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MARTIN MARIETTA

Environmental Sciences Division Annual Progress Report for Period Ending September 30, 1991

Environmental Sciences Division
Publication No. 3826

MANAGED BY
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Environmental Sciences Division Annual Progress Report for Period Ending September 30, 1991

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Preface

This progress report summarizes the research and development activities conducted in the Environmental Sciences Division of Oak Ridge National Laboratory during the period October 1, 1990, through September 30, 1991. The report is structured to provide descriptions of current activities and accomplishments in each of the division's major organizational units. Following the sections describing the organizational units is a section devoted to lists of information necessary to convey the scope of the work in the division.

Abbreviations

ARARs	applicable or relevant and appropriate requirements
ARM	Atmospheric Radiation Measurement
BFDP	Biofuels Feedstock Development Program
BIOMOVS	International Biospheric Model Validation Study
BMAP	Biological Monitoring and Abatement Program
BMWTD	Biofuels and Municipal Waste Technology Division
BTX	benzene-toluene-xylene
CAS	Chinese Academy of Sciences
CDIAC	Carbon Dioxide Information Analysis Center
CDIARP	Carbon Dioxide Information Analysis and Research Program
CDRD	Carbon Dioxide Research Division
CEQ	Council on Environmental Quality
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	*Code of Federal Regulations*
COMPMECH	compensatory mechanisms in fish populations
CVI	Coastal Vulnerability Index
CYRTF	Coal Yard Runoff Treatment Facility
DCE	dichloroethylene
DDRP	Direct/Delayed Response Project
DGM	dissolved gaseous mercury
DM	dissolved mercury
DNA	deoxyribonucleic acid
DO	dissolved oxygen
DOD	Department of Defense (U.S.)
DOE	Department of Energy (U.S.)
ECG	Environmental Compliance Group
EDTA	ethylenedinitrilotetraacetic acid
EEO	equal employment opportunity
EFPC	East Fork Poplar Creek
EIA	environmental impact assessment
EIS	environmental impact statement
EMAP	Environmental Monitoring and Assessment Program
EPA	U.S. Environmental Protection Agency
EPRI	Electric Power Research Institute
ER	Environmental Restoration
ESD	Environmental Sciences Division
ESRI	Environmental Systems Research Institute
FDA	Food and Drug Administration
FERC	Federal Energy Regulatory Commission
GCM	general circulation model
GIS	geographic information system
GRIDSS	Global Resource Intelligent Decision Support System
GSI	gonadal somatic index
GSMNP	Great Smoky Mountains National Park
HBCU	historically black colleges and universities

HEC	herbaceous energy crops
IAEA	International Atomic Energy Agency
IEA	Institute for Energy Analysis International Energy Agency
IFIM	Instream Flow Incremental Methodology
IFS	Integrated Forest Study (funded by EPRI)
IIASA	International Institute for Applied Systems Research
IMI	infield methanol immersion
IR	infrared spectrometer
IUFRO	International Union of Forest Research Organizations
LTER	Long-Term Ecological Reserve
MCL	maximum contaminant level
MEI	minority educational institution
MM	monomethylmercury
MMO	monooxygenase
MP&T	modified purge and trap vial
NADP	National Atmospheric Deposition Program
NAPAP	National Acid Precipitation Assessment Program
NAS	National Academy of Sciences
NASA	National Aeronautics and Space Administration
NATO	North Atlantic Treaty Organization
NEPA	National Environmental Policy Act
NEVOO	Nevada Operations Office
NDP	Numeric Data Package
NFS	National Science Foundation
NOAA	National Oceanic and Atmospheric Administration
NOM	natural organic matter
NOV	Notice of Violation
NPDES	National Pollutant Discharge Elimination System
NPL	National Priorities List
NRC	National Research Council Nuclear Regulatory Commission
NRI	National Resource Inventory
NRWTF	Nonradiological Wastewater Treatment Facility
NSF	National Science Foundation
NTS	Nevada Test Site
OHER	Office of Health and Environmental Research (DOE)
ORAU	Oak Ridge Associated Universities
OREIS	Oak Ridge Field Office Environmental Information System
ORHSP	Oak Ridge Hydrology Support Programs
ORNL	Oak Ridge National Laboratory
ORR	Oak Ridge Reservation
OTD	Office of Technology Development
PCA	principle components analysis
PCE	tetrachloroethylene
PEIS	Programmatic Environmental Impact Statement
PID	photoionization detector
PIP	Performance Improvement Process
PLFA	phospholipid ester-linked fatty acids

PM	particulate mercury
PNL	Pacific Northwest Laboratories
PRC	People's Republic of China
PS	photosynthesis
QA	quality assurance
R&D	research and development
RCRA	Resource Conservation and Recovery Act
RFI	RCRA facility investigation
RI/FS	remedial investigation/feasibility study
SARA	Superfund Amendments and Reauthorization Act of 1986
SCOPE	Scientific Committee on Problems of the Environment
SEIS	Supplemental Environmental Impact Statement
SERP	Sedimentary Rock Program
SRIC	short-rotation intensive culture
SRWC	short-rotation woody crops
SSM	mercury-on-suspended matter
STP	Sewage Treatment Plant
STRIVE	Science Teachers Research Involvement for Vital Education
SWDA	Solid Waste Disposal Act
SWSA	solid waste storage area
TCE	trichloroethylene
TM	total mercury
TRC	total residual chlorine
TVA	Tennessee Valley Authority
UEP	University and Educational Programs Office
UNESCO	United Nations Educational, Scientific, and Cultural Organization
USAP	U.S. Antarctic Program
USDA	U.S. Department of Agriculture
USGS	U.S. Geological Survey
UTM	Unified Transport Model
UV	ultraviolet
VAMP	Validation of Assessment Model Predictions
VC	vinylchloride
VOCs	volatile organic compounds
WAG	waste area grouping
WBW	Walker Branch Watershed
WOC	White Oak Creek
WOL	White Oak Lake
WSRS	Westinghouse Savannah River Site

Research Overview

The Environmental Sciences Division (ESD) at Oak Ridge National Laboratory (ORNL) conducts environmental research and analyses associated with both energy technology development and the interactions between people and the environment. The division engages in basic and applied research for a diverse list of sponsors. While the U.S. Department of Energy (DOE) is the primary sponsor, ESD staff also perform research for other federal agencies, state agencies, and private industry. The division works collaboratively with federal agencies, universities, and private organizations in achieving its research objectives and hosts a large number of visiting investigators from these organizations.

ESD also has an extensive education program, providing opportunities for research participation and other educational activities in environmental sciences while meeting division programmatic objectives. These activities range from precollege programs to undergraduate, graduate, and postgraduate opportunities.

Given the diverse interdisciplinary specialization of its staff, ESD provides technical expertise on complex environmental problems and renders technical leadership for major environmental issues of national and local concern. This progress report highlights many of ESD's accomplishments in these and other areas in FY 1991.

Earth Systems Section

The Earth Systems Section addresses environmental research, natural resource management, and global-scale data and information systems. The goal of the section is to obtain scientific understanding of natural and anthropogenic processes important to the entire earth system. The section relies on interdisciplinary research to evaluate and predict, through experimental and mathematical simulations that are correlated with monitoring data, the effects of natural and human processes on present and evolving earth systems components.

The primary focus of the section is on the development of interdisciplinary earth systems models that integrate state-of-the-art understanding of biogeochemical dynamics, climatology, ecological systems, and renewable resources. Each of these disciplines is linked through a sound understanding of data and model systems. Research encompasses both the pragmatic development of global information systems and the development of theoretical and laboratory studies. In addition, the section provides sponsor agencies with technical reviews of programs and reports on global change issues.

Examples of the types of research activities that Earth Systems staff undertake include the development, implementation, and error analysis of global carbon cycle models; development of ocean lateral transport models; worldwide analysis of trace gas emissions; changes in nutrient dynamics associated with global change; analysis of annual trends in atmospheric constituents; assessment of impacts that global climate change would have on renewable resources; compilation of global data bases; use of satellite imagery to discern changes in tropical deforestation

rates; and coupling of terrestrial ecosystem dynamics with atmospheric general circulation models.

Ecosystem Studies Section

Research in the Ecosystem Studies Section focuses on characterizing the structure and functional relationships of regional landscapes and terrestrial and aquatic ecosystems, communities, and populations. This information is then used to predict the responses of these regions and ecosystems to both natural and man-induced disturbances. Major research areas include theoretical ecology, biogeochemical cycling, environmental risk, and the physiological ecology of terrestrial plants.

Biogeochemical cycling research centers on the Walker Branch Watershed Project, which investigates the relative importance of hydrogeochemical transport and biogeochemical cycling in regulating productivity in forests and streams. In addition, research projects investigate the effects of atmospheric deposition in high-elevation red spruce forests, and the effects of fertilization regimes on sycamore plantations; a new project funded by the National Science Foundation focuses on nutrient cycling and stability in stream ecosystems. Important to biogeochemical cycling research is the use of light stable isotopes to study ecological processes. Research on the physiology of terrestrial plants focuses on effects of pollutants such as ozone, acid deposition, and nitrogen oxides on terrestrial systems. A current emphasis is on the effects of increased atmospheric CO_2 on forests. We are also investigating the effects of ultraviolet radiation on terrestrial vegetation.

The development of ecological theory is an important underpinning of research in ESD. The Ecosystems Studies Section develops simulation and mathematical models to describe and predict the behavior of ecological systems. Currently research in landscape ecology and individual-based population modeling is emphasized. Environmental risk assessment staff develop methods for the quantitative assessment of risks and provide guidance to regulatory agencies on the uses of environmental risk assessment. Section staff are also engaged in important international activities in the evaluation of risk models.

In addition, the section is involved in important interactions with the Tennessee Valley Authority, the Great Smoky Mountains National Park, the Southern Appalachian Man and the Biosphere Program, The University of Tennessee, and many other universities. Major sponsors of our research include the DOE Environmental Sciences Division of the Office of Health and Environmental Research, the DOE Biofuels Feedstock Development Program, the U.S. Department of Agriculture, the U.S. Environmental Protection Agency, the Electric Power Research Institute, and the Martin Marietta Energy Systems, Inc., Environmental Restoration Division.

Environmental Analyses Section

The Environmental Analyses Section develops theory and methods, analytical tools, and numeric data bases to evaluate environmental issues, and it prepares interdisciplinary assessments of environmental issues at spatial scales ranging from the individual site to the regional landscape and the globe. The section also provides technical assistance for the development of policy concerning compliance with environmental regulations.

