicates exist, particularly with regard to protease and dehydrogenase activity.

Soil molecular microbial diversity

Phase I of the study has been primarily devoted to optimizing techniques for use in wetland and upland soils characteristic of the Fort Benning site. Progress to date has included:

- Optimization of DNA (deoxyribonucleic acid) purification protocols from different Fort Benning soil types.
- Optimization of PCR (polymer chain reaction) using bacterial, archaeal, and ammonia monooxygenase primers.
- Optimization of PCR using labeled primers suitable for T-RFLP (terminal restriction fragment length polymorphisms) using the above PCR primers. T-RFLP is a relatively new technique to assess richness and composition of specific phylogenetic groups, and will be one of the primary means of analysis for this project.

- Working with the University of Florida Biotechnology core facility for analysis of the labeled PCR products for T-RFLP analysis.

Vegetation

Woody Plant Cover

During July and August, all soil sampling sites were visited. Within each watershed, the sampling points were distributed among ridge top, slope, and bottomland locations. Submeter GPS orientation was used to return to these sites for vegetation sampling. At each point, woody plant foliar cover below 2 m was measured along three, 5-m line intercept transects. Foliar cover of each species was measured separately. Portions of unknown species were collected and returned to the University of Florida Herbarium for identification.

Ground Vegetation

Percent cover and above-ground standing crop of all herbaceous species and litter were estimated at approximately 20 percent of the soil sampling sites (at the soil biogeochemistry triplicate sampling sites). Percent cover of bare ground also was estimated. Ocular cover estimates were made within three, 1-m^2 quadrats, located at 2.5-m distances in the 120^o, 240^o, and 360^o azimuths away from the central point, as well as a count of the number of broomsedge and low panicum plants. Above-ground biomass of all plant species, up to a maximum height of 1 m, within half of each quadrat was clipped and separated into woody and herbaceous plants. Litter also was collected within the 0.5-m^2 quadrats. Root biomass was sampled by collecting and combining two 5-cm x 20-cm cores at each of the three quadrat locations.

Above-ground plant and litter samples were returned to the laboratory and oven-dried at 65 °C for a minimum of 72 hours before obtaining dry weight.

General Observations

Analysis of the data is not complete. However, field observations indicated that the Natural Resource Management program on Fort Benning has maintained a very progressive and active prescribed burning program. Nearly all ridge top and slope sites had been burned within the previous 3 to 4 years, with many of the sites burned within the past 1 to 2 years. This fire program is maintaining a balance between hardwood and pine dominance in the uplands. Oak dominance is greater on the more xeric sandy sites, with pines more dominant on the more mesic sites.

Soil disturbance is associated with military training activities (armored vehicle training and bivouac areas) and timber extraction activities (thinning, skidding, loading, and, most importantly, road construction). These disturbances when located on slopes have resulted in varying degrees of erosion, from minor rill formation to major gully development. Some plant species seem to withstand moderate to severe soil disturbance and may become important indicators. *Rubus* sp and *Cretagus* sp commonly occur within most uplands regardless of disturbance, but seem to withstand disturbance, or even proliferate with disturbance (*Rubus*). Therefore, the relative dominance of these two woody plant species may become an indicator of disturbance.

Riparian vegetation response to two major types of disturbance was observed: erosional deposition of soil and impoundment/flooding associated with beaver activity. Erosion most commonly is associated with the numerous road crossings. The beaver population on the installation is unknown at this time.

Watershed hydrology

During this year, the hydrology group completed the following tasks: (1) identify Phase I monitoring locations, (2) streamflow gauge installation and monitoring, and (3) canopy interception installation and monitoring. The initial work to date has focused on the field tasks. Preliminary work has been done on data analysis and modeling.

Surface hydrology measurements were concentrated in the Bonham Creek watershed during Phase 1. Adjacent subbasins (2^{nd} order) with similar soil and vegetation were selected for initial studies: a minimally-impacted watershed (Bonham-1) and a moderately- to highly-impacted watershed (Bonham-2). Bonham-2 encompasses a portion of the Rowan Hill tank training area, while Bonham-1 is not affected by mechanized training.

Canopy throughfall collectors were installed at 68 sites in Bonham-1 and Bonham-2 watersheds. These, along with precipitation collectors, are monitored regularly to provide calibration data for throughfall and other hydrologic models. Streamflow measurement (stage) stations were established near the discharge points of the Bonham tributaries that drain the two subbasins under study.

Stream discharge, throughfall, and precipitation monitoring activities are ongoing in Bonham-1 and Bonham-2. An extensive set of canopy cover measurements was collected in the Bonham watersheds, and sediment tiles were installed in heavily impacted areas of the Bonham watersheds. Approximately 70 canopy cover measurements were made in the Bonham watersheds using a spherical densiometer.

Stage-discharge curves were completed for the Bonham-1 and the Bonham-2 sites. Preliminary analysis of storm response shows that the pattern of rainfall-runoff response differs between the two watersheds. Watershed modeling tools will be developed to characterize and simulate this response.

Geographic Information Systems (GIS) tools are being used to analyze the rainfall and throughfall data on the basis of land cover type. The GIS analysis was used to identify distinct regions in the land cover in Bonham-1 and Bonham-2. Canopy cover measurement locations were based on these regions. The measurement will be used to develop the Gash throughfall model. It is anticipated that the Gash throughfall model will be integrated with the GIS software by the first quarter of next year.

Soil hydrologic properties

Measurement and evaluation of soil hydrologic (physical) properties for Phase I were performed in the Bonham Creek and Sally Branch watersheds. The most intensive measurements were made in the Bonham-1 and Bonham-2 subbasins, and in the general vicinity of the Rowan Hill tank training area.

Depth to Clay

Soils found in the Bonham-1 watershed are characterized by the presence of an argillic or a kandic horizon (with an accumulation of clay via illuviation). This horizon will have significantly lower hydraulic conductivity compared to the more-permeable soil layers above this unit. Thus, this clay layer can impede downward flow of water during infiltration events, which can result in a temporary, perched water table and lateral flow downslope. Therefore, depth to this clay horizon is an important characteristic that can determine the contribution of lateral flow to runoff during a significant storm event.

At each of the locations where field measurements of hydraulic conductivity were made, soil was sampled to a maximum depth of 73 inches using a hand auger. Soil texture variations with depth were noted by visual observation, and depth to clay or the presence of a shallow water table was noted. A preliminary analysis of these observations indicated that the clay layer was found at 9 of the 26 sites sampled, while a water table was noted at 1 location. In general, the clay layer was more likely to be at higher elevations (near the ridges) than at lower elevations. But depth to clay was quite variable and ranged from 14 inches to 65 inches.

Undisturbed Soil Cores

Undisturbed soil cores (2.25-in. diameter, 2-in. length) were collected at 26 locations within the Bonham-1 watershed, corresponding to throughfall collection sites. At each sampling location, duplicate soil cores were collected. Bulk soil samples were also collected from these locations and an additional 26 locations along the same transects. Soil-water characteristic curves (relationship between soil-water potential and soil-water content; also referred to as the pressure-saturation curves) and saturated hydraulic conductivity values were determined using the undisturbed soil cores, while soil particle-size distribution will be determined using the bulk soil samples and the cores. Analysis of these data was used to determine if additional soil cores should be collected at other locations within the Bonham Creek watershed, and other watersheds (e.g., Sally Branch).

Soil Permeability

Constant-head infiltration tests were conducted at 26 locations within the Bonham-1 watershed. Two sizes of infiltration rings were used to take measurements at each site. One ring was a 4-in. diameter PVC fitting, and the other was a 6-in. diameter metal air duct piece. Each ring was approximately 6-in. long and was set 3-in. into the soil for the infiltration tests.

Saturated hydraulic conductivity (K_{sat}) values calculated based on the data from the infiltration tests using both the 4-in. and 6-in. rings agreed with each other reasonably well. Overall, these results showed a small range of high K_{sat} values, which were normally distributed about a mean of 100 cm/hr with a standard deviation of 40. Because of the small range of values, no trends in the data are immediately apparent with landscape position (e.g., elevation or watershed transect). However, the high K_{sat} values are consistent with the expectations for sandy soils observed at the site. These field-measured values will be compared with lab-measured K_{sat} values for the undisturbed soil cores taken at the same locations. These K_{sat} values will also be compared with values reported by the U.S. Department of Agriculture, Natural Resources Conservation Service (NRCS).

As a follow-up study of soil permeability, during a 3-week investigation we conducted over 90 permeability tests and collected 52 undisturbed soil cores. We also grabbed several bulk samples along sediment channels and deposition areas near the Rowan Hill and Cannons sites.

Each test was performed using a 4-in. diameter (3.75-in. I.D.) by 6-in. long PVC ring inserted 3-in. into the soil surface. Water was supplied to the ring via a 4-liter constant head supply reservoir. At each test sight, we examined the soil profile using a 4-in. diameter bucket auger. The profile, not included in this report, allowed further correlation with the NRCS soil survey (NRCS 1997). We mapped each test site using a hand-held global positioning unit. The mapped points were plotted over the soil series map in ArcView to correlate soil types.

Permeability computations were made using the equation given by Elrick and Reynolds (1992) for 3-dimensional, or “bulb” flow through a pressure infiltrometer, and using the function K(h) as described by van Genuchten, Leij, and Yates (1991). The van Genuchten parameters needed to solve the integral for the matrix flux potential were obtained from moisture-release data derived from soil cores taken in the Bonham-1 watershed January 2000. While these core samples represent only a small fraction of the data, they are the best estimators available at this time. To validate this data, $\alpha^* = Kfs / \phi m$ was computed after Kfs was found using the van Genuchten parameters. The computed values of α^* ranged from 0.13 to 0.14 cm^{-1}. Elrick and Reynolds suggest a α^* of 0.12 cm^{-1} for "most structured soils from clays through loams" (Elrick and Reynolds 1992). Noting the good correlation between computed and suggested values, a ϕm corresponding to a α^* of 0.11 to 0.14 cm^{-1} was used for soil types not represented well in the soil core samples.

Mapping

We mapped many of the preferential flow and sediment pathways in the Bonham-1 watershed, on Rowan Hill and environs, and in the Cannons area. Mapping was recorded with a GPS unit and imported into ArcView. Bonham-1 has several large gully-type formations. These formations, or channel depressions, are not significantly eroded and it is unclear whether they transport any channelized flow during storm events. Observation of the watershed as a whole suggests that and sustained overland flow (runoff commencing near the upper watershed areas and reaching the stream) is highly unlikely. However, a few short, localized overland flow and sediment transport pathways are evident. The major sediment transport feature within Bonham-1 is an old road that joins Hourglass Road and has created a pathway for sand from Hourglass to enter the watershed. A definite line of sediment runs from the old road downslope to a small flat area where nearly 6 in. have accumulated.

Rowan Hill has several channels running radially from the top of the hill. While these channels do carry a good deal of sediment, it appears that much, maybe most, of the sediment is deposited shortly below the bottom of the hill and is not carried far downstream. Cannons, on the other hand, has a main flow channel thick with sediment. The channel runs across the impacted Cannons area then nearly one-half mile downstream where there is a large deposition area. Profiling in the deposition area revealed a layer of dead leaves and other organic material at a depth of approximately 15 to 20 in.

It appears there are at least two reasons for the more impressive sediment transport and deposition in Cannons rather than at Rowan Hill. First, Cannons has a much larger area and perhaps a longer history of training activity. Second, Cannons has a system of roads running parallel with the slope gradient that are major suppliers of sediment. Many of these roads cross the main sediment channel. This significant contribution of roads to soil loss and sediment transport seems to be typical across the base, especially when the roads run parallel with steep gradients (a good example of this, besides Cannons, is along 1st Division Rd between Hourglass Road and Cannons).

Soil Type Correlation

A major purpose in testing the saturated soil conductivity is to correlate our measurements with the NRCS soil survey of Marion and Chattahoochee Counties (NRCS 1997). We conducted the majority of the tests within the Bonham Creek Watershed with several tests also being conducted inside the Sally Branch Watershed. Combining these tests with the tests previously conducted yields a database of over 100 points.

The soil type correlation shows a fairly strong relationship between the survey predictions and the actual measurements. Most soil permeability values (neglecting organic matter [OM] and impacted areas) fall within the predicted range. Each soil type has many inclusions, so spatial variability is expected, but mean values are encouraging. The two troublesome areas are the Cowarts series soils and allowing for the effects of the organic mat. Hopefully with improvement of the testing procedure and apparatus, and a better understanding of the "organic mat" areas, the correlations can be further refined.

While the soil types now sampled most likely represent 80 percent of the base area, several soil types are still left unsampled or undersampled. These soil types are: Ailey, Esto, Fuquay, Lucy, Orangeburg, Vaucluse, and Wahee and the Udorthents group.

In addition, samples of all soils types need to be taken in areas other than the Bonham and Sally Branch watersheds to ensure that the measurements are spatially repeatable. Besides conducting more tests, the testing procedure needs to be reexamined and further refined. The effect of the organic mat is not understood. It is also possible that some test values are deceiving due to flow around the sidewall, disturbance of the surface crust, or some other fault of the ring insertion.

A main goal of the soil correlation effort is to develop thematic permeability maps. Maps were created from the available data set and existing soil survey information. The current maps use the revised mean values (excludes organic mat and outlying samples) and assumes a complete correlation between the soil survey and measured values. The validity of this censorship and association assumption remains somewhat unclear and should be validated with the further testing.

Effect of Impact

We spent a major effort trying to characterize the impact on Rowan Hill by collecting soil cores, conducting ring infiltration tests, and examining the soil profile. Test and samples were obtain along five transects which began at the top of Rowan Hill and extended radially outward. In all, 25 sites were sampled. Table 4 gives the results of the tests by transect and by radial impact zone. The impact zones are labeled as follows: Top – top of Rowan Hill, Transition – grass is just beginning to grow, Grass – grass and occasional shrubs begin to be more noticeable, Tree – shrubs and trees begin to grow, and Pine – pine trees and relatively un-impacted environs.

Table 4 shows two columns of values. The first column reports statistics including all of the values sampled on the transect. The second column omits the high and low from each grouping of impact zone. With the high and the low values removed, the average permeability tends to slightly increase as samples move out from the impact center. While this is intuitive, a more impressive increase was expected. The impacted zones on Rowan Hill are constantly overturned, re-compacted, and otherwise altered, causing soil characteristics to change both temporally and spatially. This may explain why the trend is not more dramatic.