Researchers in the section prepare impact analyses for use by sponsors within DOE, the Federal Energy Regulatory Commission, the Nuclear Regulatory Commission, and the U.S. Department of Defense as part of their compliance with

the National Environmental Policy Act. They also conduct regulatory analysis and environmental compliance activities in support of a number of sponsors, such as the DOE Environmental Guidance Division, the Hazardous Waste Remedial Actions Program, and the U.S. Air Force. During the past year, the section has provided technical support for the Office of the Secretary of Energy in the area of environmental compliance and for the President's Council on Environmental Quality in an analysis of long-term strategies for the reporting of environmental trends.

The Environmental Analyses Section also conducts basic research leading to analyses of natural systems that incorporate patterns in space and time, and it develops and applies modeling techniques—including simulation, optimization, statistics, uncertainty analysis, and geographic information system applications—to solve environmental problems.

Environmental Biotechnology Section

The Environmental Biotechnology Section is involved in basic and applied research on the mechanisms through which contaminants affect biological systems, the ways in which receiving systems affect the availability and distribution of materials to which they are exposed, and the modification of biological and environmental systems to enhance degradation or immobilization. Research is conducted from the subcellular and biochemical level to the ecosystem level with experimental, observational, and simulation studies. Researchers investigate both the role that molecular, biochemical, and physiological processes have in regulating the biological accumulation of contaminants and the adverse effects that the contaminants have on the environment.

Section activities center on the response of Oak Ridge Reservation (ORR) streams to waste management and cleanup activities and on the development of capabilities for predicting direct and indirect effects of contaminants released to the environment. Further areas of research are environmental transport, fate of contaminants in aquatic environments, and biogeochemistry of contaminants. Major emphasis is on the off-site environments surrounding ORR. The section provides data management responsibilities for the environmental restoration project at Energy Systems facilities.

Research in the section also addresses the sources of chronic and acute toxicity in wastewaters and streams on ORR and the development of in situ and laboratory tests to detect and quantify toxicity. In addition, section staff are participating in a major effort in incorporating molecular biology with traditional microbiological tools to understand and control degradation of soil and groundwater contaminants.

Geosciences Section

Staff of the Geosciences Section engage in basic and applied research and conduct demonstration projects directed toward understanding and controlling the physical and chemical mechanisms that influence the movement of material through the lithosphere, hydrosphere, and atmosphere. The major areas of emphasis involve geochemistry, geology, geophysics, environmental chemistry, soil science, hydrology, atmospheric chemistry, oceanography, and environmental engineering. The scope of the studies includes field characterization, testing and demonstration, laboratory experiments, and mathematical and computer modeling.

The section strives to maintain a balance between basic and applied studies. The

staff address issues that are necessary to understand the impact of energy technologies on the environment.

The common theme of most section activities is the study of waste materials and by-products from energy production, and activities span major portions of the energy cycle. The staff of the Geosciences Section are heavily committed to investigating many of the critical issues that are essential in dealing with the cleanup of DOE facilities in order to bring them into environmental compliance. Innovative waste treatment technologies have been developed, including bioremediation of organic contaminants and mercury, as well as oxidation and venting of organic contaminants that occur in soils and groundwater.

Biofuels Feedstock Development Program

The Biofuels Feedstock Development Program (BFDP) manages DOE's national research on the production of dedicated energy crops. It is supported by DOE's Office of Transportation Technologies. The primary objective of BFDP is to develop systems for producing biomass feedstocks for liquid transportation fuels that are cost-effective and environmentally acceptable.

The program emphasizes high-priority model species, both woody and herbaceous, suitable for major U.S. crop production regions. Research on specific crops is primarily subcontracted to land grant universities and to U.S. Department of Agriculture research facilities. Resource assessment, environmental analysis, and economic studies, including basic physiology and nutrient-cycling research, are performed largely within ESD and ORNL, with some subcontracted support. In FY 1991, BFDP had four major research and analysis components—Model Wood Energy Species, Model Herbaceous Energy Species, Environmental Research and Analysis, and Economic Analysis and Integration. Other efforts included Fuel Cycle Analysis, Information and Data Handling, and participation in the International Energy Agency's biomass production activities.

Center for Global Environmental Studies

ORNL's Center for Global Environmental Studies, established in FY 1988, is under the programmatic guidance of ORNL's Associate Director for Environmental Life and Social Sciences. The center draws on the talents of researchers throughout the Laboratory and develops collaborative relationships with established centers of excellence at universities and research institutions both here and abroad. Activities have revolved around sharpening the center's focus on five major research themes: data systems; large-scale environmental studies; policy, energy, and human systems analysis; measurement science and instrumentation; and global systems analysis.

The center seeks to understand complex global issues such as climate change, ozone depletion, globally distributed contaminants, erosion desertification and urbanization, water resources, biodiversity, deforestation, and resource depletion, all of which require support through research and analysis in data systems; measurement science and instrumentation; policy, energy, and human systems; and large-scale environmental studies. The goals of the center are (1) to improve understanding of the global-scale workings of environments in air, on land, and in water and (2) to develop capabilities to predict long-term consequences of human actions that may alter, perhaps irreversibly, the vital balances of nature.

Section Activities 1

Earth Systems

Introduction

The Earth Systems Section of the Environmental Sciences Division (ESD) at Oak Ridge National Laboratory (ORNL) addresses environmental research, natural resource management, and global-scale data and information systems. The goal of the section is to obtain scientific understanding of natural and anthropogenic processes important to the entire earth system. The section relies on interdisciplinary research to evaluate and predict, through experimental and mathematical simulations that are correlated with monitoring data, the effects of natural and human processes on present and evolving earth systems components. The section is composed of three groups: Earth Systems Modeling, Data and Information Analysis, and Renewable Resources. The Carbon Dioxide Information Analysis Center (CDIAC) and the ORNL National Environmental Research Park are also administered by the section.

Earth Systems Modeling

The Earth Systems Modeling Group develops, applies, and evaluates mathematical models used in addressing global-scale environmental issues. Current research emphasizes the development of new models and the examination and integration of disparately scaled existing models to comprehensively address global carbon dynamics. This work is designed to increase understanding of the global carbon cycle and to forecast the effects of changes in atmospheric carbon emissions on global climate and ecological resources during the next century.

Group interests also include quantification of the implications of model uncertainties on model performance. Sensitivity and uncertainty analyses are used to evaluate performance and to place model forecasts in the context of global risks. Earth systems modelers use an innovative synthesis of techniques to address problems in mesoscale, regional, and global modeling.

Data and Information Analysis

The purpose of the Data and Information Analysis Group is to provide the information and data support essential to performing comprehensive, resource-intensive regional- and global-scale environmental projects successfully. The group employs state-of-the-art information and data management techniques to ensure proper information exchange between project components and to facilitate information transfer between projects and the external research community. The group subscribes to the "value-added" model of information processing; the staff actively identify and solve problems to enhance the product. To achieve the careful balance of information and data support needed to meet project requirements, the group relies on information theory, computer science, telecommunications, scientific visualization, and data management.

The group designs information and data systems for the acquisition, analysis, display, and storage of data related to regional and global projects. It develops data acquisition software to control the quality of incoming data automatically at the source. The group also evaluates commercial and custom data management, analysis, and display software for project

use. In addition, the group develops data handling, quality assurance, documentation, and archiving procedures. Furthermore, it supervises and executes system integration and deployment. Special emphasis is placed on quality assurance and documentation.

Renewable Resources

The objectives of the Renewable Resources Group are to develop improved analytical methodologies in evaluating renewable resource dynamics and to evaluate resource management approaches that provide greater human benefit and reduced environmental risk.

Efforts of the group fall into four areas, which are generally global or regional in scope: (1) changes in land use and in coastal zones as a result of changing climate, (2) biosphere studies to assess man's effects on natural ecosystems, (3) plant-crop improvement and environmental evaluation for biomass-based energy systems, and (4) broad evaluation of tropical deforestation processes involving the interpretation of geographic information system (GIS) and remote imagery. Important activities include the development of methodologies for analysis, synthesis of GIS data, and participation in cooperative multi-institutional research. The group makes use of specific technical expertise in regarding plant community productivity, soil and nutrient-cycling processes, land-development processes, and the effects of energy use on ecosystems.

Carbon Dioxide Information Analysis Center (CDIAC)

CDIAC, operational since 1982, is a fully integrated information analysis center whose primary function is to acquire or compile, ensure the quality of, document, archive, and distribute information related to CO_2 in support of the U.S. Department of Energy (DOE) Carbon Dioxide Research Program. CDIAC supports the extensive data and information needs of the international research, policy-making, and education communities to assist them in the evaluation of complex environmental issues that are associated with elevated atmospheric CO_2.

CDIAC staff identify users' needs by attending workshops, reviewing literature, and maintaining personal contacts. The center obtains and evaluates data, articles, and reports for potential worldwide distribution. In addition, the center produces digital Numeric Data Packages and Computer Model Packages, and it distributes DOE and other CO_2-related reports. Center staff also produce the newsletter *CDIAC Communications*, which has a worldwide distribution to 6000 researchers in more than 150 countries. For the research and policy-making communities, CDIAC has produced such varied products as *TRENDS '90: A Compendium of Data on Global Change* and *Glossary: Carbon Dioxide and Climate*.

National Environmental Research Park

Studies related to the Oak Ridge National Environmental Research Park, a project funded by the DOE Office of Health and Environmental Research (OHER), focus on the analysis, synthesis, modeling, and marketing of ecological investigations performed on the Oak Ridge Reservation (ORR). The emphasis is on the coordination of research efforts and comparison of results at the six DOE Research Park sites.

Technical Summaries

1

Artificial Intelligence, Expert Systems, and Dynamic Models Can Be Integrated to Support Global Carbon Issues

S. M. Bartell

The objective of this research is to develop a prototype of the Global Resource Intelligent Decision Support System (GRIDSS). The purpose of GRIDSS is to integrate dynamic models of carbon emissions and global carbon distribution with global data in a user-intensive operational context provided by artificial intelligence and expert systems technologies. Decision makers can use GRIDSS to rapidly explore the implications of changes in energy policy on subsequent carbon emissions and risks of CO_2 increases and distribution on a global scale.

The prototype GRIDSS will include a published energy-economics-based carbon emissions model and a simple ocean-atmosphere carbon distribution model. The input data include the initial conditions and parameter values for both models. The expert system will provide the user interface, appropriately modify the input data, and perform the necessary simulations in response to user explorations of alternative energy policies. The artificial intelligence engine of the GRIDDS will execute risk-based decision methods to assist the decision maker in assessing the global risks and benefits associated with alternative energy policies. The prototype will focus on alternatives in regional emphasis on specific energy technologies in relation to the economics of energy supply and demand. The GRIDSS will estimate the probability of atmospheric CO_2 doubling as a function of time and energy policy alternatives selected by the user.

Experience gained from repeated use of the GRIDSS can help the decision makers and the model developers to identify areas for future refinement of the prototype. Planned modifications include the incorporation of several energy models and carbon distribution models to provide additional analytical flexibility. As the GRIDDS evolves, it will become an increasingly useful instrument for decision makers and scientists who must integrate large amounts of information and diverse expertise to effectively explore the global implications of future energy policy.

2

Water Resource Analysts Must Adapt GCM Output for Use in Climate-Impact Studies

R. M. Cushman

Using general circulation models (GCMs) to provide regional climate data to assess the impact of changing climate on water resources stretches the design limits of the models. Problems that must be addressed include (1) disagreement on a regional scale among GCMs and between the modeled and observed climates, (2) coarse spatial resolution of the models, and (3) overly simplistic representation of surface hydrology.

On a regional scale, the various GCMs disagree on the possible changes in temperature and precipitation, and they do not correctly simulate all features of the current climate. Because the spatial

resolution of GCMs is coarse (up to 8° by 10° latitude-longitude) and their representation of geography and topography is only approximate, relating the model output to actual locations on the earth's surface is difficult. Some processes that function at subgrid scales are represented statistically. Importantly, the models' representation of surface hydrology is simplistic. For example, soil moisture in GCMs is often simulated as a "bucket" 15 cm deep; when precipitation and snowmelt (less evaporation) cause soil moisture to exceed 15 cm, the excess becomes runoff.

Because of the lack of agreement among climate models, it is useful to examine a range of climate scenarios by using the output from more than one model. To partially resolve the difficulty in relating the coarsely gridded output to specific locations on the earth's surface, several investigators have analyzed the output for several model grid points near the area of interest. Both statistical and modeling techniques have been suggested for deriving finer-scale climate information from GCM output. While analyses of the effects of climate change on water resources can be performed with the monthly temporal resolution of the GCM output, the model's monthly averaged output may also be converted into a daily time series by using a weather generator.

The crude representation of soil moisture and runoff in GCMs has led to difficulties in some analyses. Some analysts avoid using the soil moisture and runoff data from GCM output; instead, they use GCM projections of temperature and precipitation to drive a hydrologic model, such as a water-balance model. GCM simulations of the current climate are not yet reliable so researchers often use actual data on present climate to define the "base-case" climate. The base case is then used in model simulations to project future climate. Researchers disagree, however, about the best way to make the projections: should model simulations of the future be taken at face value, or should they be adjusted to compensate for their inherent unreliability? Unfortunately, researchers currently have no established method for adjusting the simulations.

Given the interest in the potential effects of climate change on water resources, analysts will probably continue to use the simulations from GCMs as the basis for assessing climate impacts, perhaps in combination with either hypothetical or historical-analog climate scenarios. It is important that continued progress in the methodology for using GCM output in climate-impact assessments be made, concurrent with progress in hydrologic modeling.

3

CDIAC Disseminates Climatic Data Bases of the People's Republic of China, 1841–1988

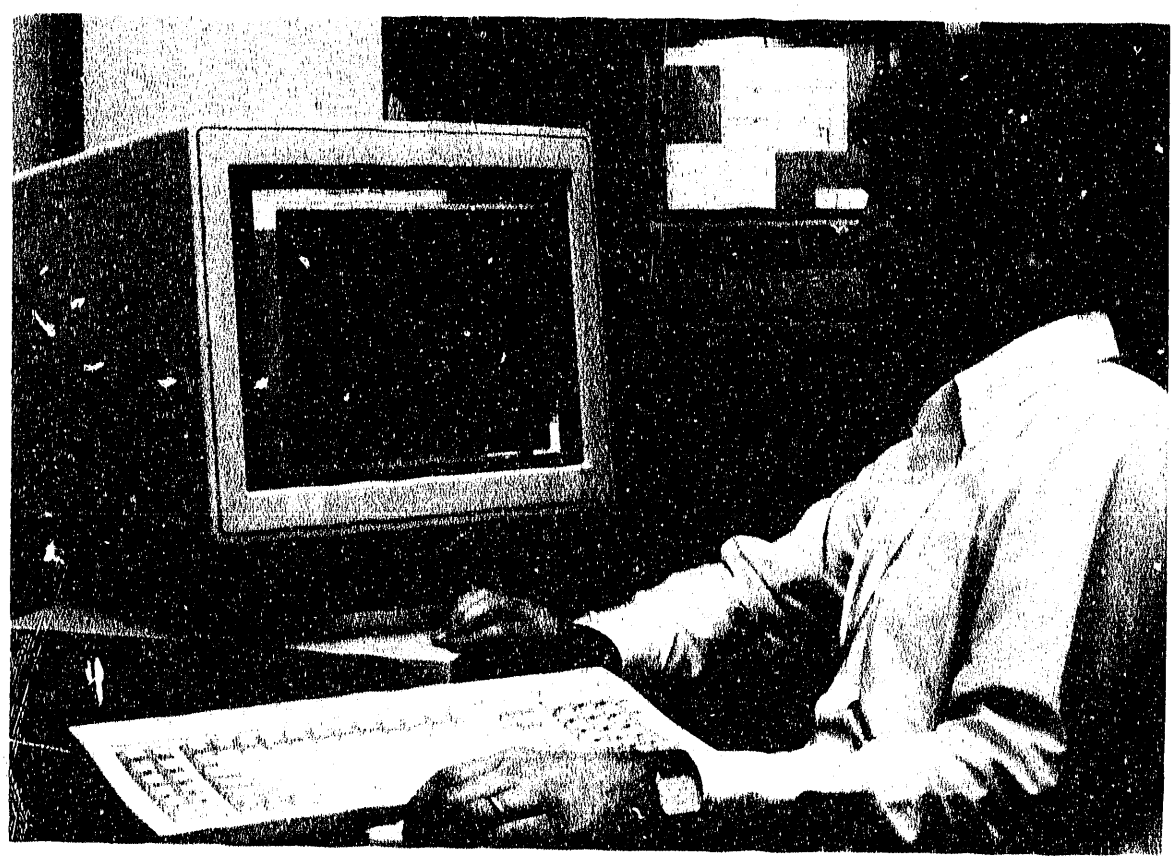
D. P. Kaiser[1] and T. A. Boden

Evidence of rising concentrations of radiatively active trace gases such as CO_2 and CH_4 in the global atmosphere has led to fervent national and international efforts in monitoring and predicting the impacts of an accompanying enhancement of the greenhouse effect. One such effort has been undertaken by DOE and the People's Republic of China (PRC) Chinese Academy of Sciences (CAS), who signed an agreement on August 19, 1987, to carry out a joint research program on possible CO_2-induced climate changes. Some of the main tasks included in the program are the preparation, validation, and analysis of regional-climate data. To date, DOE and CAS have prepared several climate data sets containing observations of basic

meteorological variables from their respective countries.

CAS has prepared five climate data sets containing meteorological observations from PRC and turned them over to CDIAC at ORNL for quality assurance reviews and subsequent publication and dissemination. The data sets, with the longest period of record from each shown in parentheses, are as follows:

1. 60 stations (1841–1988) providing monthly values of mean station pressure, mean temperature, mean maximum temperature, mean minimum temperature, total precipitation, mean relative humidity, sunshine duration,



Tom Boden reviews a data base that will soon be distributed by the Carbon Dioxide Information Analysis Center. During the past 5 years, the center has analyzed and documented about 50 data bases and distributed over 2000 copies to requesters in 63 countries.

mean cloud amount, number of days with snow cover, dominant wind direction, mean wind speed, dominant wind frequency, and extreme maximum and minimum temperatures;
2. 206 stations (1880–1988) providing monthly values of mean temperature and total precipitation;
3. 40 stations (1984–1988) providing monthly values of mean maximum and minimum temperatures and extreme maximum and minimum temperatures;
4. 180 stations (1951–1982) providing daily precipitation totals; and
5. 147 stations (1951–1988) providing 10-day precipitation totals.

Valuable ancillary information is available for those stations in the 60-station data set (several of these stations also contribute to the 180- and 147-station data sets), including station histories and documentation of instrument usage and data collection procedures. No such ancillary data are available for the remaining stations at this time. The comprehensive nature of the 60-station data set allows American scientists to analyze these data for long-term trends. Using monthly mean temperatures from urban-rural station pairs within this network, Wang et al. (1990) reported a 0.23°C urban heat island effect from 1954 to 1983.

Quality assurance checks performed at CDIAC identified numerous errors and suspect values in the data sets, many of which CAS has corrected. The data are now believed to be of generally good quality. CDIAC has written a DOE technical report on these data sets, which CAS is currently reviewing, and the center is now preparing a Numeric Data Package that focuses mainly on the 60-station data set because of its broad array of meteorological variables, generally long periods of record, and valuable ancillary information.

These data offer the most comprehensive, long-term instrumental Chinese climate data presently available. The coverage (298 stations) offered by these data sets greatly improves the spatial and temporal coverage offered by other published sources, such as the *World Weather Records* and *Monthly Surface Station Climatology for the World.*

[1]*The University of Tennessee, Knoxville.*

4

Emissions of CO_2 to the Atmosphere from Global Energy Use Are Compiled and Analyzed

G. Marland and T. A. Boden

With increasing concern about the effect of rising concentrations of greenhouse gases in the global atmosphere, there is a corresponding increase in interest in what might be done to limit or minimize these concentrations. Carbon dioxide is of particular concern, not only because of the magnitude of its postulated contribution to climate change but also because of its essential linkage to the global-energy supply system.

To understand what is happening in the atmosphere, to appreciate why this is happening, and to be serious about trying to limit future atmospheric concentrations of CO_2, the magnitude and locations of sources of CO_2 emissions must be understood.

The Carbon Dioxide Information Analysis Center (CDIAC) at ORNL maintains and distributes a data base of CO_2 emissions from fossil fuel use and cement manufacture. These emission estimates are fully documented and available free from CDIAC. Since 1988, CDIAC has

distributed this data base to more than 300 individuals in 26 countries. This data set, organized by country and fuel, is continuous from 1950. Upon the receipt of the annual update on global energy production from the U.N. Statistical Office, the CO_2 emissions time series, which currently runs through 1989, is amended .