Perhaps a more illustrative example of the effect of impact is a comparison between the Troup soil measured on the direct impacted area of Rowan (direct impact refers to areas overrun by tanks and excludes sediment deposition areas) and Troup soil measured on less impacted areas in the Bonham Watershed. Figure 5 shows the 20 Rowan impacted Troup samples compared against the 20 Bonham samples (one chosen randomly from Sally Branch to complete the set). The two sets are ranked and samples of the same ranking are plotted as an (x,y) pair. The one:one line, denoting a perfect correlation, is shown. Also depicted is a regressed line through the 20 plotted points. The regressed points indicate that impact on Rowan Hill has decreased the permeability by around one-half of its original value. While the trend of decreased permeability is much lower than unimpacted areas, it is not as low as might be expected. The nature of impacted permeability on Rowan Hill is more complicated than simply compacting the soil.

Table 4. Rowan Hill impact summary.

ROWAN HILL

By radial impact zone

Top		all samples	minus hi/lo
TrB	Row-Top	10.18	10.18
TrB	B2-R6	8.58	8.58
TrB	B2-R17	24.53	
TrB	B2-R22	21.45	21.45
TrB	B2-R27	3.14	
	mean	13.58	13.40
	Std deV	9.05	7.02
	CV	0.67	0.52

Trans			
TrB	Row-Trans	29.03	29.03
TrB	B2-R7	4.27	
TrB	B2-R12	47.24	
TrC	B2-R18	5.20	5.20
TrB	B2-R23	17.71	17.71
TrB	B2-R28	26.46	26.46
	mean	21.65	19.60
	Std deV	16.25	10.75
	CV	0.75	0.55

Grass			
TrB	Row-Grass	17.73	17.73
TrB	B2-R8	13.23	
TrB	B2-R13	21.75	21.75
TrC	B2-R19	13.88	13.88
TrB	B2-R24	24.02	24.02
TrB	B2-R29	23.79	
	mean	19.07	19.34
	Std deV	4.84	4.48
	CV	0.25	0.23

Tree				
TrB	Row-Tree	28.36	28.36	
TrB	B2-R9	9.02		
TrB	B2-R14	19.47	19.47	
TrC	B2-R20	80.40		
TrB	B2-R30	26.24	26.24	
CwE	B1-R25	*258.60		rejected
	mean	32.70	24.69	
	Std deV	27.71	4.65	
	CV	0.85	0.19	

Pine			
TrB	B2-R11	7.59	
TrC	B2-R15	27.20	27.20
CwE	B2-R21	20.46	20.46
CoD	B2-R26	35.58	35.58
	mean	18.42	27.75
	Std deV	9.96	4.76
	CV	0.54	0.17

By transect

	one			
top	TrB	Row-Top	10.18	
trans	TrB	Row-Trans	29.03	
grass	TrB	Row-Grass	17.73	17.73
tree	TrB	Row-Tree	28.36	28.36
		mean	21.32	23.05
		Std deV	9.05	7.51
		CV	0.42	0.33

	two			
Top	TrB	B2-R6	8.58	8.58
Transition	TrB	B2-R7	4.27	
Grass	TrB	B2-R8	13.23	
Tree	TrB	B2-R9	9.02	9.02
Pine	TrB	B2-R11	7.59	7.59
		mean	8.54	8.40
		Std deV	3.21	0.73
		CV	0.38	0.09

	three			
top	TrB	B2-R6	8.58	
trans	TrB	B2-R12	47.24	
grass	TrB	B2-R13	21.75	21.75
tree	TrB	B2-R14	19.47	19.47
pine	TrC	B2-R15	27.20	27.20
		mean	24.85	22.80
		Std deV	14.23	3.97
		CV	0.57	0.17

	four			
top	TrB	B2-R17	24.53	24.53
trans	TrC	B2-R18	5.20	
grass	TrC	B2-R19	34.86	34.86
tree	TrC	B2-R20	80.40	
pine	CwE	B2-R21	20.46	20.46
		mean	33.09	26.62
		Std deV	28.51	7.42
		CV	0.86	0.28

	five			
top	TrB	B2-R22	21.45	21.45
trans	TrB	B2-R23	17.71	
grass	TrB	B2-R24	24.02	24.02
pine	CoD	B2-R26	35.58	35.58
tree	CwE	B1-R25	*258.60	
		mean	24.69	27.02
		Std deV	7.71	7.53
		CV	0.31	0.28

	six			
top	TrB	B2-R27	3.14	
trans	TrB	B2-R28	26.46	56.1
grass	TrB	B2-R29	23.79	
tree	TrB	B2-R30	26.24	53.11
		mean	19.91	54.61
		Std deV	11.25	2.11
		CV	0.56	0.04

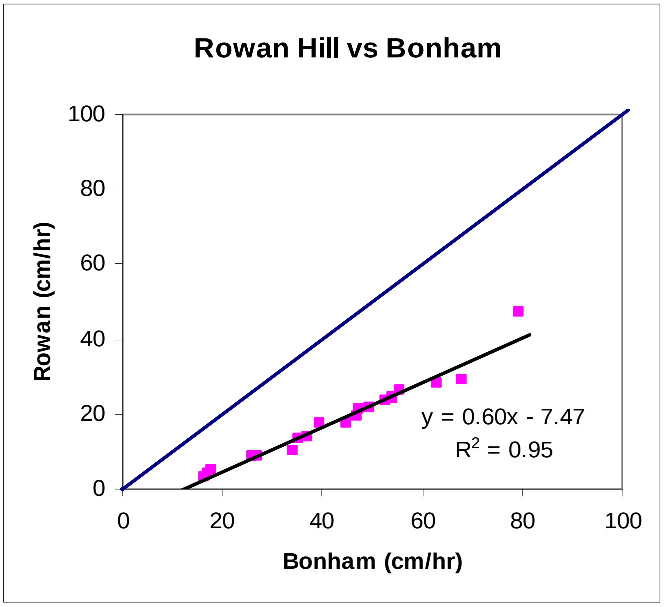


Figure 5. Rowan Hill vs. Bonham (impact vs. nonimpact).

Small-Scale Variability

Many of the soil types examined show high variability in some of the permeability values. It appears that a "mat" of organic material at the soil surface in highly vegetated areas is largely to blame for this variability. The organic surface layer often seems to create several preferential flow paths that increase the permeability. In an effort to quantify this variability, we measured infiltration rates along a 10-m transect that extends from under a canopy area into a small clearing. Rates were not significantly different and further tests need to be conducted.

Development of Ecological Indicators for Land Management

The lead principal investigator for this proposal was Dr. Anthony J. Krzysik. Dr. Krzysik has moved to the Embry-Riddle Aeronautical Institute, Prescott, AZ. Dr. Harold Balbach, ERDC, has assumed the ERDC/CERL POC position. Other team members and the task/topic they are working on are listed in Table 5.

Table 5. 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	Structures and Geotech Laboratory, 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 would be an important land management tool.

Objective

The objective of this research is to develop ecological indicators based on ecosystem-relevant design criteria and multiscale 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 would be: (1) the ability to assess and monitor multiscale ecosystem stressor effects independent of natural environmental variability and disturbance regimes, (2) their direct applicability to ecoregional contexts, and (3) the ability to extend developed approaches, analysis, and modeling capabilities 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 multiscale metrics;
- geoindicators;
- ecofunction groups; and
- indicator taxa (and possibly communities).

Progress to Date

Ten Ecological Indicator (EI) systems are being researched to develop and integrate a “guild system” for assessing disturbance gradients, ecological changes, and thresholds relevant to land use management decisions, primarily addressing military training environmental impacts. Nine EI systems are applicable to different ecological systems and scales, while the tenth represents the synthesis of the first nine.

Field research was conducted at the six research sites that were established in 1999 in the Bonham Creek watershed at Fort Benning, GA. Bonham Creek watershed is located in the east central portion of the installation encompassing Training Ranges D11, D12, D13, D14, D15, and D17. Two critical factors directly influenced the selection of research sites in this portion of the installation and at this specific watershed. First; Bonham Creek contained the installation’s heaviest use of tactical vehicles and training scenarios at the Cannons site (D15) and at Rowan Hill (D12). Concurrently, portions of this watershed also represented habitats that were excluded from military impacts (e.g., the “Wildlife Plot” area in D13). Second; the landscape, including the streams, represented Sand Hills physiography. From east-central Fort Benning, the Sand Hills runs northeastward in a narrow band of the upper Atlantic Coastal Plain, also including Fort Gordon, GA; Fort Jackson, SC; and Fort Bragg, NC. Therefore, research results at Fort Benning can be appropriately applied and are ecologically relevant to other major southeastern Army installations. Fort Benning is physiographically complex, with the Piedmont province entering the installation from the north, while the Loomy Hills province enters the installation from the west and southwest.

Research sites were visually assessed and selected to represent a gradient of three levels (low, medium, high) of landscape disturbance from military training activities with replication. Environmental disturbance was judged by vehicular damage to vegetation and soils. The Universal Transverse Mercator (UTM) loci are the locations of the centers of upland lysimeters, specifically lysimeter number 2. Each research site represents an area of approximately 20 hectares.

Three new research sites, again representing low, medium, and high disturbance levels were located in Sally Branch watershed in May 2000. This watershed lies east and adjacent to Bonham Creek watershed. As in Bonham Creek, Sally Branch contains landscapes that range from low to high disturbance.

The original experimental design (Proposal: Development of Ecological Indicator Guilds for Land Management) was dependent on identifying and "experimentally" using disturbance gradients based on entire watersheds. In other words, we expected to find heavily disturbed, moderately disturbed, and lightly disturbed watersheds where the vegetation and soil disturbances from military training activities, including tactical vehicle impacts, extended throughout upland, riparian, and aquatic ecosystems. This was not the case. At Fort Benning we found that the majority of military training activities, particularly when significant tactical vehicles (especially armor) were involved, were limited to upland ridges, and were characterized by patchy rather than continuous impacts to the landscape. The riparian zones and adjacent wetlands or seeps visually appear untouched. The direct effects of mechanized infantry and armor training were conspicuously absent from riparian and aquatic ecosystems.

Fort Benning is the Army's premier infantry school, and undoubtedly foot traffic of training personnel (possibly extensive) does occur in riparian and aquatic ecosystems. However, the climate is conducive to rapid regeneration and growth of vegetation, and these ecosystems must be highly resilient to these "light" perturbations. Additionally, Fort Benning's training and environmental staff are knowledgeable and responsible land managers, cognizant of the ecological value and sensitivity of these wetland natural resources.

The training landscape at Fort Benning, characterized by patchy disturbance to pine woods uplands, had a direct influence on the current research site selection and research approach on EIs. Additionally, we realize that the habitats are also subjected to potentially severe natural disturbance regimes — fires (wild, training ordinance, controlled burns), storms, and insect pest outbreaks. Within individual watersheds we were able to find gradients of training disturbances as patches in the landscape. Working in individual watersheds also has the advantage of minimizing confounding effects and influences from interwatershed differences in geology, geomorphology, and soils, and eliminates interphysiographic contrasts. Therefore, the experiments on plant physiological responses and invertebrate communities, including developmental instability, were limited to disturbance gradients in upland pine forest ecosystems. Although initially we have worked only with a gradient of three levels of habitat impacts, we desire to expand this to at least five levels and to quantify disturbance. However, even more disturbance levels would be desirable. The need for a number of disturbance levels is critical for four important reasons: (1) quantify the disturbance-effects trend gradient (more points more reliable results and patterns), (2) assess shape of trend gradient (linear or specific curve), (3) detect threshold effects (which may vary for different EI test systems or specific impacts), and (4) maintain the capability of studying a research site along a disturbance gradient even if one or more of the sites become "unavailable" in the future or through additional research knowledge we find that our original "visual disturbance classification" was incorrect.

Although lotic-aquatic ecosystems are not directly impacted by tactical vehicles at Fort Benning, disturbances to vegetation and soils in the uplands eventually leave their impression in the installation's streams. The impacts to the streams are mainly in the form of increased sediment load (often dramatic), turbidity, and dissolved nutrients and organics. Another important impact, but not usually recognized or emphasized, is an increase (variance) in the magnitude (both high and low) and fluctuations of in-stream water level and flow volume. Currently, we are conducting a paired-comparisons study of lotic-aquatic ecosystems, where the paired-comparisons contrast upstream and downstream sampling at landscape patches with high upland disturbance.

Developmental instability

The leaves from six species of plants were evaluated for Developmental Instability (DI): Muscadine Grape (*Vitis rotundifolia*), Winged (Dwarf) Sumac (*Rhus copallina [R. copallinum]*), Sassafras (*Sassafras albidum*), Mockernut Hickory, (*Carya tomentosa*), Man-Root [Man-of-the-Earth] (*Ipomoea pandurata*), and Tred-Softly (*Cnidoscolus stimulosus*) were collected, pressed, and digitized for measurement. Muscadine Grape was collected in 1999, sumac in 1999 and 2000, the other species were collected only in 2000. The grape did not show DI, while the sumac did. Because of the extremely large number of leaf measurements that must be made in the laboratory, as well as extensive ANOVA, the final results are not yet completed. Complete analysis of the sumac data will be completed in the near future.

A pilot study was initiated to assess how natural induced stress from insect galls affects fluctuating asymmetry in Mockernut Hickory leaves. A number of parameters are currently being measured to assess fluctuating asymmetry of these leaves.

Plant physiology and stress metrics

The compound leaves of Mockernut Hickory, both infected and uninfected by insect galls, were also used to assess important physiological metrics. The metrics were: net photosynthetic rate, transpiration rate, and stomatal conductance. These measurements were conducted in the field with a portable photosynthesis system (CI 510, CID Inc., Vancouver, WA). At each site (H2 [high, Rowan Hill] and L1 [low, Wildlife Plot]) 18 plants were use; 9 infected with galls and 9 uninfected. For each plant, 4 leaves were selected, and from each of these leaves 4 leaflets were selected for the actual physiological measures. Individual physiological responses represented a number of sequential time series measures on each leaflet. Within-leaflet variance represents the variability of these time series measures.

Net photosynthetic rate (NPR) was similar at both the low and high disturbance sites when there was no gall infection, but with gall infection NPR was lower at the high disturbance site. Gall infection did not affect NPR at the low disturbance site, but at the high disturbance site gall infection lowered NPR. Within-leaf variance was higher at the high disturbance site, but at each site there were no differences due to gall infection.

Transpiration rate (TR) was higher at the high disturbance site irrespective of gall infestation (at the low disturbance site there was no difference in TR with gall infections, but at the high disturbance site, TR was higher for uninfected leaflets). The high disturbance site also exhibited higher variability. Within-leaf variance was similar at both sites and independent of gall infections.