Total global CO_2 emissions reached 5.954 $\times 10^9$ metric tons of carbon in 1989, an increase of 1.09% over 1988. This estimate represents the largest annual emission ever from fossil fuel consumption and cement production and continues an increasing trend that has prevailed since 1983. Decreases of emissions that followed the oil price shocks of the 1970s into the early 1980s have now been erased, and a new upward trend seems well established, even though the 1989 growth rate is considerably less than the 4.05% growth from 1987 to 1988. Growth is most prominent in some developed countries; emissions from the centrally planned economies of Asia, for example, are now 54% higher than in 1979. By contrast, emissions from Western Europe are still 12% below the 1979 maximum and are virtually unchanged since 1982. African CO_2 emissions are up 33% from 1979, and those from Latin America are up 16% over the same time interval.

The three largest emitting nations in 1989—the United States, the Soviet Union, and China—accounted for a little more than half (50.5%) of the global CO_2 emissions from fossil fuel burning, cement production, and gas flaring. U.S. emissions reached 1.329 $\times 10^9$ metric tons of carbon in 1989 (5.37 metric tons of carbon per capita and 22% of the global total), exceeding the previous high, which was set in 1988, and continuing an increasing trend that began in 1983. U.S. emissions grew by 1.14% in 1989, down from the 4.78% growth recorded in 1988, thus marking the third consecutive year the U.S. growth rate was higher than the global average.

5

Areas on the Oak Ridge Reservation Open for Deer Hunting Are Reevaluated for Contamination and Hunter Safety

P. D. Parr, B. Lu, F. R. O'Donnell,[1] and J. W. Evans[2]

Areas on ORR open for public deer hunting were evaluated for hunter safety with respect to potential contamination. The purpose of the evaluation was to (1) identify areas now open for hunting that may pose potential contamination risks to hunters, (2) determine what radionuclides are involved in any identified contaminated areas, and (3) perform dose rate calculations to evaluate the impact on individuals who have hunted in identified contaminated areas previously open for hunting.

Public deer hunting began on ORR in 1985 through an agreement between DOE and the Tennessee Wildlife Resources Agency in an effort to reduce the white-tail deer population and, consequently, the number of vehicle collisions with deer. Prior to initiation of the hunts, efforts were made to evaluate areas open for hunting to ensure hunter safety. During preparations for the November 1989 hunt, however, it was discovered that one area previously open for hunting (White Wing Scrap Yard) was contaminated. The area was immediately roped off and removed from the list of areas for hunting. During 1990, surface radiological investigations were performed and potential radiation doses to hunters were calculated. All areas on ORR open for hunting were

reevaluated to determine if any additional sites were potential contamination risks for hunters. Within ORNL jurisdiction, two small, former research plots (ES-11) were identified on Chestnut Ridge. These were restricted from the list of areas for hunting in 1990, and potential radiation doses were calculated. No additional areas were identified through the K-25 Site or the Oak Ridge Y-12 Plant. A chain link security fence is scheduled to be installed around the perimeters of the two areas after National Environmental Protection Agency review and approval.

At White Wing Scrap Yard, typical grou.:i surface gamma exposure rates varied from 0.01 mR/h (background) to 0.11 mR/h. The average surface gamma exposure rate in the block with the highest rate was 0.06 mR/h. A maximally exposed hunter (one who remained in the block with the highest exposure rate for 72 h) could have received an effective dose equivalent of 0.7 to 8 mrem. Based on the average exposure rate, the hunter's dose equivalent could have been 4 mrem. Exposure at 1 m (midbody height) could lower estimated doses 10%. For the ES-11 site, hypothetical dose calculations were made using (1) total quantities of radionuclides contained in seed fed to small mammals, (2) the size of the areas in which they were spread, and (3) a decay period of 20.5 years. The effective dose equivalent rate at 1.0 m above the center of a plot is estimated to be 0.0003 mrem/h. If the remote possibility of inhaling resuspended radionuclides is taken into consideration, a maximally exposed hunter could have received an effective dose equivalent of ~0.2 mrem. Almost all of this dose is attributable to photons emanating from nuclides on the ground, with about 1% due to inhalation of resuspended radionuclides.

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[2]*Tennessee Wildlife Resources Agency.*

6

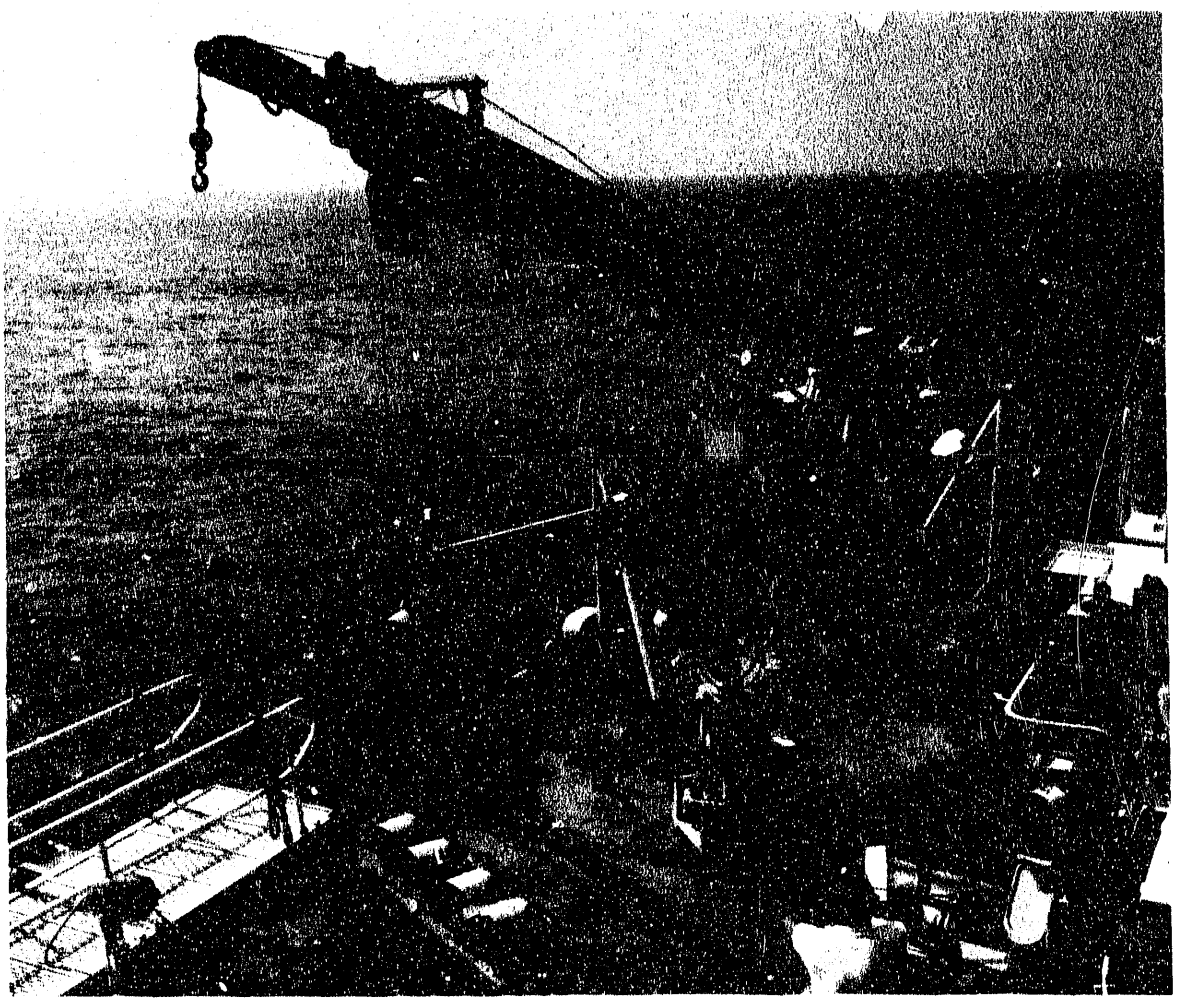
Iron Fertilization in the Antarctic Ocean Reduces Atmospheric CO_2 Levels Insignificantly in the Next Century

T.-H. Peng

The rising concentration of atmospheric CO_2 resulting from fossil fuel combustion and terrestrial ecosystem disturbances potentially threatens our living environment by causing undesirable climate changes. In addition to improving our understanding of how rising atmospheric CO_2 may change the climate, it is imperative to have a preventive strategy whereby the rise in atmospheric CO_2 may be reduced or even eliminated before a possible catastrophic and irreversible climate change takes place.

Although the most obvious way to reduce the increase in atmospheric CO_2 is to reduce CO_2 emissions, Martin et al.[1] recently proposed an ingenious method of increasing the oceanic uptake of CO_2 by enhancing the biological pump through iron fertilization. Field incubation experiments show that if nutrient-rich Antarctic surface waters are fertilized with dissolved iron, a higher phytoplankton productivity is achieved. If the Antarctic surface water could be successfully fertilized with dissolved iron, then the organic particulate resulting from enhanced production would sink to the deeper water. Thus, dissolved total CO_2 in the surface water would be effectively carried away to the deep, and this sinking action would reduce the partial pressure of CO_2 (pCO_2) in the surface water and allow for more absorption of carbon from the atmosphere.

The magnitude of the possible reduction in atmospheric pCO_2 in the next century that would result from the hypothetical iron fertilization of the Antarctic Ocean is estimated by using a box-advection-diffusion model with dynamical constraints derived from tracer distribution. To evaluate the possible increase in atmospheric CO_2 both with and without fertilization, we use a business-as-usual scenario of anthropogenic CO_2 emissions proposed by the Intergovernmental Panel on Climate Change working group. Assuming completely successful iron fertilization, we calculate the percentage of atmospheric CO_2 reduction for each



A sampling crew from Scripps Institute of Oceanography readies a large-volume water sampler for lowering into the ocean. The device collects seawater samples for researchers to analyze the ^{14}C and other chemical tracers in the water. ESD's T.-H. Peng uses the ^{14}C data to calibrate his ocean model for estimating oceanic uptake of atmospheric CO_2.

dynamic condition. We find that these percentages reach a constant value after a rapid increase. Within considered dynamic limits, the reduction percentage ranges from 3% to 12%. Hence, if the atmospheric pCO_2 reaches 800 μatm in the next century, then the maximum possible reduction is about 96 μatm. However, the most likely dynamic condition, with a 17.4-sv upwelling flux in the Antarctic Ocean, would reduce atmospheric pCO_2 only by 64 μatm (or 8%) by A.D. 2090.

These results are obtained under the assumption that iron fertilization would work perfectly and continuously over the entire Antarctic Ocean for the next 100 years. However, iron fertilization would neither achieve 100% efficiency nor continuously fertilize the entire Antarctic Ocean during all seasons. Under adverse circumstances, the atmospheric pCO_2 reduction would be much smaller. It is apparent that iron fertilization in the Antarctic Ocean would not reduce atmospheric CO_2 content significantly over the next century.

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[1] *J. H. Martin, S. E. Fitzwater, and R. M. Gordon, "Iron deficiency limits phytoplankton growth in Antarctic waters,"* Global Biogeochemical Cycles *4(1), 5-12 (1990).*

7

A Global Litter Data Base Is Developed

W. M. Post

Litter production and decomposition processes in ecosystems form an important connection between the uptake of CO_2 from the atmosphere and the net storage of carbon in soils. These processes also determine the availability of nutrients that modify the rate of CO_2 uptake. Knowledge of litter dynamics is the key to understanding ecosystem dynamics.

Data on mass and nutrient concentrations of litterfall and littermass were collected from literature and primary sources. A bibliography of more than 250 references was assembled containing primary data from ~3,000 stands or plots. So far, 735 stands or plots have been entered into a computer data base (dBase III Plus), and preliminary analyses have been performed.

Twenty percent of the studies have data on both litterfall and littermass, and 19% of the studies have data on branch, bole, and reproductive litter as well as leaf litter. In addition to carbon, data on nitrogen, phosphorus, sulfur, and base cations were also recorded. Approximately 57% of the studies contain information about one or more base cations (usually calcium). Only carbon, nitrogen, and phosphorus data have been the subject of preliminary analyses to date.

Sample stands or plots were classified according to Holdridge Life Zone, a climate classification based on temperature, precipitation, and evapotranspiration. On a global scale there is an inverse correlation between temperature and latitude or altitude in this classification scheme.

Annual litterfall (i.e., annual litter production) shows a striking pattern across global life zones. Lowest values of less than 0.25 kg/m^3 occur in cool, dry life zones (dry and moist tundra and boreal) and increase in a regular pattern as temperature and precipitation increase. Highest values of ~1 kg/m^3 occur in wet tropical, wet subtropical, and rain warm-temperate forest life zones. Littermass shows a more complicated pattern with climate. As latitude and temperature decrease, littermass increases from <1 kg/m^3 in tropical life zones to a

peak of >3 kg/m^3 in boreal life zones, where mean annual temperature decreases to 6°C. Below this temperature, littermass decreases along with temperature to less than 1 kg/m^3 in moist and dry tundra. In wet and rain tundra/boreal forest, however, peat accumulations were not included in littermass. This trend could be the result of a more rapid response of decomposition to temperature than litter production in life zones above 6°C. Below 6°C, litter production decreases faster than decomposition or incorporation into surface peat.

Nitrogen in litterfall and littermass shows similar patterns with life zone as does carbon or mass. As a result, carbon/nitrogen ratios do not show any trends with life zone. This is contrary to the hypothesis that tropical vegetation processes nitrogen more efficiently than vegetation in other life zones. Phosphorus does, however, occur in lower concentrations in tropical litterfall and littermass, perhaps as a result of higher efficiency of plant remobilization from tissues before abscission and as a result of faster mineralization and uptake from the forest floor.

8

A Gridded Surface Air Temperature Anomaly Data Set Is Found Suitable for Long-Term Climate Analyses

R. J. Sepanski[1] and T. A. Boden

For 20 years much attention has been given to the potential climatic effects of increasing concentrations of atmospheric greenhouse gases. This is not surprising because these potential climatic effects could have far-reaching environmental, economic, and social consequences. Much of the work performed during this period involved (1) climate modeling or empirical analyses attempting to attribute climatic changes to various astronomical and atmospheric factors and (2) assembly and examination of new geological, historical, and instrumental data. To isolate the "greenhouse signal," or that part of the climate change that is attributed to increased concentrations of greenhouse gases, it is imperative to have long-term observational records for identifying the climate changes that have already occurred. Fortunately, for the past century many climatic variables (e.g., surface air temperature) have been measured at a large number of meteorological stations, mostly at land locations in the Northern Hemisphere. These observational records have been used by various researchers to compile global data sets of surface air temperatures, which are crucial for understanding past climatic trends and for comparing future estimates.

CDIAC recently completed, documented, and analyzed one of these global data sets that was compiled by Jones et al. at the University of East Anglia in Norwich, United Kingdom. The data base and the accompanying documentation are available from CDIAC without charge. The long-term record of temperature anomalies may be used in studies addressing possible greenhouse-gas–induced climate changes. To date, these data have been employed in generating regional, hemispheric, and global time series for determining whether recent (i.e., post-1900) warming trends have taken place.

The documentation prepared by CDIAC presents land-based monthly surface air temperature anomalies (departures from the mean of a 1951–70 reference period) on a 5° latitude by 10° longitude global grid. Monthly surface air temperature

anomalies (departures from the mean of a 1957–75 reference period) for the Antarctic (grid points from 65° S to 85° S) are presented in a similar way as a separate data set. The data were derived primarily from the *World Weather Records* and the archives of the United Kingdom Meteorological Office.

This document also presents the monthly mean temperature records for the individual stations that were used to generate the set of gridded anomalies. The periods of record vary by station. Data from the Northern Hemisphere stations have been corrected for inhomogeneities, whereas Southern Hemisphere data are presented in uncorrected form.

All data have been assessed for quality (gross accuracy and consistency, temporal variability, and spatial and temporal completeness of record) and for long-term homogeneity. Although the period of record extends from 1851 to 1990, few grid-point locations have contributed data for the entire period of record.

Analysis of these gridded anomaly data for surface air temperatures during 1881–1984 shows a linear warming trend of 0.52°C for the Northern Hemisphere and 0.51°C for the Southern Hemisphere, excluding the Antarctic. A similar trends analysis incorporating the entire data set through 1990 has not yet been published.

[1]*The University of Tennessee, Knoxville.*

9

Diameter Increments of Three Tree Species in the Southeastern United States Are Modeled

D. C. West, R. J. Luxmoore, M. L. Tharp, and J. J. Beauchamp

Tree-ring chronologies and a forest simulation model were used to analyze diameter development patterns for three tree species at two sites. Annual tree-ring increment data from yellow-poplar (*Liriodendron tulipifera*) and white oak (*Quercus alba*) on the Walker Branch Watershed in eastern Tennessee and longleaf pine (*Pinus palustris*) at the Tall Timber Research Site in southwest Georgia were used to compare actual and simulated growth data. The simulations were initialized with specific plot data obtained from the two sites. For each year of the simulation, a growth increment was calculated for each tree on the basis of climatic input and existing stand conditions, and it was subtracted from the tree's diameter for the previous year. This technique allowed the forest model to simulate growth backward through time and generate annual tree growth increments for direct comparison with the tree-ring increment data recorded from extracted cores of trees at the study sites.

Beginning in 1981, the model simulated annual tree-ring increments for all trees on 21 Walker Branch Watershed plots; simulation for the 38 Tall Timber plots began in 1987. The measured and simulated annual increments were averaged for yellow-poplar, white oak, and longleaf pine over all plots, and a runs test was applied to the differences between the

averaged annual measured and simulated growth increments. Yellow-poplar and longleaf pine had significantly fewer runs ($P < 0.01$) than expected for a random process. For white oak the number of runs was not found to be significantly less than expected. The general trend of modeling yellow-poplar and longleaf pine is an underestimation at the beginning of the simulation in 1981 to about 1960. Prior to 1960, the model results show both overestimation and underestimation about the zero line until 1930. The differences in the measured and simulated values appear unbiased in this time period. In general, the annual differences between measured and simulated ring increments for white oak show random behavior throughout the simulation.

Results show that tree-ring chronologies can be used in conjunction with mathematical models of forest growth to detect and evaluate tree growth rates and forest dynamics. When simulated with local climate and stand-specific environmental variables, white oak and yellow-poplar in eastern Tennessee and longleaf pine in southwestern Georgia showed apparent overall growth characteristics typical of those species for their respective regions. However, a comparison of actual growth measurements with the simulated increments revealed significant differences for the three species included in this study. Yellow-poplar showed the most significant deviation with a runs test and with auto regressive analyses. In general, the model

Larry Pounds and Rebecca Cook classify plant species growing in a wetland on the Oak Ridge Reservation. As part of an on-going project, they will use this information along with soil samples and hydrologic data to identify the boundaries of wetlands so that activities planned on the Reservation can be directed away from these federally protected areas.

underestimates tree growth for the three species from about 1960 into the 1980s. The statistically significant deviation of measured tree-ring increments from simulated growth and the indication of anomalous diameter increases of species at two sites at approximately the same time provide evidence that some environmental change is common to each location. Given the known fertilization response of tree seedlings and the timing of the growth pattern changes described here, the atmospheric increase in CO_2 is one factor that may be contributing to the augmented growth of the three species.

10

Researchers Assess Vulnerability of the Gulf Coast of the United States to Rising Sea Level

T. W. White and V. M. Gornitz[1]

The Global Coastal Hazards Data Base is being developed to provide an overview of the relative vulnerabilities of the world's coastlines to inundation and erosion hazards associated with increasing sea level rise. The data base integrates information on seven variables in a GIS: elevation, lithology, geomorphology, vertical land movements, erosion or accretion, tidal ranges, and wave heights. The GIS assigns a coastal risk value from one to five to each variable and calculates a Coastal Vulnerability Index (CVI) for the shorelines. The CVI is calculated by taking the square root of the quotient that results when the mean product of the seven variables is divided by the number of variables present. An analysis of the Gulf Coast of the United States concludes the following.

The U.S. Gulf Coast extends from Key West, Florida, to Port Isabel, Texas, and is 14,356 km long. Its shorelines are particularly vulnerable to inundation because of low-lying topography. High-risk values for elevation, lithology, geomorphology, vertical land movements, and erosion/accretion variables are predominant throughout the gulf. Ninety percent of the shoreline lies at an elevation of 5 m or less, with a lithology of unconsolidated sediments. Fifty-four percent of the shoreline consists of salt marshes, and the remaining is lagoons, estuaries, and barrier beaches. Measurements of local vertical movement indicate that the entire Gulf Coast is experiencing a relative change in sea level by >1 mm/year and that 43% of the shoreline measures ≥5 mm/year. About 51% of the gulf shoreline is eroding, whereas 46% is stable, and 3% is accreting. The Gulf Coast is a low-energy coastline, its mean tide ranges are microtidal or less than 2 m, and its wave heights that are less than 5 m.