Stomatal conductance closely paralleled transpiration rates (the only exception was that within-leaf variance was lower for gall infected plants at the low disturbance site).

Soil microbial diversity and related soil parameters

Soil samples were collected during 25 through 29 May 2000 at the vicinity of the 36 lysimeters at the 6 research sites established in Bonham Creek watershed. The following parameters were measured in the laboratory: soil moisture, pH, extractable NO3 and NH4, soil organic matter, bacterial functional diversity, fungal functional diversity, and soil microbial biomass carbon.

Microbial functional diversity relates to the number of biological interactions with soil ecological processes and directly reflects organic decomposition, substrate diversity, and mineralization diversity. Microbial functional diversity is estimated by the ability of the soil fungal and bacterial communities to use a variety of carbon compounds.

Fungal functional diversity was highest in the low disturbance sites and lowest in the high disturbance sites. On the basis of Principal Components Analysis, the medium sites were intermediate in fungal functional diversity and overlapped to some extent with the high disturbance sites. The medium sites may be on an ecological recovery trajectory that brings them closer to the low disturbance sites.

Soil parameters were based on calculating the mean and standard deviation for low, medium, and high disturbance sites. Standard deviation was based on a sample size of four representing the means from the upland and lowland samples at each of the two replicates for each disturbance level. Each of these four means was based on six soil samples, each of which in turn was derived from the composite of five individual soil samples. Therefore, each mean was derived from 120 individual soil samples, while the standard deviation represented parameter variability between upland and lowland areas and the two respective replicates.

Soil organic matter was highest for the low disturbance sites and lowest for the high disturbance sites, while the medium sites were intermediate. This is as expected because visually higher vegetation biomass as well as more complex physiognomy appeared to inversely vary with site disturbance level.

Interestingly, soil microbial biomass carbon showed exactly the opposite trend, with microbial biomass being lowest in the least disturbed sites. The lower levels of microbial biomass in the low disturbance sites are indicative of soils for which an equilibrium between carbon inputs from plants and the breakdown of soil carbon in decomposition has been established. Although this at first appears unusual, it can be attributed to the extremely high turnover rates in the microbial community where there is a great deal of organic substrate and high mineralization rates. A similar effect can be seen in limnetic plankton communities, where the standing biomass of zooplankton exceeds that of phytoplankton, a seemingly violation of ecological trophic pyramids. However, the high turnover rates of phytoplankton relative to zooplankton makes the biomass pyramid inverted, while the energy pyramid is correctly oriented.

Soil ammonium ($NH4^+$) concentrations were much higher (>100 mg/kg) in the low disturbance sites and were very low at the medium and high disturbance sites (<20 mg/kg). This is consistent with the high microbial turnover and mineralization rates discussed above.

Nitrate ($NO3^-$) concentrations were similar at both the low and medium disturbance sites, and lower at the high disturbance site. More sampling and at different seasons of the year is required to further elucidate the patterns of nitrate and ammonium soil concentrations relative to disturbance levels.

Soil pH varied directly with disturbance level, being highest and most variable at the high disturbance sites. This may be attributed to the higher humic acid concentrations in the presence of more organic detritus and higher levels of microbial activity.

Soils samples collected 16 and 17 November 2000 are currently being analyzed. These data represent the late fall sampling period. Soil moisture was appreciably higher at this time because the May samples were collected during a major drought period. Preliminary results indicate that there were fewer differences among the disturbance classes. Contrary to the May samples, microbial biomass was lowest in the high disturbance sites and highest in the medium disturbance sites. These early results may indicate that an important effect of disturbance is to reduce the ability of the microbial community to function effectively during moisture stress.

Nutrient flux

Nutrient flux in the soil will be quantified from mobile soil water collected with porous cup tension lysimeters. These samples will be analyzed in the laboratory using a Dionex DX-120 Ion Chromatograph (Dionex Corporation). A total of 36 lysimeters were installed at the six research sites in Bonham Creek watershed in May 2000. Six lysimeters were located in each research site, three in the uplands and three in each lowland (riparian) ecosystem. Although nitrogen is the primary nutrient of interest, other anions and cations can be investigated.

UTM coordinates for each lysimeter were determined with a military Rockwell AN/PSN-11 PLGR GPS receiver. These coordinates are the basis for identifying the study sites. We have made measurements with our specific instruments that were within 1m of accuracy as referenced to software-corrected base-station calibrated civilian Magellan GPS receivers.

The Fort Benning region experienced a severe drought during 1999-2000. Most lysimeter samples collected on 31 May and 23 September 2000 were dry. Samples that contained leachate were high in sulfate. There was appreciable rainfall at Fort Benning in late September and early October. The 6 October data were available for only 32 lysimeters, the other four were vandalized. Although the data were highly variable, samples collected both during drought and high precipitation periods contained high sulfate concentrations. This pattern was particularly evident at the high disturbance sites.

Invertebrate indicators

Terrestrial

Terrestrial invertebrates were sampled in May 2000 using pitfall trap clusters and sweep net sampling at nine study sites, the six at Bonham Creek and three newly selected sites at Sally Branch. There were four pitfall trap clusters at each site, and each cluster consisted of five pitfall traps. The sweep net samples consisted of two sets of timed sweeps at each of the nine sites. The invertebrate samples require a great deal of laboratory time for sorting, classification, and taxa identification. Over 30,000 individuals were obtained and are currently being sorted. The collected invertebrates will be used for: (1) indicator species,

(2) community and biotic integrity indices, and (3) Developmental Instability of selected species.

Several very widely distributed taxa that may represent potentially useful indicators include: ants, especially *Dorymyrmex pyramicus*, Green Lynx Spider, and several orthopterans (grasshoppers, crickets, and a field katydid). The abundance appears to be directly related to site disturbance level. Annual plants typically increase with vegetation and soil disturbance. An important characteristic of annual plants is their inherent high seed production, therefore providing more food resources to seed harvesters such as specific ant species.

Interestingly, the grasshoppers sampled in highly disturbed sites were physically smaller than those captured in less disturbed sites. This suggests the possibility of nutrient or caloric deficiencies, and experiments will be designed for the Spring of 2001 to test this hypothesis.

Aquatic

Aquatic invertebrates will be assessed from Spring and Fall samples collected from pine log bundles used as colonizing substrate in paired comparisons. Four replicates of pine log bundles will be used at each site.

Vertebrate indicators

Vertebrates have been reliably and effectively used as Ecological Indicators for over a century, but caution is required in the application and interpretation of field data. Birds represent ecological indicators at two levels: (1) habitat condition and degradation and (2) disturbance associated with human activities, noise, or chemical substances. Two taxa of birds were originally identified as having high potential for ecological indicators: woodpeckers and wood warblers. However, all avian breeding species have potential for representing ecological indicators. Species that are migratory, over-wintering, and casual transients in west-central Georgia typically are not useful as ecological indicators, because they generally tolerate broad and unpredictable habitat conditions.

A preliminary investigation of birds at Fort Benning in May 2000 indicated that the “expected” species are present even in forest habitats close to heavily used training areas.

The complete “pool” of vertebrate taxa (species and subspecies, but excluding fish) at Fort Benning is 352. However, this figure contains 50 migratory breeding birds, 54 migratory wintering birds, 15 hybrid swarms (each consisting of from 2 to 4 subspecies), 35 taxa of unknown presence on the installation, and six currently extinct species. Therefore, a more realistic assessment is 192 taxa of amphibians, reptiles, birds, and mammals that are potential subjects for use as Ecological Indicators.

The Fort Benning complete avian fauna (residents, migrant breeders, migrant wintering, unknown, and extinct) was classified into preliminary guilds based on foraging characteristics. The Insectivores/Granivores (sparrows, finches) guild contains the most species. We suspect that the woodpeckers and wood warblers represent excellent guilds for assessing habitat condition-trend dynamics.

The Fort Benning mammal community was classified into preliminary guilds, also based on foraging characteristics. Bats and small omnivorous rodents represent the major taxa on Fort Benning. Both of these taxa are logistically difficult to sample. The large extinct species are cougar, red wolf, and bison, indicating regional-scale disturbance to the original mammal fauna. Mammals may not represent good taxa to use as indicators because of sampling and abundance issues. However, research (Kosky 2000) was based on rodent trapping throughout the installation. This mammal data will be used with corresponding vegetation data to assess ecological patterns.

The Fort Benning herpetofauna community was classified by general habitat requirements. This is a useful classification, because herp communities are potentially important indicators of landscape integrity. Many taxa require access to both aquatic and terrestrial habitats for reproduction and/or hibernation. Only four salamanders can be considered completely aquatic organisms. Not surprisingly, the largest herp category is terrestrial reptiles, but the number of terrestrial amphibians is surprisingly low for the humid Southeast. This is undoubtedly due to the sandy well-drained soils resulting in low soil-litter moisture capacity. The installation riparian herpetofauna is well represented.

Although it is widely acknowledged that amphibians constitute common and widespread riparian organisms, it is not usually appreciated that reptiles are also important riparian fauna from mesic to xeric and arid environments. Riparian habitats are the actual land-water interfaces. This is spatially and environmentally where riparian organisms live. Riparian organism viability therefore, specifically requires high quality land-water interfaces. “Aquatic-Terrestrial” organisms require the use of both terrestrial and aquatic habitats to meet life history requirements relative to reproduction and/or hibernation. Note that these species do not use riparian habitats. Although importantly, high quality and intact riparian habitats are prerequisites for high water quality, including temperature regimes, in aquatic environments. Interestingly, in this guild class amphibians are primarily terrestrial, requiring aquatic habitats for egg deposition and larval development. Conversely, reptiles (e.g., fresh water turtles) are aquatic but require terrestrial habitats for nesting and for some species hibernation.

Fish

Fish were sampled at selected localities by electro-shocking and collection in a 15-ft seine. Extreme care had to be taken to collect and preserve only fish that were not listed as protected species under Georgia state restrictions and U.S. Fish and Wildlife listed threatened or endangered species. Karr's Index of Biotic Integrity (IBI) will be applied to fish and terrestrial plants (Karr 1981).

Geoindicators

Geoindicators should provide insight into the pathways of energy and mass transport through the hydrological and terrestrial ecosystem elements of the Bonham Creek watershed. For this research effort, specific geoindicators were identified that reflected the movement of water, sediment, and organic detritus down the energy gradient from uplands to the bottomland (riparian) areas, including the Bonham Creek stream channel. The effect of these processes on the upland soils will be measured in two ways: (1) monitoring changes in microtopography and (2) monitoring erosion around rain splash disks in areas of no overland flow. Microtopography will be monitored at each of the six lysimeter sites in the six previously established research sites, and an additional site located in the southeast part of the watershed at the approximate location of E 071 2250, N 358 6750. Changes in microtopography will be determined with a laser profilometer by time series measures along predetermined transects. An array of rain splash erosion disks will be established in areas of little or no surface flow at each of the seven microtopography sites. The individual disks will be situated in a variety of exposures to reflect the apparent influence of vegetation canopies, soil type, surface geometry, and other variables on the magnitude of rain splash erosion. Rain splash erosion will be determined by the extent of the development of uneroded soil pedestals beneath the disks as the soil around the disk is eroded.

Geologic processes occurring in riparian zones are important to ecosystem processes. Deposition of sediment and organic matter in the low areas of riparian zones is the key process in soil formation in the moisture-rich riparian zone. Sedimentation traps will be located along profiles orthogonal to the strike of the valley to provide indicators of sedimentation rate as a function of distance from the source. Riparian zones are also the product of the erosional development of the fluvial channels that flow through them. The meandering activity of the stream as it erodes one bank and deposits sediment against another provides a useful index of the processing of energy and materials by the stream channel. This planform measurement of stream channel dynamics provides information on the type and frequency of channel changes key to the recruitment of riparian vegetation and the evolution of aquatic habitats in the channel. Stream channel location will be monitored for each of the three stream reaches where hydraulic geometry measurements will be made.

Stream channels are the lower unit of the energy and mass cascade across the landscape. Streams represent the arteries of terrestrial systems where mass transport and energy dissipation is focused. As stream channels transport and temporarily store sediment, water, and organic matter, they provide distinctive aquatic conditions for plants and animals. The key ecological geoindicators for stream channels include: streamflow, water chemistry, sediment transport, and the geometric properties of the channel cross-section. The hydraulic geometry of Bonham Creek will be monitored at eight cross-sections in each of three channel reaches. The three reaches have been selected to reflect conditions in the upper, middle, and lower parts of the watershed. An additional consideration for selecting the locations of the three reaches was to examine the impact of road development, maintenance, and use on sediment contribution to local streams. Field observations throughout Fort Benning suggest that unimproved roads contribute substantial sediment loads to streams. Changes in the hydraulic geometry of the channel cross-section over time will be determined by measurement of channel profiles and calculation or determination of widths, depths, width/depth ratio, hydraulic radius, area, and roughness. As each of the 24 channel cross-sections are measured, streamflow velocity distribution will be determined, water chemistry parameters will be monitored, and bed samples will be obtained.

Integration and classification of individual ecological indicators to construct Ecological Indicators

The Ecological Indicators Team is researching nine different categories of Ecological Indicator Systems. Within each of these systems there is the potential for a large number of independent or closely related ecological indicators. The tenth system consists of the classification and integration of all of these nine Ecological Indicator Systems along with their respective subsystems.

The development of these classifications and their integration (Ecological Indicator Guilds) represents a major component of the research effort and goal in this project. Current work involves the evaluation of structural equation modeling (SEM) and other multivariate techniques. Within SEM other ecological indices and metrics will be used. Examples include: indices of biological integrity, similarity indices of comparative matrices, meta-analysis, and information theoretic approaches. SEM may represent an important tool for developing interrelationships and understanding interaction associations in complex ecological systems. SEM, also know as covariance structure analysis or latent variable analysis, is a family of multivariate techniques closely associated with multiple regression and factor analysis. SEM may also provide powerful analysis capabilities for estimating measurement errors. This represents a critical capability, because we are basing a great deal of the experimental design on the capacity to estimate local and landscape scale variance. Importantly, this family of models has great potential for being integrated into the spatial analysis capabilities we hope to develop, and fits well with ANOVA components and the General Linear Modeling that will be emphasized in variance estimation and significance tests.