CVI values range between 3.46 and 36.60 for the Gulf Coast. The median value by shore length is 9.94. Approximately 1664 km, or 12%, of the shoreline has a CVI of 22 or greater and is considered to be at high risk in terms of sea level rise.

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Ecosystem Studies

Introduction

Research in the Ecosystem Studies Section of the Environmental Sciences Division (ESD) at Oak Ridge National Laboratory (ORNL) is directed toward quantitatively characterizing the structure and functional relationships of regional landscapes and terrestrial and aquatic ecosystems, communities, and populations. This information is then used to predict the responses of these regions and ecosystems to both natural and man-induced disturbances. The section focuses on complementary areas of research, including theoretical ecology, biogeochemical cycling of materials, environmental risk of physical and chemical disturbance, and physiological ecology of terrestrial plants.

Major sponsors of the section's research are the U.S. Department of Energy (DOE) Environmental Sciences Division of the Office of Health and Environmental Research (OHER), the DOE Biofuels Feedstock Development Program, the U.S. Department of Agriculture Forest Service (USFS), the U.S. Environmental Protection Agency (EPA), the Electric Power Research Institute (EPRI), the National Science Foundation (NSF), and the Martin Marietta Energy Systems, Inc. (Energy Systems), Environmental Restoration (ER) Program.

The section has important collaboration and interaction with the Tennessee Valley Authority (TVA), the Great Smoky Mountains National Park, the National Oceanic and Atmospheric Administration Atmospheric Turbulence and Diffusion Division, and many universities (e.g., University of Georgia, University of Wisconsin, The University of Tennessee, Fort Lewis College, University of Wyoming, University of Maryland, and University of Rhode Island). Section staff are affiliated with the Southern Appalachian Biosphere Reserve of the U.S. Man and the Biosphere Program.

Biogeochemical Cycling

Staff in the Biogeochemical Cycling Group are engaged in research concerning element cycling within environmental systems; the spatial patterns and temporal trends of storage and fluxes of nutrients and pollutants; the role of biogeochemical cycling of chemicals in regulating productivity, species composition, and stability of ecosystems; and the development of innovative methods of measurement, analysis, modeling, and interpretation of biogeochemical cycles at site-specific, regional, and global scales.

The group is involved in several areas of research: (1) the DOE OHER-funded Walker Branch Watershed Project, which focuses on the relative importance of hydrogeochemical transport and biogeochemical cycling in regulating biological structure and primary productivity in forests and streams at different temporal and spatial scales; (2) the USFS-funded project on atmospheric deposition, red spruce nutrition, and aluminum toxicity in the Great Smoky Mountains National Park, a project that builds on results of the multiyear and multisite EPRI-funded Integrated Forest Study; (3) the use of stable isotopes and radioisotopes to study cycling processes in aquatic and terrestrial systems; (4) the EPA-funded Critical Loads Project, which evaluates critical loads of sulfur and nitrogen to forested areas in the eastern United States; (5) the DOE-funded biomass production research project evaluating fertilization regimes and production in plantations; and (6) our new NSF study on nutrient cycling and stability in stream ecosystems.

This year important accomplishments included a major peer review of our Walker Branch Watershed program; completion of important work on calcium availability related to forest decline; evaluation of carbon storage in forests in response to moisture gradients; analysis of stable nitrogen isotopes in precipitation and throughfall, indicating the importance of NH_4-N inputs; and the evaluation of methods for calculating leaf area by analyzing light penetration.

Physiological Ecology

The Physiological Ecology Group evaluates the effects of environmental stress on plant growth and vigor and examines the role of physiological processes in biogeochemical cycling of pollutants within terrestrial ecosystems. Specific atmospheric pollutants such as ozone, acid deposition, and nitrogen oxides are examined, as well as the effects of other changes in the chemical and physical atmospheric environment. Increases in atmospheric CO_2 and high-energy ultraviolet radiation are studied in relation to global environmental pollution. The use of physiological indicators in intensive biomass production from silviculture is being investigated as part of the search for nonfossil energy sources, and the role of interactive stresses on physiological indicators of whole-plant resource utilization has also received research attention. Primary sponsors of the group's work are DOE, EPRI, USFS, and EPA.

Significant research activities this year included a study concluding that elevated atmospheric CO_2 enhances osmotic adjustment to water stress in roots of American sycamore seedlings; analyses showing that elevated atmospheric CO_2 enhances photosynthesis in two deciduous trees under field conditions; and an evaluation of the role of soil heterogeneity in the success of soil barriers in shallow land burial facilities.

Theoretical Ecology

The Theoretical Ecology Group develops simulation and mathematical methods to describe and predict the behavior of ecological systems. The tools developed within the group are applied to a spectrum of problems including environmental assessments, theoretical questions in population and ecosystem dynamics, and analyses of phenomena that span scales from the landscape to the globe. Research focuses on landscape ecology (funded by the DOE Environmental Sciences Division), development of individual-based models of fish population (funded by EPRI), and development of biological indicators and landscape models for the Environmental Monitoring and Assessment Program of EPA. Important collaborations have been developed with Fort Lewis College and the University of Wyoming to support research on the fires in Yellowstone National Park.

This year the group has gained new insights into the roles of disturbance, pattern, and stability in landscape equilibrium; developed a framework for using life history information for predicting responses of fish to disturbance; and developed and tested an individual-based model for smallmouth bass.

Environmental Risk

The Environmental Risk Group develops methods for quantitative assessment of environmental risks; applies these methods to local-, regional-, and national-scale environmental problems; and provides guidance to regulatory agencies on the uses of environmental risk assessment. Specific areas of interest include defining and measuring the health of ecological resources, extrapolating test data from laboratory to field and from individuals to populations and ecosystems, quantifying ecological risks at the watershed and landscape levels, and predicting the

movement of contaminants through food chains.

Research is conducted jointly with other ESD groups and with other ORNL divisions. Current sponsors include EPA, the DOE Naval Petroleum Reserve, and Energy Systems ER Program.

This year the ORNL Center for Risk Management was created to help integrate our environmental risk expertise with companion disciplines at ORNL. Additional important activities included the quantification of wet interception of radionuclides by natural vegetation; assistance to EPA in the development of ecological indicators for regional modeling; and the development of a strategy for ecological risk assessment at hazardous waste sites.

Tennessee Valley Authority Ecology Program

As a consequence of a common interest in the environmental impacts of energy development and utilization, TVA and DOE Oak Ridge Operations have developed an agreement to pursue joint research activities, specifically involving ESD staff and members of the Division of Water Resources at TVA. Under this arrangement, TVA personnel are assigned to ORNL to develop programs investigating air- and water-emission impacts on terrestrial and aquatic resources. This relationship combines the experience gained from TVA's power-producing activities with the unique research-support facilities of ESD to produce timely and relevant research findings.

A number of major projects have been implemented. Whereas initial research projects centered on water quality and nutrient-cycling issues in the context of acid rain, more recent—as well as proposed—activities focus on ozone and other chemical and physical changes in the environment that are associated with the general topic of global climate change. The section recently documented that tropospheric ozone and acid rain reduce the growth rate of loblolly pine and completed a major review of soil chemistry changes in North American red spruce-fir stands.

Technical Summaries

11

An Individual-Based Model for Smallmouth Bass Has Been Developed and Tested

D. L. DeAngelis

As part of a program on Compensatory Mechanisms in Fish Populations, which is funded by the Electric Power Research Institute, a model of a smallmouth bass population was developed. The model is based on submodels for the processes of foraging for prey, growth and metabolism, mortality due to predation and starvation, and reproduction. Time-varying environmental conditions, such as temperature and prey availability, are also simulated in the model.

The model has been applied in a preliminary fashion to three particular parts of the smallmouth bass life cycles. First, individual brood swarms of young-of-the-year smallmouth bass were modeled during the time they were being guarded near the nest by the male parent. The model indicated that brood swarms that occupied large territories were able to grow faster and survive better than brood swarms in smaller territories. This result emphasizes the reproductive advantage of larger male parents, who can defend large nest territories and thus make more food available to their offspring. The second problem was to determine the relationship between the number density of new larval smallmouth bass produced in a given nesting area during a single spawning season and the number of these that recruit to the yearling class 1 year later. This relationship was predicted to be nonlinear under typical conditions, with peak recruitment at intermediate-number densities of larvae and a decline in recruitment for higher densities because of depletion of prey resources. The third application was to examine the total life cycle of smallmouth bass males. The model is structured so that various reproductive strategies (age and size at which reproduction can take place) can be assigned to males. It was found that the cost of spawning, during which the male guards the nest and frequently does not eat for a month, is so high that it may be a net advantage for a male to wait 1 year after it is capable of reproduction to actually spawn.

The model for smallmouth bass has been put in a menu-driven form that will enable collaborators outside of ESD to apply it to their specific problems.

12

Analysis of Stable Nitrogen Isotopes in Precipitation and Throughfall Indicates a Potential Importance of Atmospheric NH_4-N Inputs to Walker Branch Watershed

C. T. Garten, Jr.

Although atmospheric deposition of anthropogenic nitrogen (N) is recognized as an important component of acidic deposition, numerous questions remain about its fate in forest ecosystems. Studies of stable N isotope ratios (^{15}N:^{14}N) in N deposition may help improve our understanding of potential changes in forest N cycling that could arise from increasing or decreasing anthropogenic N emissions to the atmosphere. However, there are few studies of stable N isotope

ratios in precipitation and other forms of atmospheric deposition. In this work, the differences were examined in the stable isotope composition of ammonium (NH_4-N) and nitrate (NO_3-N) in bulk precipitation and throughfall at Walker Branch Watershed (WBW), near Oak Ridge, Tennessee.

Over a 1-year period on WBW, the mean ($\pm$SD) δ^{15}N-value for NH_4-N in bulk precipitation and throughfall (-3.4 ± 2.1‰) was significantly less than that for NO_3-N ($+2.3 \pm 2.4$‰); thus, NH_4-N contained proportionately less ^{15}N than did NO_3-N. The isotopic composition of NH_4-N in bulk precipitation and throughfall was consistent with its origination from the washout of atmospheric NH_3, which has been reported to be strongly depleted in ^{15}N. The mean δ^{15}N-value for NO_3-N in bulk deposition and throughfall on WBW was higher than values reported in previous studies of stable N isotopes in precipitation. One possible explanation may be the importance of dry N deposition (nitric acid vapor, N oxides, or nitrate aerosols) to the watershed. The isotopic composition of NO_3-N in bulk precipitation and throughfall on WBW is consistent with its origin from the washout of particulate and aerosol nitrate from the atmosphere, as well as nitrate formation from gaseous anthropogenic precursors (both nitrate in dry deposition and nitrogen dioxide from auto exhaust are reported to be enriched in ^{15}N). Our hypothesis is that throughfall nitrate becomes enriched in ^{15}N by washoff of dry-deposited nitrate aerosols and that rainfall becomes enriched by precipitation scavenging of nitrate aerosols in air.