Fundamentally, SEM models interdependent series of multiple regression equations. Its uniqueness in modeling is that guidance from prior knowledge, feedback from conjoint experiments or other models, or exploratory analysis is used to assist the association of independent variables with dependent variables, where in turn some dependent variables become independent variables in subsequent relationships. SEM possesses high statistical efficiency in dealing with simultaneous multiple relationships. SEM is related to other important analysis techniques in the following way. In multiple regression, linear combinations of many independent variables are used to predict a single dependent variable. Multivariate analysis of variance (MANOVA) and canonical correlation analysis take this a step further and relate many independent variables to many dependent variables, with the important constraint that there is only a single relationship between dependent and independent variables. Only SEM models multiple relationships among both dependent and independent variables. SEM will be used to model interrelationships, interactions, and interdependencies within and between nested hierarchical estimated parameters, derived vectors, and calculated indices; and assist General Linear Models in error term estimation.

GIS technologies, spatial analysis, and spatial models will be used to interpret ecological, chemical, and physical field measurements, and assist in the construction of Ecological Indicators.

Indicators of Ecological Change

The principal investigator for this proposal is Dr. Virginia H. Dale from Oak Ridge National Laboratory. Other team members and the task/topic they will be working on are listed in Table 6.

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.

Table 6. 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 Management Division
Jack Feminella	Macroinvertebrates	Auburn University
Thomas Foster	Historic Land Cover	Penn State University
Ken Fritz	Macroinvertebrates	Auburn University
Sarah McNaughton	Soil Microbiology	University of Tennessee
Pat Mulholland	Aquatic Ecology	Oak Ridge National Lab
David White	Soil Microbiology	University of Tennessee

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 below-ground 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.

Progress to Date

Terrestrial indicators

A field study was conducted to establish and collect vegetation and soil data from a series of transects located along a gradient of low to high military training intensity within the longleaf pine habitat. By selecting study sites at various points along the disturbance gradient we planned to test the hypothesis that changes in species composition, cover, etc., could be used to indicate and monitor ecosystem stress resulting from military training activity.

With help from Randy Druckman in the NRMB (Natural Resources Management Branch) we created a GIS image of the current longleaf pine stands throughout the installation and then overlaid the military training compartments and military training intensity classifications with the stand locations. Based on this map and input from Pete Swiderek, Chief, NRMB, we selected 14 study sites throughout the base, 12 sites were representative of the various levels of the military training activity gradient (reference-light-moderate-heavy); the remaining 2 sites represented recovering habitat. Although the use of the GIS information was extremely helpful in narrowing down potential sampling sites, it was also necessary to spend a significant amount of time in the field investigating potential study sites. Road conditions and range/training activity played a considerable role in limiting the site selections. Patty Kosky (former Host Site Coordinator) was a big help in selecting sites in the field and assisting with sampling.

Within each of the selected study site we established one, randomly located 60-m transect. Samples of the herbaceous layer were conducted within a 5-m radius circle located at 15-m intervals on the transect. Herb layer data collection was based on a modified Braun-Blanquet analysis of species cover and sociability. In addition, soil samples were taken in each quadrat for analysis of soil microbiology (discussed later in this report) and soil carbon and organic matter by Chuck Garten of Oak Ridge National Laboratory (ORNL). When a canopy layer was present, we also recorded canopy density and cover as well as stand age. The analysis of these data is not yet completed.

Stream chemistry and biology indicators

Site selection for the stream studies was completed. Twelve streams were chosen for study, including 4 that appear to be either undisturbed or minimally disturbed reference sites, 3 with low levels of disturbance, and 5 with moderate to high levels of disturbance. Automatic samplers were deployed in December 1999 at five of the sites for collecting water samples during storms (Lois Creek-O13, Bonham Creek tributary-D12/D13, Bonham Creek tributary-D13, Randall Creek tributary-O13mid, and Upper Sally Branch-F2). Six storms were sampled over the period from December 1999 to March 2000. From 5 to 20 samples were collected over each of the storm hydrographs at each site. The samples were returned to the laboratory, filtered, and frozen until analysis. In addition, measurements of water temperature, specific conductance, and dissolved oxygen were made at 30-minute intervals over several days during this period. Diel variations and minimum levels of dissolved oxygen concentration will be used to determine differences in metabolism characteristics among the study sites.

We used two methods to sample stream invertebrates: (1) Hester-Dendy multi-plate samplers collected from 4 stations within each stream, incubated for about 6 weeks; and (2) semi-quantitative sweep net samples (2 minutes within a 1-m^2 area) collected from the upstream and downstream ends of study reaches within each stream. Samples from both methods will be analyzed separately to determine which method better characterizes the invertebrate community and thus is most useful in describing community differences among streams associated with potential impacts of military training. It is possible, however, that both methods provide separate and useful information about communities, in which case we will continue to sample streams with both methods. We also measured the following environmental parameters: water temperature; pH; conductivity; dissolved oxygen; stream discharge; average current velocity, water depth, and channel width; amount of coarse woody debris in the channel. We also installed several scour pins within the streambed (4 to 5 per site) to quantify sediment movement.

Laboratory sorting, identification, and enumeration of invertebrates collected from November 1999 are ongoing, as are compilations of reference collections of all invertebrate taxa for each stream. Preliminary analyses of invertebrate assemblages indicate low abundance and diversity of species across most sites, although inter-stream variability in these measures is high.

Soil microbiology

Soil core samples were collected from sites located at Fort Benning, GA in the Fall 1999. Solvent washing (in methanol) was used throughout to ensure no cross sample contamination. Cores were approximately 20 cm long and 2 cm wide. For each core taken, the depth of the core and the presence/absence of an "A" horizon was reported. Five samples were taken from separate plots at each transect (14 transects x 5 = 70 samples). Of the transects selected, 2 were reference transects (A and M, stand ages 24 and 74 years, respectively), 3 were heavy usage (B, H, and J, tracked vehicle training), 3 were moderate usage (C, I, and K, areas adjacent to tracked vehicle training), 4 were light usage (D,E, L, and N, infantry training) and 2 came from a site currently undergoing remediation (F and G, both light usage). Samples were stored at 4 °C, then stored at –80 °C prior to analysis. Soil physical characteristics and type were documented upon Sarah McNaughton's return to the Center for Environmental Biotechnology (CEB) (Table 7). Soil mass, total carbon, and total nitrogen are being analyzed by Chuck Garten at ORNL. Soil lipid biomarker (phospholipid fatty acid [PLFA]) content and moisture content are being analyzed at the University of Tennessee, CEB.

Table 7. Summary of soil physical properties at each transect.

Transect	Understory Cover	A Horizon	Definition	Color	Type
A (Reference)	75-100% cover	6.3	Good	BROWN	Sandy loam
B (Heavy Use)	Less than 5% cover	0	None	Brick red	Sandy loam
C (Moderate Use)	50 - 75% cover	0	None	Brick red	Sandy loam
D (Light Use)	75-100% cover	3.36	Good	Brown	Sandy Loam
E (Reference)	75-100% cover	1.94	Bad	BROWN	Loamy
F (Remediated)	75-100% cover	0	None	BROWN	Sandy loam
G (Remediated)	75-100% cover	0	None	DARK BROWN	Sandy loam
H (Heavy)	Less than 5% cover	0	None	BROWN	Sandy loam
I (Moderate)	50-75% cover	0	None	BROWN	sandy loam
J (Heavy)	Less than 5% cover	0	None	BRICK/RED	Sandy loam
K (Moderate)	50-75% cover	0	None	BROWN	Sandy loam
L (Light)	75-100% cover	6.1	Bad	Brown	Sandy loam
M (Reference)	75-100% cover	5.8	Bad	BROWN	Sandy loam
N (Light)	75-100% cover	6	Good	Sandy brown	Sandy loam

Analyzing the data for the historical trends at Fort Benning

The goal of this analysis of the historical data is to identify and map trends that have occurred over human history at Fort Benning and also to develop ways to measure these changes. The historical data on land use at Fort Benning is being developed so that we can explore trends in ecological conditions over time, such as vegetation type and pattern.

Long-term environmental changes at Fort Benning are being characterized with historical land survey maps. These maps were compiled as part of the federal and state public land distribution. As lands were opened up for public distribution in the United States, they were surveyed by the General Land Office (now the Bureau of Land Management). Among the states that formed from the 13 colonies, lands were distributed at a state level. The states' process of distribution was similar to the federal system. Fort Benning is mostly bounded by land that was surveyed in the early 19th Century by the State of Georgia.

The land distribution and survey system changed over time in Georgia. When the land bordered by Fort Benning was surveyed in 1827, land was divided into roughly equal lots within districts. Districts were to be roughly 9 miles square and lots were to be 202½ acres square. Lots varied in size but were, on average, ½ mile on a side. The lots were then issued at a lottery.

As part of the land distribution, the Surveyor General surveyed the land, noting the location of trees at each corner that marked the boundary of each lot. These trees were indicated on a map. The surveyor indicated the corner tree and four witness trees. The district maps are a sample of the forests during the early 19th Century. These maps and survey data provide an extremely valuable and unique method of characterizing long-term changes in the forests for a given region.

A small section of Fort Benning is in Alabama, which the Federal General Land Office also surveyed. These surveys are slightly different than the Georgia survey but provide similar information. Surveyors in the Fort Benning area of Alabama recorded only corner trees so only species frequency can be determined.

We are using the survey maps and field notes to create a digital GIS model of the forests from the early 19th Century for the Fort Benning area. Although Indians had been living in the area for thousands of years, the model will be the best known representation of the forests in a prewestern agricultural environment. Thus, the 1827 map will provide the baseline conditions for the installation.

Current Status

This work has involved error correction and translation of the Georgia and Alabama sections of the data layer. Translation involves assigning standard scientific names for the common names used by the surveyors on the historic maps. All data has been entered into the Arcview GIS. The forest cover in 1827 can now be summarized for the Fort Benning area. Table 8 shows the percentages of tree species. We observed and mapped 4108 individual trees.

Terrestrial understory vegetation as an ecological indicator

We are in the process of analyzing data collected from sites at Fort Benning that can support long leaf pine forests within four training intensity categories (minimal, light, moderate, and heavy) and a site undergoing restoration. All species identified were assigned a percent cover score and a sociability classification based on a modified Braun-Blanquet classification system (Clarke 1985). The species were also classified using Raunkier's life form classification system (Kershaw and Looney 1985) based on the height of perrenating buds. Out of the 137 identified species 12 species were Chamaephytes, 39 species were Cryptophytes, 31 species were Hemicryptophytes, 36 species were Phanerophytes, and 17 species were Therophytes.

Examining the species presence data, we cannot reject the hypothesis that there are significant differences between life forms within each training category. Using a two-way analysis of variance with training categories and life form as the treatments, we find that we cannot reject the hypothesis that there are no differences between life forms of training intensity (and the order of treatments makes no differences). We are in the process of examining differences in growth forms and cover and in selecting species that may serve as useful indicators.

Table 8. Count and percentage of historic trees at Fort Benning.

Species	Count	Percentage
Aceraceae	17	0.0041
Carpinus caroliniana	9	0.0022
Carya	20	0.0049
Castanea	10	0.0024
Cornus florida	19	0.0046
Diospyros virginiana	8	0.0019
Euonymous atropurpureus	3	0.0007
Fagus grandifola	58	0.0141
Fraxinus	10	0.0024
Ilex opaca	25	0.0061
Juniperus virginiana	1	0.0002
Morus rubra	1	0.0002
Nyssa Sylvatica	22	0.0054
Nyssa sylvatica	51	0.0124
Oyydendrum arboreum	1	0.0002
Persea	28	0.0068
Pinus	3213	0.7821
Platanus occidentalis	3	0.0007
Populus	13	0.0032
Prunus persica	2	0.0005
Quercus	40	0.0097
Quercus alba	29	0.0071
Quercus falcata	1	0.0002
Quercus marilandica	202	0.0492
Quercus muehlenberrgii	1	0.0002
Quercus nigra	15	0.0037
Quercus phellos	11	0.0027
Quercus rubra	128	0.0312
Quercus stellata	140	0.0341
Quercus velutina	4	0.0010
Sassafras albidum	16	0.0039
Ulmus	5	0.0012
Viburnum prunifolium	2	0.0005

Soil microorganisms as a measure of the below-ground aspect of ecological integrity

The analytical chemistry for all samples from Fort Benning is complete. Briefly, the soil was extracted with the single-phase chloroform-methanol-buffer system of Bligh & Dyer. The total lipid extract was fractionated into neutral lipids, glycolipids, and polar lipids by silicic acid column chromatography. The polar lipids were transesterified to the fatty acid methyl esters by a mild alkaline methanolysis. Fatty acid methyl esters (FAMES) were recovered from the organic fraction of the sample. The FAMES were analyzed and quantified by capillary gas chromatography with flame ionization detection. Preliminary peak identification was by comparison of retention times with known standards and detailed identification of peaks was by gas chromatography/mass spectroscopy (GC/MS) of selected samples. Double bond position of monounsaturated PLFA was discovered by GC/MS analysis of the dimethyl disulfide (DMDS) adducts. Methyl nonadecanonate (about 19:0) was used as the internal standard, and the PLFA expressed as equivalent peak response to the internal standard.

Data analysis is commencing using both biomass and relative proportion of PLFAs expressed per gram of soil. In addition to traditional ANOVAs, exploratory multivariate statistical methods such as Principal Components, Discriminant, and Hierarchical Cluster analysis are being used to discover trends in the data, and may be used to develop hypotheses for testing with the next sample set.

Stream chemistry and biology indicators

We have continued processing and analysis of stream water samples collected during the period December 1999 to March 2000. Based on the storm concentration profiles of ammonium and nitrate, these metrics may be promising disturbance indicators. Both ammonium and nitrate concentrations were positively related to discharge rates and the rate of change in discharge rate on the rising limb of hydrographs in the three disturbed streams, with weak positive relationships found for the reference stream, Lois Creek. During baseflow, ammonium and nitrate concentrations were consistently elevated only for the most disturbed stream (upper Sally Branch), indicating that baseflow suspended sediment concentrations are not a sensitive measure of disturbance. Analyses of dissolved phosphate concentration profiles during storms at these sites may provide an additional disturbance metric. These samples will be analyzed soon.

Benthic invertebrates and their habitats were resampled (5 to 13 May and 4 Aug to 18 Sept 2000) in six of the original seven streams (upper Sally Branch-F2/F3, upper Pine Knot-K20, Lois Creek-K13, Bonham Creek tributary-D13, Bonham Creek tributary-D12/D13, Lizzy Branch-A17), using Hester-Dendy multiplate and sweep net methods. Continued monitoring of some sites has been hampered by the Summer 2000 drought. The seventh stream (Randall Creek tributary-O13S), which replaced stream O13N found to be intermittent in May, itself became intermittent during August, and was abandoned. Selection of a replacement site (for O13S) and several additional sites (new reference and high-disturbance sites) will be made in October 2000 during summer baseflow. Site selection during this period should help assure that all new sites are perennial.

During this period we observed the following ranges in physico-chemical parameters across the seven streams: water temperature (18-20.7° C); pH (4.65-6.82); conductivity (8-29 µS/cm); dissolved oxygen (2.54-8.46 mg/L); turbidity (1.23-7.49 NTU), total dissolved solids (TDS - 13-45 mg/L), water depth (0.03-0.15 m), channel width (0.7-2.1 m), and current velocity (0.04-0.22 m/s). Coarse woody debris (CWD) in the channel ranged from almost zero (upper Pine Knot - K20) to more than 50 percent of the sampling reach containing CWD (Bonham Creek tributary-D12/D13).

Stream sediment movement (accretion, erosion), as measured by scour pins (4 to 5 per stream), tended to be higher in watersheds receiving medium to high military training intensity (i.e., average of a 22.5-mm decrease in streambed elevation, or erosion; n= 3 streams) than in low-disturbance or reference watersheds (i.e., 3.0- and 4.4-mm decrease in streambed, respectively). Using this measure, beds of low-disturbance streams appeared more stable than those of high-disturbance streams. We therefore would predict lower benthic invertebrate diversity and lower abundance of intolerant species in high-disturbance streams.

Laboratory sorting, identification, and enumeration of invertebrates collected during November 1999 and May 2000 are ongoing, as are compilations of reference collections of all invertebrate taxa for each stream. Preliminary data from multiplates collected during the November to January sampling period indicates that streams were somewhat variable in invertebrate species, ranging from 3 to 8 Ephemeroptera, Plecoptera, and Trichoptera (EPT) species per site (i.e., total number of species within the three most pollution-sensitive aquatic insect orders(EPT) and from 22 to 45 total species per site. Richness appears highest in the reference stream (Lois Creek-K13) and relatively lower in streams draining watersheds with moderate to high military disturbance, especially Bonham Creek tributary-D12/D13.

Terrestrial biotic indicators of change along an anthropogenic disturbance gradient within a longleaf pine habitat, Virginia Dale (Oak Ridge National Lab) and Suzanne Beyeler (Miami University)

Introduction

Anthropogenic activity within a landscape is typically expressed as a complex gradient of modified and altered ecological components and changes in natural disturbance dynamics and succession patterns. Human activity may affect the presence of appropriate species, populations, and communities as well as the occurrence of processes at various rates and scales, which collectively are referred to as ecological integrity. Understanding the implications of anthropogenic disturbances on the integrity of a system is complicated by spatial and temporal variability in the system's response to modification and alteration. Clearly however, land managers need to have a basic understanding of the effects of human-induced changes on ecological integrity. Only with such an understanding can a land manager effectively focus management efforts and resources on the best environmental management practices.

The longleaf pine (*Pinus palustris*) forest system of the southeastern United States is a clear example of the effects of anthropogenic activity on a natural system. Forests of the southeastern United States comprise an ecological landscape that has experienced significant anthropogenic activity in the form of land development, resource utilization, and changes to the natural disturbance regime. The need for a clear understanding of human impacts on the longleaf pine system and its associated species and ecological functions takes on even greater importance when considering the fact that much of the remaining longleaf pine forest supports not only ecological processes but also a multitude of human use activities.

Our perspective is that a suite of indicators is necessary to capture the full spatial, temporal, and ecological complexity that should be measured. We, therefore, have proposed a candidate suite of indicators for longleaf pine forests at Fort Benning, GA, that together characterize the spatial and temporal scales of interest as well as the diversity in soils and other environmental gradients. Understory vegetation is the element of this suite thought to represent ecological changes that may occur over a few years to decades within a forest stand and should reflect the differences in military training regime.

Study

The study was conducted at Fort Benning, GA, which occupies 73,503 ha in Chattahoochee, Muscogee, and Marion Counties of Georgia, and Russell County, Alabama. The study was designed based on a subjective stratified sampling methodology. The study was blocked based on five training intensity categories (minimal, light, moderate, heavy, and restoration). Study site locations were limited to land areas suitable for longleaf pine growth. Determination of potential site location was achieved by using a combination of existing forest stand information. The classification of each training compartment was primarily based on historical records of training activity. However, due to the variability of training intensity within a training compartment, final site selection was achieved through personal communications with natural resource personnel and field reconnaissance. Training intensity categories are defined in Table 9.

Table 9. Definition of training intensity categories used for study site selection.

Minimal Training	Areas often included in exclusion zones around firing ranges, therefore experiencing little to no training activities.
Light Training	Areas limited to infantry training and individual orienteering activities.
Moderate	Areas adjacent to tank training zones, exposed to moderate amounts of tracked vehicle maneuvers, as well as light vehicle and infantry traffic.
Heavy	Ares used exclusively for heavy wheeled and tracked vehicle training exercises.
Restoration	Areas which have historically been significantly degraded through military activities, but are currently off limits to military training activity and are undergoing restoration efforts.

Three study areas were located in each of the minimal, light, moderate, and heavy training classifications. Two areas were located in zones classified as "restoration." We randomly placed one transect within each of the 14 study areas.

All species identification and characteristics descriptions were based on Godfrey (1988) and Radford, Ahles, and Bell (1968). All species identified were assigned a percent cover score and a sociability classification based on a modified Braun-Blanquet classification system (Clarke 1985). All identified species were also classified using Raunkier's life form classification system (Kershaw and Looney 1985) based on the height of perennating buds.

Preliminary Results

Analysis of variance (ANOVA) was used to examine for differences in the ranks of the cover scores for all species found within the plots (i.e., zeroes were eliminated). There were significant differences in the cover ranks by life forms within the light, medium, and moderate intensity classes and the restoration sites, but not within the heavy intensity sites (Table 10). The two-way ANOVA showed significant differences in cover ranks considering both life form and training intensity. Analysis of the data is continuing in an effort to select individual species or groups of species that are indicative of change.

Fort Benning PLFA analysis (Aaron Peacock and David White)

The data analysis phase is ongoing. To date a traditional ANOVA has shown significant differences related to land use for several soil microbiological variables. A brief list of results is given below.

Statistical analysis of PLFA profiles

The relative proportion (percentage mole fraction) or biomass (pmol/g) of PLFA was used to test the null hypothesis that degree of land use would not influence the composition of the soil microbial communities. To test that hypothesis, we used an ANOVA using the General Linear Model STATISTICA procedure (Statsoft Inc., Tulsa, OK) for a completely randomized design with four treatments. The values reported are least square means of 15 replicates; standard errors of the means were determined. Differences in the mean proportions of PLFA in each treatment were tested using a Fisher's Least-Significant-Difference procedure.

Table 10. Frequency of understory species representing major life forms in training treatments.

Life form	Training intensity				Restoration	Total
	Minimal	Light	Moderate	Heavy		
Phanerophyte	96	153	46	1	43	339
Chamaephyte	32	33	25	0	15	105
Hemicryptophyte	132	87	36	0	54	309
Cryptophyte	152	136	92	27	83	490
Therophyte	17	27	69	20	32	165
Total	429	436	28	48	337	1408

The microbial biomass in the soil decreased with increased land use (Figure 6). Specific PLFA components can be related to certain subsets of the microbial community, and PLFA patterns can be used to define changes in the community composition. What follows are some standard PLFA groups that can describe certain portions of the soil microbial community structure.

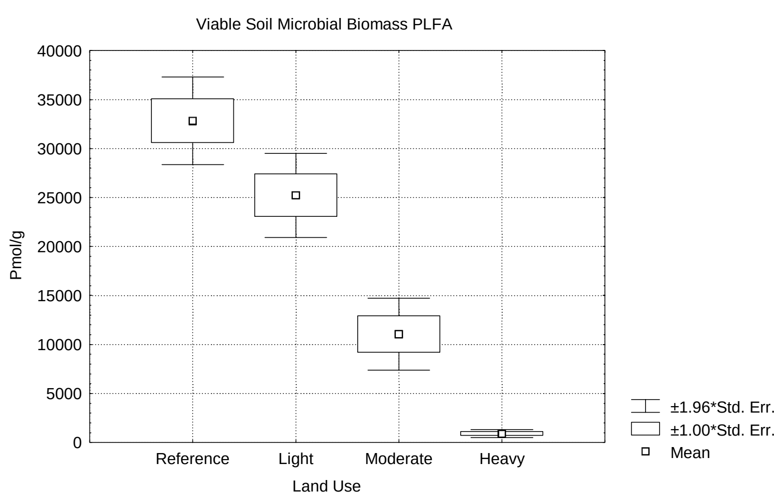


Figure 6. Viable microbial biomass.

Normal saturated PLFA is a general microbial marker and a relative increase has been shown to correlate with decreased diversity. In Figure 7, the increase in this marker suggests a decrease in diversity. Monounsaturated PLFA's are indicative of predominantly Gram-negative bacteria. An increase in the amount and type of carbon sources has been shown to increase this marker.

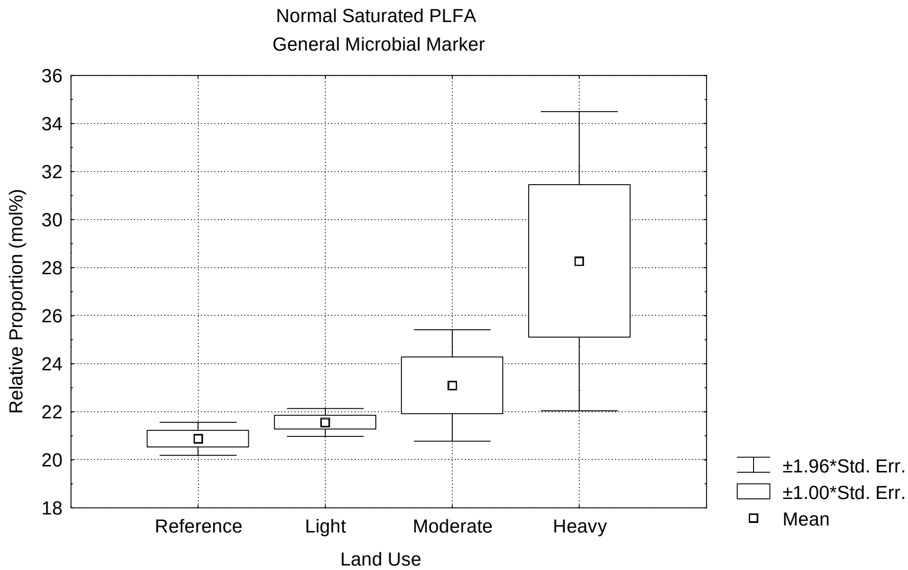


Figure 7. Normal saturated PLFA.

Terminally branched saturated PLFA (Figure 8) are indicative of Gram-positive bacteria, including Arthrobacter and Bacillus spp. Many of these types of bacteria can be spore formers and can exist in environments that are lower in overall organic carbon content.

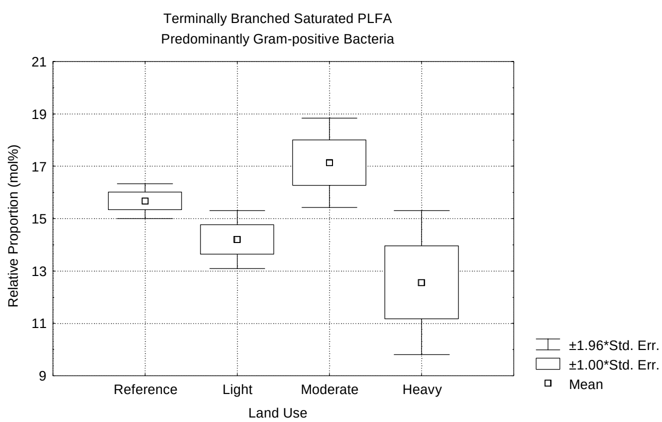


Figure 8. Terminally branched saturated PLFA.

Threshold Projects

The objective of the FY00 SON entitled, “Ecological Disturbance in the Context of Military Landscapes,” 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. Two research projects were selected to support the SON (Table 11).

Table 11. Research projects supporting the SON for threshold projects.

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 for this proposal is Mr. Charles Garten, Jr., from Oak Ridge National Laboratory, Oak Ridge, TN. Other team members are listed in Table 12.

Table 12. 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 study 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.

Progress to Date

Research efforts during April through June 2000 focused on laboratory analyses of soil samples from the sampling sites and the preparation of soil samples from approximately 40 sites under 5 different land covers visited at Fort Benning during March 2000.

Sampling Sites

Surface soils were sampled in 1999 along a gradient that included five levels of military disturbance (light, medium, and heavy use, as well as reference and remediated sites). Light-use sites were subject to infantry training and heavy-use sites were subject to tracked vehicle training. Reference and light-use sites had 75 to 100 percent vegetation cover while heavy-use sites had less than 5 percent vegetation cover. The soil samples were analyzed for differences in bulk density, soil C and N concentrations, soil C and N stocks, and C:N ratios. Composite soil samples were prepared from the 14 sampling locations for analysis of soil C and N associated with particulate organic matter and mineral associated organic matter. The composite soil samples were also prepared for analysis of anaerobic net N mineralization potential.

LCTA Sampling Sites

Soil samples collected in March 2000 from 40 sites at Fort Benning (many near LCTA [Land Condition Trend Analysis] sampling sites). The study design included five different land cover/land use categories: deciduous forest, evergreen forest, mixed forest, transitional grassland, and barren land. Soil samples were prepared for C an N analysis, analysis of particulate organic matter, soil aggregate stability, and net N mineralization potential. Aerobic laboratory incubations were initiated to measure net N mineralization potential and samples were also prepared for anaerobic laboratory incubations to measure ammonification potential.

A primary objective of the research during the first year was to characterize the effect of military land use on key measures of soil quality and on the potential recovery of soil quality on disturbed lands at Fort Benning, GA. A preliminary analysis indicated significant changes in key measures of soil quality along the disturbance gradient. Medium and heavy military use was associated with increased surface soil bulk density, reduced soil C and N inventories, and lower soil C:N ratios. Soil C and N stocks in particulate organic matter were also lower at medium- and heavy-use sites than at reference and light-use sites. Some measurements at remediated sites indicated a recovery of soil quality following military disturbance. Some soil properties (in particular soil C and N stocks and measures of soil N availability) differed by land cover/land use category at Fort Benning. We are currently in the process of analyzing and interpreting the data from the first year's work along the disturbance gradient and at the LCTA sampling sites. Soil properties under different land cover categories are being compared using analysis of variance and differences among individual sites are being explored using multivariate statistical methods.