Data on the isotopic composition of inorganic N in precipitation and throughfall have the potential for tracing the fate of N inputs to forest ecosystems. For example, on WBW ridges and slopes, the mean ($\pm$SD) δ^{15}N-value of total leaf N in red maple trees is -3.4 ± 1.1‰, which is similar to that of NH_4-N but different from that of NO_3-N in bulk precipitation and throughfall. The similarity suggests that foliar N in red maple trees may be partly derived from NH_4-N in bulk precipitation and throughfall inputs to the forest canopy or to shallow roots in the forest floor. Prior studies with enriched ^{15}N under laboratory conditions showed that NH_4-N applied to red maple and white oak leaves in simulated rainfall was preferentially retained relative to NO_3-N. This finding was consistent with prior field observations of flux or concentration differences between rain and throughfall that indicated the uptake of deposited NH_4-N by the forest canopy. Together, these studies indicate the potential importance of atmospheric NH_4-N inputs to N cycling in an N-deficient forest such as the Walker Branch Watershed.

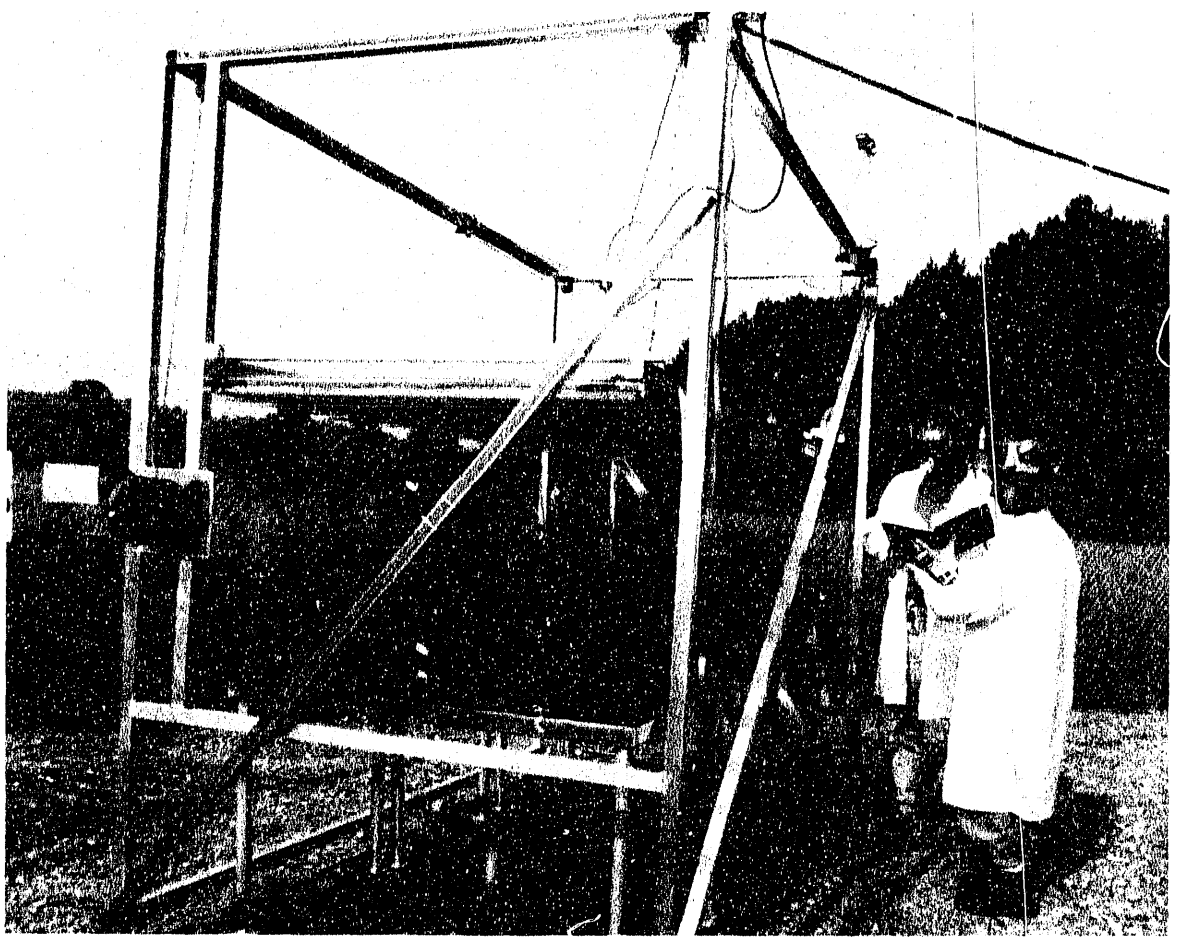
13

Elevated Atmospheric CO_2 Enhances Photosynthesis in Two Deciduous Tree Species Under Field Conditions

C. A. Gunderson and R. J. Norby

An increased rate of photosynthesis is a widely documented response of many plants to elevated concentrations of atmospheric CO_2. If the photosynthetic rate of forest trees also increases in response to the globally rising atmospheric CO_2 concentration, then the biosphere may be an increasingly important sink for the carbon released from the burning of fossil fuels. Some researchers have suggested, however, that the enhancement of photosynthesis in elevated CO_2 will not be sustained over time because internal plant feedback mechanisms lead to a down-regulation, or acclimation, of photosynthesis.

A 4-year field study of tree responses to elevated CO_2 was established in which tests will determine whether photosynthetic enhancement is sustained over several growing seasons. Yellow-poplar (*Liriodendron tulipifera* L.) and white oak (*Quercus alba* L.) seedlings were planted in the ground in six open-top field chambers in May 1989. The atmospheres in the chambers were enriched with CO_2 to three levels: +0 μmol mol^{-1} (ambient), +150 μmol mol^{-1}, and +300 μmol mol^{-1}, with two replicate chambers per treatment. The CO_2 enrichment was continuously maintained during the 1989 and 1990 growing seasons. Throughout the 1990 growing season, gas exchange of upper, light-saturated leaves was periodically



Students Clint Rash and Denise Kay measure ultraviolet-B (UV-B) irradiance levels at the ESD UV-B exposure facility on the Oak Ridge Reservation. They are working with Nelson Edwards and Tim Tschaplinski on a project evaluating the responses of terrestrial vegetation to enhanced levels of UV-B.

surveyed, and leaves of different ages and canopy positions were occasionally measured.

Net photosynthesis (P_N) of leaves of both species remained higher at elevated CO_2 levels throughout the season, regardless of increasing leaf age and duration of exposure to CO_2 enrichment. P_N was 28 to 32% higher in the trees in the +150 treatment and 49 to 67% higher in the +300 treatment. Stomatal conductance remained unchanged or decreased slightly with increasing CO_2, but instantaneous water-use efficiency (P_N/transpiration) increased significantly with CO_2. Analysis of P_N vs internal CO_2 concentration indicated no significant treatment differences in carboxylation efficiency, CO_2-saturated P_N, or CO_2 compensation point. Thus, we conclude that there was no downward adjustment of photosynthesis to CO_2 enrichment in this system.

These results indicate that photosynthesis in forest tree species can be stimulated by elevated atmospheric CO_2 concentrations under field conditions and the response can be sustained over at least two growing seasons. Our experimental trees have been continuously exposed to elevated CO_2 concentrations longer than any other forest tree species. The responses of these trees will help predict the responses of forests to global change and the role that forests may play in sequestering carbon released from fossil fuels.

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Carbon Storage of Oak-Hickory Forests Is Being Evaluated in Response to Moisture Gradients

P. J. Hanson, S. D. Wullschleger,[1]
D. E. Todd, and W. K. Roy

Unresolved sinks in the global carbon cycle have led to renewed interest in long-term carbon storage capabilities of terrestrial ecosystems both as a means of resolving current unknowns and as a means of mitigating increasing levels of CO_2. Unfortunately, existing forest carbon storage estimates may not apply under the modified environmental conditions (i.e., warmer temperatures and altered precipitation) projected to result from global warming.

Measurements of tree growth and forest gas exchange are being conducted along topographic moisture gradients to provide information on key processes necessary to modify carbon budgets for future drought scenarios. The research sites are located on the Walker Branch Watershed and include mesic slopes, xeric slopes, ridgetop sites, and riparian zones. Dendrometer bands are used to measure seasonal changes in tree stem diameter to indicate the relative growth of canopy trees. Measurements of forest floor and stem respiration are made to quantify biological sources of CO_2 flux to the atmosphere. Environmental data are collected from which process-level models of the component carbon cycling processes are generated. These measurements, together with previous and future data on photosynthesis and stand structure, are being used to evaluate net carbon storage within these forest stands.

Seasonal stem growth of deciduous trees is exhibiting uniform phenological patterns of

development between species and across topographic locations, indicating that models of carbon storage can be somewhat simplified. Conversely, topographic moisture patterns differentially affect species. Yellow-poplar trees show marked reductions in growth on xeric slopes, but oak species seem somewhat insensitive to growth location. These observations agree with long-term growth trends on the Walker Branch Watershed that show little change in oak growth during the dry 1980s but as much as a 50% reduction in yellow-poplar growth during those same drought years. Recent dormant-season observations have also shown that forest floor respiration under photosynthetically active pine canopies is double that of forest floor locations under deciduous trees, indicating that spatial and temporal location can have a dramatic impact on the carbon budgets of forest stands.

The understanding of carbon cycling processes obtained from this research will allow robust estimates of forest carbon gain applicable to a variety of climate scenarios. Accurate estimates of forest ecosystem carbon sequestration are currently needed to resolve questions about the impact of biological systems on global carbon cycling.

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15

Wet Interception of Radionuclides by Natural Vegetation Is Quantified Through Field and Laboratory Studies

F. O. Hoffman, K. Thiessen, M. L. Frank, and B. G. Blaylock

The interception of wet-deposited radionuclides by pasture vegetation is typically assumed in risk assessment models to be 25% regardless of the amount and intensity of rain or the density and species composition of the vegetative canopy. Experimental work at ORNL indicates that this assumption is invalid for soluble ^{131}I. Soluble ^{131}I, as well as other anions, appears to run off the vegetation surface as the surface becomes saturated. This effect is less pronounced for many cations and insoluble substances.