Research efforts during July through September 2000 focused on the statistical analysis and interpretation of data from laboratory analyses of soil samples collected along a disturbance gradient in the Fall of 1999, and from sites visited at Fort Benning during March 2000.

Disturbance Gradient

Laboratory analyses of soils from 14 sampling locations along a gradient that included 5 levels of disturbance history (light, medium, and heavy use, remediated, and reference sites) were summarized into different electronic data files. The data were analyzed using various statistical methods to test hypotheses about how differences in soil quality are associated with soil disturbance. We have concluded that there are statistically significant differences in measurements of soil quality along a disturbance gradient and that these differences deserve further attention and confirmation during FY01 at a different set of sites at Fort Benning.

Land Use/Land Cover Sites

Soil samples collected in March 2000 from 40 sites at Fort Benning were analyzed for a key set of variables related to soil structure, nutrient availability, and biological activity. Data on soil C and N, particulate organic matter, soil aggregate stability, and net nitrogen mineralization potential were summarized into electronic data files and the data were analyzed using analysis of variance and multivariate statistical methods to arrive at a better understanding of the effect of land use/land cover (LU/LC) on measures of soil quality at Fort Benning. In addition, we used a raster-based GIS program to construct preliminary maps of soil C and N stocks under different LU/LC categories.

At this time, we have concerns about achieving one of the original objectives of the project which was determination of thresholds that establish a potential for recovery of soil quality on disturbed lands at Fort Benning. A quantitative measure of site disturbance is needed because current measures, like training days per year in a compartment, are imprecise and visual classifications of disturbance are subjective. Multivariate statistical methods hold some promise for empirically classifying sites according to their position along disturbance gradients, but such methods are data intensive. We may be able to move toward an empirical classification scheme based on two or three readily measured variables related to soil structure, nutrient availability, and microbial activity, but these measures will need to be tested with field experiments and further soil sampling to ascertain their efficacy as measures of site disturbance and soil quality.

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

The principal investigator for this proposal is Dr. Beverly S. Collins from Savannah River Ecology Laboratory, Aiken, SC. Other team members and the task/topic they will be working on are listed in Table 13.

Table 13. Research team members for "Thresholds of Disturbance: Land Management Effects on Vegetation and Nitrogen Dynamics."

Name	Task/Topic	Institution
R. Sharitz	Plant Ecology	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 involves 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 our 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 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-yr cycle, burned on a 4-yr cycle, thinned, unthinned) and to either heavier (open to vehicles) or lighter (primarily infantry) military use.

Progress to Date

Research efforts during the first year concentrated on identifying sites and conducting a baseline vegetation survey. Upland mixed pine-hardwood sites subjected to prescribed burning during the Winter 1999-2000 were chosen. A 100- x 100-m sampling plot was established in each site. Canopy tree (point-quarter method), shrub (line intercept), and ground layer (line intercept) composition were determined each 20 m along 5 sampling transects in each sampling plot.

Initial data analyses were conducted during September and October to determine if there are pretreatment differences in vegetation among sites. We wished to determine if any differences are related to site characteristics, such as soil type or land use history, or could confound treatment allocation. Preliminary analyses indicate no differences that could confound treatment allocation. Vegetation differences among sites do reflect site characteristics and land use history. Tree density is greater on sites with lighter vs. heavier military training. The range of tree density is greater on clayey soil than sandy soil, which suggests a greater effect of disturbance on tree density on clayey soil. Tree species richness is similar for both soil types and is reduced by approximately 50 percent with heavy land use.

4 Environmental Characterization and Monitoring Initiative (ECMI)

The ECMI is structured in three phases as described in the Executive Summary Long-Term Monitoring Program Fort Benning, GA, Version 2.1 (Kress 2000). The ECMI is currently in the Phase I (FY99-FY01): the extended design and implementation phase. Several components of the characterization and monitoring plan were still in the design phase in late 1999 and early 2000, while other components were ready for the implementation process. However, all components will be implemented and resampling or monitoring will be underway by end of 2001.

Aquatic Component Implementation and Monitoring

Aquatic monitoring activities, other than meteorology, are sited near the outlet of the selected watershed units. Measurements taken in these outlet locations represent spatially integrated values for the drainage area upstream of the site (Executive Summary, April 2000).

Meteorology

During late 1999 and early 2000, ten meteorological stations were installed throughout the installation to represent the installation as a whole, rather than specific watershed units (Figure 9). Air temperature, relative humidity, barometric pressure, solar radiation, wind speed, wind direction, precipitation, and evaporation (1 station) data are downloaded daily to a server at ERDC/EL. These data are then converted to a format compatible with the data repository, edited, and placed on the repository on a monthly basis. Currently, meteorology data through December 2000 are on the repository. Based on a request from the Research Coordination Group and the Technical Advisory Committee, a process is being developed to allow the meteorology stations to download data on a daily basis directly to a discrete site on the repository in an unedited format. Software will be provided to the point of contact at ERDC/CERL and installation personnel to allow near-real-time access to the data from the repository. This should be completed in early 2001.

Figure 9. Ten ECMI meteorological stations on Fort Benning.

Surface water quality

The ECMI Design Plan (Kress 2000) called for surface water quality to be monitored at six locations. Five of these represent entire watershed units (Sally Branch, Bonham, Randall, Oswichee, and Little Pine Knot), and one midstream station is on Upatoi Creek near the northern installation boundary. Because of drought conditions during 1999 extending through 2000, and subsequent low stream flow, only three of the six hydro labs could be installed in early 2000. These were removed during early Summer 2000 due to further reduction in stream flow. Currently, only stream level is being monitored. We expect to redeploy the full hydro labs during Spring 2001.

Surface water flow

The ECMI design plan (Kress 2000) called for surface water flow to be monitored in 10 locations. Six of these locations are integrated with the water quality stations and 8 of the locations represent watershed units. The remaining two are midstream stations in Uchee Creek near the western boundary and Upatoi Creek near the northern boundary. Because of the extended drought conditions, only the six integrated with the hydro labs were deployed during 2000. We expect to deploy all flow sensors during Spring 2001.

Rapid Bioassessment Protocol (RBP) and aquatic productivity and decomposition

Based on a preliminary reconnaissance of 10 suitable stream sites made on 23 and 24 May 2000, it was determined that the RBP and aquatic productivity and decomposition components should be postponed until stream flow conditions improved. The procedures were conducted on 5 and 6 December 2000 for nine of the sites (Table 14). Halloca Creek at Red Diamond Road was not suitable for sampling since the water was too low; therefore, it will be excluded from the sampling program.

Table 14. Data from aquatic sites at Fort Benning 5 and 6 Dec 2000.

GPS Latitude (N)	GPS Longitude (W)	Site	Location	Code	RBP	Prod & Decomp	Invert Col
32.384756	84.866536	1	Field Laboratory				
32.420606	84.695578	2	Little Pine Knot	LPK	x	x	x
32.419335	84.837434	3	Wolf Creek	WC	x	x	x
32.454633	84.791102	4	Randall Creek (at Buena Vista)	RC	x		x
32.438427	84.738118	5	Sally Branch	SB	x	x	x
32.426341	84.764425	6	Bonham Creek	BC	x	x	x
32.295830	84.977285	7	Uchee Creek	UCC	x		x
32.541115	84.725331	8	Cox Creek	CC	x		x
32.518984	84.697718	9	Upatoi Creek	UPC	x	x	x
32.305877	84.939691	10	Oswichee Creek	OC	x	x	x

The procedures will be conducted once a year for the next 5 to 10 years as part of the SEMP. Plans were to collect samples in the Fall; however, a decision was made to perform the work in April or May starting in 2001 because of uncertainty over water levels in streams during the Fall. The extended drought in the southeast for the past 2 years made fall aquatic sampling in small streams virtually impossible (Figure 10).

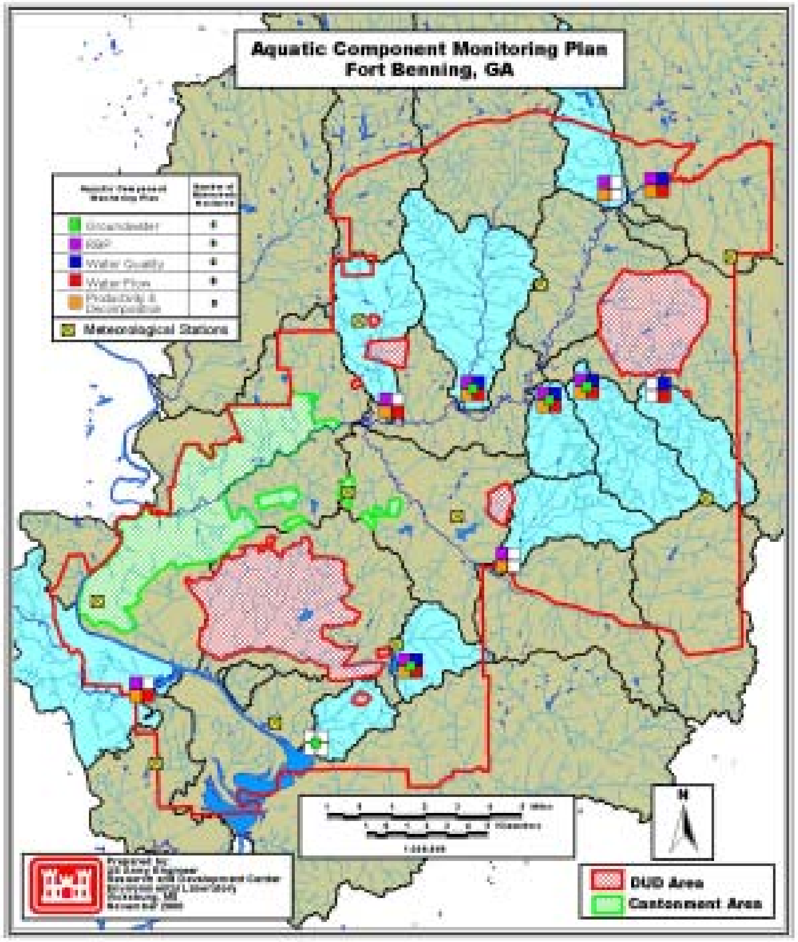


Figure 10. ECMI aquatic component monitoring plan (November 2000).

Summary of Field Work

The RBP was conducted at all sites and samplers were deployed to monitor leaf decomposition and primary productivity at six sites. Samplers were not deployed at Uchee Creek because it appeared this area received much public use, leaving concern that research materials could be vandalized. Discharge in Randall Creek was too low to deploy samplers although the site will be sampled in the Spring. No samplers were placed at Cox Creek.

Three sets of samplers were deployed at each of the six sites. Each set contained (1) preweighed leaves held in a 0.5-mm mesh bag, (2) a plastic box containing 10 glass microscope slides, and (3) preweighed leaves held in a 5-mm mesh bag. After 4 weeks the samples will be retrieved. Leaves will be dried and weighed to determine decomposition rate in water with and without the presence of macroinvertebrates (most macroinvertebrates are excluded by the 0.5 mm mesh). The amount of algae (periphyton) that colonizes the glass slides will be weighed to measure primary production.

In addition, photographs were acquired and collected, and three naturally occurring leaf-packs were obtained at all nine sites. The photographs will be used to describe habitats and to monitor changes brought about by changes in season or climate. A leaf-pack is an accumulation of leaves that has become trapped among twigs, rocks, or roots in moving water. Leaf-packs accumulate silt and sand, as well as macroinvertebrates, and provide an indicator of past conditions. Leaf-packs were returned to the laboratory for processing. Macroinvertebrates will be identified from each, and the total particulate matter (sand and silt) associated with the leaves will be extracted and weighed. The dry weight (to 60° C) of the leaves will be recorded, and an ash-free weight (fired to 550° C) will be obtained for a measure of total organic content.

The RBP was used to collect physical, biological, and chemical data (Table 15) at each site. Some biological information (presence/absence of major taxa) was taken at each site and will be augmented with taxonomic data from the leaf packs. The physical, chemical, and biological information will be summarized into index scores that reflect the overall health of the ecosystem.

Table 15. Water quality measurements at nine stream sites.

Way-Point	Location	Date	Time	Water Temp (°C)	Specific Cond (micromho)	DO (mg/l)	pH
2	Little Pine Knot	5 Dec 00	1000	5.5	37	11.4	5.3
3	Wolf Creek	5 Dec 00	1130	7.7	31	10.6	5.8
4	Randall Creek at Buena Vista	5 Dec 00	1300	8.6	90	12.5	7.6
5	Sally Branch	5 Dec 00	1400	4.5	52	12.7	3.8
6	Bonham Creek	5 Dec 00	1430	6.4	33	11.9	4.3
7	Uchee Creek	5 Dec 00	1630	8.8	83	12.2	6.0
8	Cox Creek	6 Dec 00	930	3.4	99	11.6	6.3
9	Upatoi Creek	6 Dec 00	1030	6.0	30	12.0	6.0
10	Oswichee Creek	6 Dec 00	1245	6.1	44	11.8	4.2
			Min	3.4	30	10.6	3.8
			Max	8.8	99	12.7	7.6
			Mean	6.3	55	11.9	5.5

Findings/Future Considerations

1. A low pH, and low dissolved solids characterize these streams. Typically the most productive flowing water systems are neutral or slightly basic (pH 7 to 8), with high dissolved solids (specific conductance greater than 300 micromohos).

2. Substratum at most sites consisted of clean sand with small amounts of gravel and little or no cobble. Macroinvertebrates typically are most productive in gravel and cobble substratum.
3. Streams consisted of riffle/run habitat rather than the more common pool/riffle habitat.
4. No evidence of pollution was detected and there was minimum physical disturbance at all sites. The lack of stable substratum (presence of shifting sands) made the habitat fairly unsuitable for many aquatic macroinvertebrates; however, this appeared to be related more to local soil and topographic conditions than to land use.
5. Leaf-packs and glass slides will be retrieved in early January. All data from the RBP will be analyzed by February. Leaf packs will be analyzed by late February or early March.
6. A combination of field evaluations (RBP), and data on primary production and leaf decomposition, as well as data from naturally occurring leaf-packs, will provide an excellent monitor of the aquatic ecosystem at Fort Benning.

Ground water level

The shallow alluvial ground water level will be monitored at the five surface water quality sites. This component is designed to allow quantification of the ground water contribution to surface flow for five watershed units. A contract was awarded in August 2000 to have the wells drilled. The permitting process was then initiated and permits were issued in December 2000. The initial plan was to drill the wells during January 2001; however, the intense training schedule at Fort Benning during January and February 2001 prevented access to the training compartments. Plans are to drill the wells during March and April 2001. The contractor will be provided an explosive ordnance disposal (EOD) briefing and training in March and the wells will be established in late March and April 2001.

Terrestrial Component Implementation and Monitoring

The USGS hydrologic unit which includes Fort Benning is the organizational basis for analysis of remote sensing data to support the terrestrial component monitoring program (Kress 2000). This component focuses on changes in regional land cover characteristics.

Net primary productivity

Regional net primary productivity will be obtained from the NASA Earth Observing System Satellite, MODIS (Moderate Resolution Imaging Spectroradiometer). Data will be acquired directly from NASA for the Fort Benning region as soon as they are available. Net Photosynthesis and Primary Productivity (MOD17) are tentatively scheduled for release in March 2001.

Land cover type and vegetation density indices

LandSat Enhanced Thematic Mapper (ETM) imagery was acquired during 2000 and image analyses was initiated. A land cover map and vegetation indices were developed (December 2000) and will be transferred to the repository in March 2001. An accuracy assessment of the land cover map will be completed by end of June 2001. Additionally, MODIS data (MOD12) is scheduled to be made available for Land Cover/Land Cover Change by the end of March 2001.

Land cover pattern

Statistical analysis of landscape fragmentation will be used to develop a vegetation pattern analysis data layer during July through September 2001. These data layers will be included in the repository.

Soil erosion and deposition dynamics

The design for the erosion/deposition characterization and monitoring technique was completed during Spring 2000 (Kress 2000); however, in an effort to work more closely with the SEMP researchers, implementation was delayed until Spring 2001. A new laser tracker system was evaluated and will be used to measure ground surface profiles at designated sites and determine erosion/deposition dynamics. This technique will provide data for accurate determination of erosion and deposition at both the watershed unit scale and the installation scale. The procedure will be implemented during March and April 2001 and the first resample during September and October 2001. Resampling will be on a yearly basis thereafter (Table 16).

Woody productivity

Work has been initiated to develop a process to estimate woody productivity. Coordination is underway with the Installation Forester, Fort Benning, to review the existing forest stand inventory database. The procedure will be tested in March 2001 and woody productivity will be calculated on an annual basis as part of the data analysis and modeling component of ECMI.

Table 16. Summary of ECMI components, implementation, or anticipated implementation; planned sampling schedule for monitoring.

	Field equipment installed or Lab work started	Anticipated field installation or Lab analysis	Sampling frequency
Meteorology	Late 1999 and early 2000 (10 stations)		daily
Surface Water	Late 1999 and early 2000	Re-install Spring 2001 (6 full hydro-labs, plus 9 flow sensors)	daily
Ground Water		March/April 2001 (5 wells)	daily
RBP and Aquatic Macro-invertebrates	Dec 2000 (9 sites)		Each Spring
Aquatic Productiv-ity/Decomp.	Dec 2000 and Feb 2001 (7 sites)		Each Spring
Land Cover Data	Oct – Dec 2000	On-going	Acquire LandSat image each year and MODIS data when available
Soil Erosion/Deposition		March/April 2001	Each Autumn
Woody Productivity		March/April 2001	In conjunction with Forest Inventory
Data Analysis & Modeling	Oct – Dec 2000	On-going	

Data analysis and modeling

During 2000 the data analysis and modeling component was initiated. Several standard summary type analyses have been developed for the meteorology data. These derived data will be included with the original data in the data repository. Conceptual level demonstrations of three models that should have direct relevance to Fort Benning management needs will be developed. These models are the Two-Dimensional Cascading (CASC2D) overland flow model, the Ecological Dynamics Simulation (EDYS) model, and the Training Use Distribution Model (TUDM). Data from the ECMI repository, along with other needed data will be used to parameterize conceptual versions of these models for initial demonstration purposes during 2001.

5 Data Repository

The SEMP/ECMI Data Repository is operational and located at http://206.166.205.173/ (Figure 11).

Figure 11. SEMP/ECMI Data Repository 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.

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 RDBMS based.

The four main design components of the ECMI data repository are illustrated in Figure 12. These components are Data Storage, Data Index, User-Web Interface, and the User Profile.

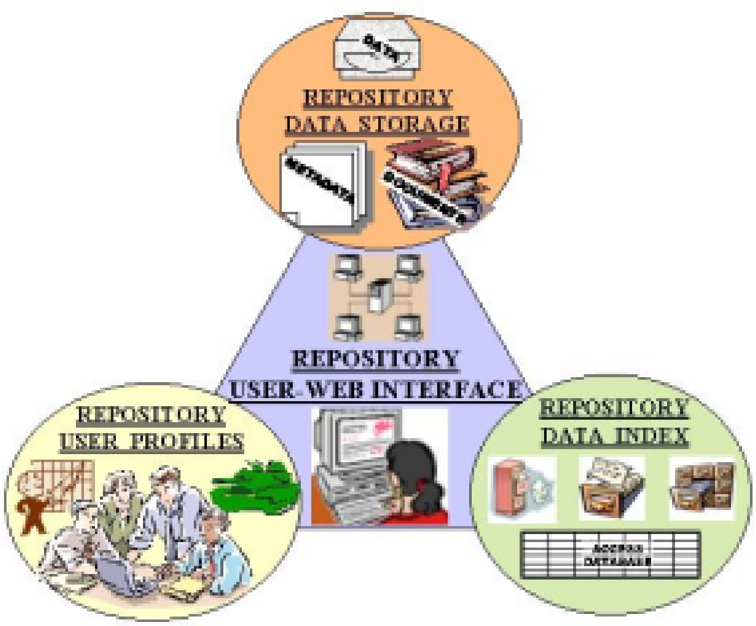


Figure 12. ECMI conceptual design components.

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 Spatial Data Standard/FIE (version 1.95, 1999). Figure 13 shows the directory structure of the repository.

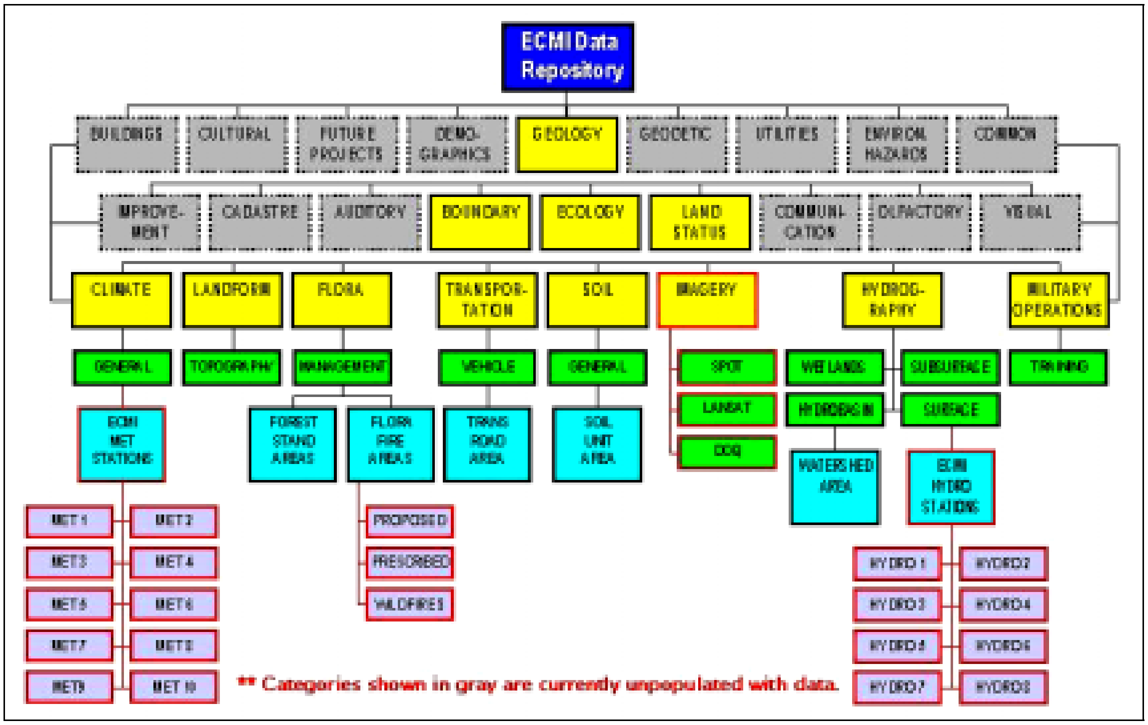


Figure 13. ECMI Data Repository directory structure.

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 17 shows the Index items. Most Index items can be used as search fields. The repository is not searchable by geographic coordinate.

Table 17. ECMI Data Repository standard index fields.

ECMI – Data Repository Index

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 Web browser. Either Microsoft Internet Explorer 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 Fort Benning 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 13 indicates the SDS/FIE entity sets that contain data.

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 (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 that contain the metadata. Geospatial data are accompanied by metadata meeting the Federal Geographic Data Committee/Content Standard for Digital Geospatial Metadata (FGDC/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.

User Concerns

The two primary users concerns for the SEMP repository are:

1. The availability of certain data about Fort Benning military installation, outside of the installation and the SEMP participants
2. The availability of data collected by the researches, to those outside the SEMP circle, before the SEMP members complete academic publications.

6 FY00 Accomplishments

Presentations

- March 2000. A briefing was given, by Bill Goran (SEMP Program Manager), John Brent (Chief, Fort Benning Environmental Management Division), and Suresh Rao (Purdue University), to the Scientific Advisory Board (SAB) on March 15, 2000. This briefing discussed the SEMP objectives and plans; SAB issues (from the last meeting); research projects, highlighting the University of Florida's work, host installation perspective, and the FY2001 and future plans. The briefing was well received and the SAB approved the program/funding plan for FY01.
- April 2000. Bill Goran and Rose Kress gave a briefing to the SERDP Conservation Technical Thrust Area Working Group (TTAWG). This briefing highlighted the status and progress of SEMP and also the work being done on the repository effort.
- May 2000. Bill Goran gave a briefing to the Army Conservation Technology Team. This briefing highlighted the status and progress of SEMP and the work being done within each of the five research projects.
- August 2000. SEMP participated in a workshop, booth, and discussion forums at the Ecological Society of America meetings held in Utah. Bill Goran, John Brent, Eileen Regan, Bob Holst, and Susan Walsh all participated in these meetings. The booth space and workshop were shared between SEMP, SERDP, and the Legacy Resource Management Program.
- October 2000. A SEMP overview briefing was given to the SERDP Scientific Advisory Board on 20 October 1999, by Bill Goran, SEMP Project Manager; Rose Kress, ECMI Principal Investigator; and Virginia Dale, ORNL. This briefing was given to provide an update on SEMP progress and to formalize approval for the FY00 plans.

Workshops

SEMP Framework Workshop in Columbus, GA, 9 and 10 November

Representatives from the SEMP research teams, ECMI, Fort Benning, ERDC, the SERDP program office, and the SEMP TAC spent a day and a half discussing and developing a preliminary integrated framework for the SEMP. The expectation of the meeting was to begin to define a structure and/or process to incorporate findings and results generated by the baseline monitoring and individual research projects into a conceptual framework that would serve to demonstrate the intent and purpose of SEMP. The meeting was structured to present perspectives from each of the SEMP teams (i.e., researchers, installation managers, ECMI) and from Eglin AFB, FL, to articulate their needs and utility of an integrated framework.

SERDP Symposium, 29 November– 2 December 1999

Many participants in SEMP participated in the annual SERDP Symposium, held in Arlington, VA, on 29 Nov through 2 Dec 1999. Bill Goran, the SEMP Program Manager, gave a briefing in the technical session entitled, "Ecosystem Management Research for Preserving DoD and DOE Lands." There was a SEMP booth display, which allowed other participants in the symposium to learn about SEMP as well as talk to key players involved.

Research Coordination Meeting

Plans were made to host a Research Coordination Meeting during the month of November 2000. The purpose of this meeting is to coordinate the different SEMP research projects which are being conducted at Fort Benning. The meeting will help implement recommendations made by the TAC and TTAWG.

"Along the Fall Line" Workshop

A working group was formed in September 2000 to initiate and plan the *Along the Fall Line* Ecosystem Management Workshop, which will be held in March 2001. This workshop will be held at the Savannah River Ecology Laboratory, Aiken, SC. The working group for this workshop includes: Hal Balbach, Beverly Collins, John Hall, Eileen Regan, George Carellas (Army SE Regional Support Office), Nancy Herbert (USFS Research Unit), Doug Ripley, Hugh Westbury, and Bob Sargent (Warner-Robins AFB).

SEMP Host Site Coordinator

Ms. Patricia Kosky served as the SEMP Host Site Coordinator until March 2000. Hugh Westbury, a new ERDC/CERL employee, assumed this position in June 2000. The position of Host Site Coordinator for the SEMP is to provide logistic and coordination support for research and monitoring teams coming onto Fort Benning, to help field teams with site selection, site location, equipment requirements and other logistics, and to also sometimes provide some assistance in data collection. There are two SEMP points of contact at Fort Benning (John Brent, Chief of the Fort Benning Environmental Management Division) and Theresa Davo (Environmental Management Division). The SEMP Host Site Coordinator supports these Fort Benning SEMP POCs and supports the research and monitoring teams conducting activities at Fort Benning.

SEMP Newsletter

The first edition of the SEMP newsletter entitled, "SEMP Postings," was published during the 3rd quarter of FY00. This publication highlighted Fort Benning and John Brent, Chief of the Environmental Division; SEMP roots (column by the project manager Bill Goran); new Host Site Coordinator, Hugh Westbury; two FY00 research projects; and the SEMP website. A copy of this newsletter can be found on the SEMP website at http://www.denix.osd.mil/SEMP. The editor for this publication is Teresa Aden (Teresa.Aden@erdc.usace.army.mil). There is a plan to publish two newsletters during the calendar year.

Vehicles for SEMP Teams

Thanks to Harold Balbach, there are now two vehicles (both four wheel drive) at Fort Benning available for SEMP research and monitoring teams. SEMP teams contact Hugh Westbury to schedule use of these vehicles.

SEMP TAC Meetings

2 and 3 December 1999

The SEMP TAC met in Arlington, VA, on 2 and 3 December 1999. At this meeting, Dr. Beverly Collins and Mr. Chuck Garten gave a briefing on the two FY00 new start research projects. The TAC was pleased with the adjustments made in these proposals (from the August TAC meeting) and recommended them for funding. Dr. Dave Tazik gave an update on the ECMI current plans, which had been adjusted since the August meeting.

During this meeting, discussion was held regarding the direction on the planned process of the "framework" for SEMP. The concept of developing a "framework" for SEMP emerged from previous TAC meetings and SAB presentations. A decision was made, after the August 99 TAC meeting, to include a "framework development process" in the FY2000 plan for SEMP. A workshop was held in November at Columbus, GA, to gather researchers and interested TAC members and installation participants in an effort to focus this process.

25 and 26 April 2000

SEMP TAC met on 25 and 26 April 2000 at the SERDP office in Arlington, VA. This meeting was followed by an Ecosystem Management Workshop on the afternoon of 26 April.

The three FY99 new start research projects were briefed to the SEMP TAC – by Virginia Dale (Oak Ridge), Bill DeBusk (University of Florida), and Hal Balbach (ERDC/CERL). Also, Rose Kress briefed both the monitoring plan, as it is currently proceeding, and the data repository. The data repository was in testing, but it is now operational and ready to receive data from the teams.

As per requests from the December 1999 TAC meeting, Bill Goran briefed a draft "SEMP Framework Concept" as part of a general report on SEMP. This document and the monitoring plan document were sent to TAC members in a read-ahead package before the April meeting. At the meeting, a committee was organized to review/revise portions of this document. This committee, chaired by John Hall of The Nature Conservancy, includes Virginia Dale and Beverly Collins, who focused on the chapter on research framework, and Pete Swiderik and Richard McWhite, who are focusing on the chapter on installation business processes. John Hall wrote a new chapter, attempting to link the installation Integrated Natural Resources Management Plan with outcomes from SEMP. For the most part, this subcommittee has completed its work (the installation processes chapter is still being worked) and the document is now back with Bill Goran for review and integration of these new sections.

Also, Robert Lozar (ERDC/CERL) briefed the work being done by Hunter College in gathering data for the "Along the Fall Line" region extending from Benning easterly and northerly across Georgia and into the Carolinas. This region was suggested as the logical area to attempt to "extend" the work at Benning to other similar areas. This effort, which is now underway with delivery of data and analysis products scheduled for late summer 2000, will provide extensive background data about environmental characteristics, land use, land ownership, and other information relevant to the fall line region. During this briefing, Mr. Lozar indicated that a useful analysis would be to gather and compare the land use data over the past three decades. While this analysis was not scoped as part of the original effort, it appears that it will be included in an extension of this first effort. The entire "Along the Fall Line" effort is being paid from Army research funds, not from SERDP SEMP funding. But the effort is designed to compliment SEMP. At the TAC meeting, Bill Goran indicated that the SEMP plan in FY01 calls for a gathering of land holders, stakeholders, and other interested parties in the "Along the Fall Line" region to explore a suite of ecosystem management planning issues for this region. This meeting is planned for the Spring of 2001. Since the TAC meeting, further arrangements have been made regarding this event; the Savannah River Ecology Laboratory (SREL) has offered to host this event. Beverly Collins will serve as host, with her management concurrence and support.

Also at the TAC, preliminary arrangements were made for SEMP briefings at upcoming scientific meetings. Through the efforts of Mary Barber, briefings on SEMP, SERDP, and Legacy were presented at a special session on the evening of August 7th at the Ecological Society of America meetings in Snowbird, Utah. A special session on Military Land Management is planned for the American Society of Agronomy meetings in Minneapolis, MN in October 2000, thanks to arrangements by Harold Balbach. This session included talks by Bill DeBusk, David Price, and Hal Balbach related to SEMP.

Completed Reports

- Adeyemi, H., R. Awuah-Baffour, J. Wuichet, and M. Danjaji, *Scoping Requirements for a Regional GIS*, August 1999.

  The purpose of this project was to assist the Army and its partners and stakeholders in on-going efforts to develop a regional monitoring database for ecological and related socioeconomic factors of concern to natural resource managers at Fort Benning, GA. Rather than actually setting up a fully functional system, the level of effort for this project is simply to identify and characterize some of the variables and information architectures that might be included in a comprehensive prototype system.

  This report begins with an explanation of the process used to define the extent of the regional ecosystem, the sources and formats of the variables, and the process for identifying and selecting the narrower set of data that were subjected to statistical analyses. Then the GIS layers generated and the results of the statistical analyses are presented, along with an overview of the gaps identified, and an interpretation of their implications.

- "Inventory of Fort Benning, GA Existing Data and Summary of On-Going National Monitoring Initiatives," (draft) April 1999.

- "Preliminary Variable Evaluation and Selection of Fort Benning, GA for a Long-Term Monitoring Program," (draft) April 1999. Unpublished.

  This report discusses the research and conceptual framework for the ECMI, describes the basic design used to accommodate the long-term nature of the program, and presents a preliminary list of data proposed for inclusion in the Fort Benning characterization and monitoring program. This report discusses only the thematic content of the monitoring plan. A follow-up document will detail the specific spatial and temporal components needed to fully design and implement the monitoring program.

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

  The purpose of this workshop was to get input to the ecosystem monitoring plan in relation to the Fort Benning natural resource management goals and objectives. The workshop was conducted as a series of small group discussions organized around the goals and objectives as stated in the 1/7/99 draft version of the Fort Benning Integrated Natural Resource Management Plan (INRMP). Forty objectives were selected from the 1/7/99 draft INRMP for discussion during the workshop. These forty objectives were divided into three broad topic areas. The participants were also divided into three groups, and one topic area was assigned to each group. The topic areas were: (1) training needs and effects of training activities, (2) ecosystem characterization, monitoring, and management, and (3) longleaf pine, fire management, and threatened and endangered species.

  Participants in the workshop included representatives from the Fort Benning Directorate of Public Works, Environmental Management Division, the Directorate of Operations and Training, Range Division, The Nature Conservancy, and the ERDC/Environmental Laboratory.

- "Report of Research Workshop: 26-28 Jan 1999 (Vicksburg, MS)," April 1999. Unpublished.

  This workshop was structured to accomplish five objectives: (1) develop a complete and highly relevant list and definition of ecological processes to meet ECMI objectives, (2) provide a rationale to explain the selection of the above processes, (3) develop a complete and highly relevant list and definition of variables that will describe the above processes, (4) provide a rationale to explain the selection of the above variables, and (5) provide recommendations on stratifying the installation for measurement.

  This workshop involved selected members of the research and academic communities conducting environmental research, the SEMP researchers, and staff from Fort Benning. Participants in the workshop included representatives from five laboratories in theERDC: Coastal and Hydraulics, Construction Engineering Research, Cold Regions Research and Engineering, Environmental, and Geotechnical; the University of Florida; the Fort Benning Directorate of Public Works, Environmental Management Division; and the Directorate of Operations and Training, Range Division. A complete report (unpublished) about this workshop can be found on the SEMP website.

- U.S. Army Engineer Research and Development Center (ERDC), Ecosystem Characterization and Monitoring Initiative: Design Document for Long-Term Monitoring Program at Fort Benning, GA, July 1999.

  This report was prepared as a technical review draft for the ECMI. The ECMI will complement and support the SEMP research initiative and ongoing land management by providing a baseline of ecological data and information for use by SEMP research participants and partners and DoD land managers. Broadly speaking, the intent is to characterize the biotic and abiotic elements and associated processes and properties of ecosystems associated with Fort Benning and eventually other military installations. The ECMI will address both spatial and temporal dynamics within aquatic, riparian, and terrestrial settings in a manner consistent with the needs of the research and land management communities.

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

  To assist in the development of the data repository, the JAYA Corporation was tasked to do the following (this report summarizes their findings):

1. Conduct and summarize a review of current and developing geospatial and environmental data integration and dissemination technologies that can be used to make environmental databases accessible to multiple decision makers electronically.
2. Evaluate and summarize the current and future requirements of a long-term, integrated, environmental data repository.
3. Design and develop a database structure and data access interface design concept for an environmental data repository. The design will maximize the use of commercial off-the-shelf (COTS) software components for optimal performance and maximum flexibility and growth in the out years. The interface will support local and regional ecological monitoring networks and multiple ecosystem research efforts.
4. Develop for demonstration purposes a prototype environmental data repository collection, search, and retrieval interface designed in item 3 above. The interface will be NT based, and when fully implemented and developed, will allow Internet access to the environmental data repository.

- 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.

  In 1993, CERL became involved in the United States Geological Survey, Division of Biological Resources/National Park Service (USGS/NPS) National Vegetation Mapping Program by serving as an interagency peer reviewer. This initial involvement led to discussions on vegetation mapping alternatives for military lands and a completed vegetation map for Fort Benning, GA. To validate the vegetation map and help managers realize its potential use as a natural resources and military training management tool, an accuracy assessment was conducted.

  Armed with a field key to the plan communities on the Fort Benning map and a project sampling design, intensive fieldwork was conducted to collect the data required to assess the vegetation map's accuracy. Field data was analyzed and an error analysis of the map was completed. This report includes lessons learned and recommendations for future vegetation mapping and accuracy assessment projects.

- "Work Plan: Ecosystem Characterization and Monitoring Initiative (ECMI)," (draft) December 1998. Unpublished.

  This report describes the work plan for the Environmental Characterization and Monitoring Initiative (ECMI), which is supporting SERDP's research and development investment under SEMP.

  The goal of the ECMI is to design, develop, and demonstrate an ecosystem characterization and monitoring concept that meets the needs of the SEMP. While Fort Benning will serve as the initial demonstration site, the ECMI is intended to have broad applicability across the DoD. Research issues identified in the workshop findings and the information needs of DoD installations, as reflected at Fort Benning, will serve as a framework in this effort.

References

Alef, K. 1995. "Dehydrogenase activity." In: *Methods in applied soil microbiology and biochemistry*. K. Alef and P. Nannipieri, eds. Academic Press, Inc. San Diego, CA 92101.

Clarke, R. (ed.), 1986. *The Handbook of Ecological Monitoring.* Oxford: Claredon Press.

Godfrey, R. 1988. *Trees, Shrubs, and Woody Vines of Northern Florida and Adjacent Georgia and Alabama*. University of Georgia Press.

Elrick, David E. and W. Daniel Reynolds. 1992. "Infiltration from Constant-Head Well Permeameters and Infiltrometers". *Adances in Measurment of Soil Physical Properties: Bringing Theory into Pratice.* Soil Science Society of America Special Publication No. 30.

Karr, J.R. 1981. "Assessment of biotic integrity using fish communities." *Fisheries* 6:21-27.

Kershaw, K.A., and J.H. Looney, 1985. *Quantitative and Dynamic Plant Ecology* (3rd Ed). London: E. Arnold.

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

Kosky, P. 2000. "The microhabitat of small mammal species in west-central Georgia." M.S. Thesis. Columbus State University, Columbus, GA.

Ladd, J.N., and J.H.A. Butler. 1972. "Short-term assays of soil proteolytic enzyme activities using proteins and dipeptide derivatives as substrates." *Soil Biol. Biochem*. 4:19-30.

NRCS. 1997. "Soil Survey of Chattahoochee and Marion Counties, Georgia." United States Department of Agriculture – Natural Resources Conservation Service.

Radford, A., Ahles, H., Bell, R., 1968. *Manual of the Vascular Flora of the Carolinas*. University of North Carolina Press.

Sinsabaugh, RL, S. Findlay, P. Franchini, and D. Fischer. 1997. "Enzymatic analysis of riverine bacterioplankton production." *Limnology and Oceanography* 42: 29-38.

Tabatabai, T.M. 1994. "Soil enzymes." In*: Methods of soil analysis, Part 2. Microbiological and Biochemical properties*. SSSA book series no. 5, Soil Science Society of America, Madison, WI. pp. 775-833.

Thalmann, A. 1968. "Zur Methodik der Bestimmung der Dehydrogenaseaktivitat im Boden mittels Triphenyltetrzoliumchlorid (TTC)." *Landwirtsch Forsch* 21: 249-258.

van Genuchten, M.; F.J. Leij and S.R. Yates. 1991 "The RETC Code for Quantifying the Hydraulic Functions of Unsaturated Soils". Robert S. Kerr Environmental Research Laboratory Office of Research and Development, U.S. EPA.

CERL Distribution

Chief of Engineers
ATTN: CEHEC-IM-LH (2)

Engineer Research and Development Center (Libraries)
ATTN: ERDC, Vicksburg, MS
ATTN: Cold Regions Research, Hanover, NH
ATTN: Topographic Engineering Center, Alexandria, VA

Defense Tech Info Center 22304
ATTN: DTIC-O

SERDP (2)

8
6/01

REPORT DOCUMENTATION PAGE	*Form Approved OMB No. 0704-0188*

1. REPORT DATE (DD-MM-YYYY)	2. REPORT TYPE	3. DATES COVERED (From - To)
09-2001	Final	

4. TITLE AND SUBTITLE
Strategic Environmental Research and Development Program (SERDP) Ecosystem Management Project (SEMP) FY00 Annual Report

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
Harold E. Balbach, William D. Goran, Teresa Aden, David L. Price, M. Rose Kress, William F. DeBusk, Anthony J. Krzysik, Virginia Dale, Chuck Garten, and Beverly Collins

5d. PROJECT NUMBER
SERDP

5e. TASK NUMBER

5f. WORK UNIT NUMBER
CS-1114

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Engineer Research and Development Center (ERDC)
U.S. Army Construction Engineering Research Laboratory (CERL)
P.O. Box 9005
Champaign, IL 61826-9005

8. PERFORMING ORGANIZATION REPORT NUMBER
ERDC SR-01-3

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Strategic Environmental Research and
Development Program (SERDP)
901 N. Stuart St., Suite 303
Arlington, VA 22203-1853

10. SPONSOR/MONITOR'S ACRONYM(S)

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION / AVAILABILITY STATEMENT
Approved for public release; distribution is unlimited.

13. SUPPLEMENTARY NOTES
Copies are available from the National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161.

14. ABSTRACT

This report is an annual summary of the research activities and findings and the accomplishments for the Strategic Environmental Research and Development Program (SERDP) Ecosystem Management Project (SEMP). This report provides a brief background on SEMP; shows how SEMP is organized and describes the research focus of the different teams that are involved; gives a basic background and progress update on the five research projects, the Ecosystem Characterization and Monitoring Initiative (ECMI) and the data repository; and concludes with a description of accomplishments. This document covers Fiscal Year 2000 (FY00), which is the period of 1 October 1999 through 30 September 2000.

15. SUBJECT TERMS
Strategic Environmental Research and Development Program (SERDP), ecosystem management, SEMP, sustainable facilities, environmental managementStrategic Environmental Research and Development Program (SERDP) SEMP environmental

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
					Harold E. Balbach
a. REPORT	b. ABSTRACT	c. THIS PAGE			19b. TELEPHONE NUMBER (include area code)
Unclassified	Unclassified	Unclassified	SAR	84	(217) 352-6511 x6785