Cations apparently interact chemically with the plant surface, possibly because of the predominantly negative charge of the surface, and insoluble particles (size 3 to 25 μm) rapidly settle and are sorbed by the surface. For cations and insoluble particles, the density of the vegetation canopy is more important than the amount or intensity of rain in determining the initial interception and retention of these materials on pasture-type vegetation. For biomass densities ranging from 100 to 300 g/m^2 (dry weight), the typically assumed 25% interception fraction may not be a poor approximation for cations and insoluble particles when vegetation is harvested above 5 cm from the soil surface and when rain varies in amounts of 1 to 10 mm.

For soluble anions, the interception fraction is inversely proportional to rain amount and the effect of rain intensity is of minor significance. The most important processes affecting interception of anions appears to be the amount of canopy cover and the potential for drying of the raindrop on the plant surface.

Once drying occurs, subsequent rain is not an efficient mechanism for removing the material initially deposited on the vegetation. Field loss rates (7 to 18 d) obtained from these experiments over a period of 1 month, however, are similar to other values reported in the pre- and post-

Chernobyl literature and are similar to values assumed by assessment models.

Additional data indicated that wet interception of a given chemical substance by spruce needles, tree leaves, grasses, and a variety of other herbaceous plants were similar, provided that interception is normalized for either the mass or area of the leaf. More pronounced differences were observed across chemical substances than across the different types of vegetation. The highest normalized interception occurred for reactive cations (Be^{2+}, Cd^{2+}, and Cr^{3+}); somewhat lower values occurred for Sr^{2+} and an insoluble microsphere (9 μm). The lowest values were observed for anions (I^- and SO_4^{2-}). The differences between the highest and lowest normalized interception values were approximately a factor of 5. These differences were consistent across the various species of vegetation considered in the experiment. The high values are similar to values assumed in risk assessment models for the biomass normalized interception fraction ($\sim 2\ m^2/kg$).

16

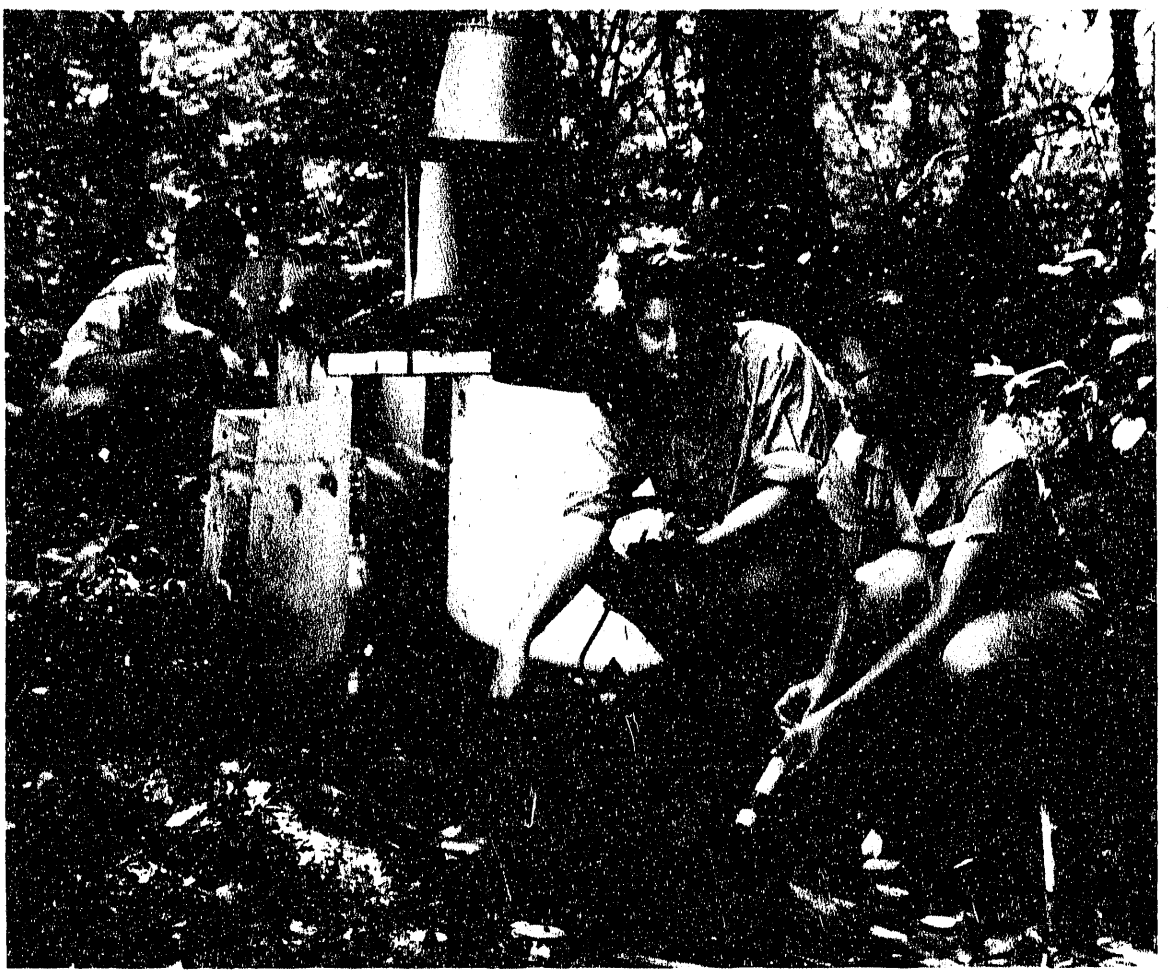
Ecological Indicators for Regional Monitoring Are Identified

C. T. Hunsaker, J. F. McCarthy,
L. R. Shugart, and R. V. O'Neill

The United States lacks an integrated approach to monitoring indicators of ecological condition, pollutant exposure, and habitat loss and degradation. Thus, it cannot be determined whether the frequency and extent of ecological problems are increasing on a regional scale, whether detected patterns are warning indicators of significant long-term changes in ecological condition, or whether potential causes are natural or anthropogenic. The U.S. Environmental Protection Agency (EPA) began planning the Environmental Monitoring and Assessment Program (EMAP) in response to this lack of adequate monitoring of ecological conditions.

A critical first task for EMAP was to develop an indicator strategy and identify appropriate indicators for selected ecosystems: near-coastal waters, inland surface waters, wetlands, forests, arid lands, and agroecosystems. Over 200 scientists participated in this EPA effort, which was led by ESD. The EMAP indicator strategy is based on a risk assessment approach in which ecological indicators are used to address an assessment end point such as habitat loss or reduced biodiversity. Three categories of indicators are being developed: (1) response indicators are biological measurements that address the overall condition of ecosystems; (2) exposure and habitat indicators are physical, chemical, and biological measurements that can be related to pollutant exposure, habitat degradation, or other causes of poor condition; and (3) stressor indicators are measures of anthropogenic and nonanthropogenic activities that can create an environmental hazard. Thus, response indicators evaluate ecosystem health, whereas exposure and stressor indicators identify possible causes of subnominal or poor conditions.

EMAP will estimate (with known confidence) current status, extent, changes, and trends in indicators of the condition of the nation's ecological resources on a regional basis. In addition to the indicator effort, EMAP has programmatic activities in landscape characterization, statistics and design, integration and assessment, and data base management. EMAP's emphasis on integrated monitoring and assessment and its commitment to interagency participation are unique. Continuing



Bonnie Lu (right) and participants in the DOE High School Honors Program in Environmental Sciences measure electrical conductance and filter water from a stream discharging into Walker Branch on the Oak Ridge Reservation. Researchers measure the concentrations of chloride, nitrate, and phosphate in the filtered spring water as part of an experimental tracer study to determine the pathways of groundwater flow and the potential for nitrate removal from the stream.

EMAP work includes assisting with development of an integrated assessment approach and demonstrating the usefulness of landscape characterization data for regional risk assessment.

17

Analysis of Light Penetration into Forests Allows Calculation of Leaf Area of Forest Canopy

M. A. Huston, J. W. Chason, and D. Baldocchi[1]

The surface area of leaves in plant canopies is strongly correlated with total plant productivity, uptake, and release of greenhouse gases and the deposition of gaseous and particulate atmospheric pollutants. Traditional methods of measurement of leaf area are time consuming and difficult, particularly in the forest canopies that are responsible for most of the global plant productivity and gas exchange.

We compared two indirect "remote sensing" methods for estimating leaf area of the forest canopy on Walker Branch Watershed with a direct estimate based on the collection of leaves that fell from the canopy in autumn. Both indirect methods are based on the principle that leaf area can be estimated from the proportion of full sunlight that penetrates through the forest canopy. The higher the leaf area, the less sunlight reaches the forest floor. One indirect method used a device that measured penetration of direct beam sunlight and, consequently, could only be used on sunny days; the other indirect method used a device that measured diffuse light penetration and could only be used on cloudy days when there was no direct sunlight. Measurements were made over the period of autumn leaf drop, covering a wide range of leaf area conditions from fully leafed out to leafless.

Both methods produced consistent measurements of the relative proportion of light penetrating through the forest canopy along different path angles. However, the accuracy of the estimates of leaf area produced by both the direct-beam and diffuse-light methods depended on the specific light penetration model that was used to analyze the light penetration data. For both direct and diffuse light penetration, better estimates were obtained by using a binomial model than by using the Poisson model supplied with commercial versions of the two devices. The difference between the two models for analysis of the light penetration data is that the Poisson model assumes that the light-blocking foliar elements are randomly distributed over the hemisphere of the sky, whereas the binomial model assumes that the foliar elements are clumped. Previous empirical work on Walker Branch Watershed, along with the results of this study, indicate that leaves tend to be clumped. Failure to consider this clumping results in an underestimate of leaf area because several leaves may block out the same area of sky.

Light penetration data from both the direct-beam and diffuse-light methods produce more accurate estimates of canopy leaf area when analyzed with the binomial rather than the Poisson model. Because of the ease with which data can be collected using the commercial device for measurement of diffuse light penetration, this method offers great promise in providing data on this important ecosystem parameter that can be used in models of forest production, gas exchange, and pollutant uptake.

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18

Soil Heterogeneity May Lead to Macropore Formation and Failure of Compacted-Soil Barriers in Shallow Land Burial Facilities

R. J. Luxmoore

The integrity of compacted-soil caps and liners in shallow land burial facilities depends on the long-term stability of the water content of these barriers. Periodic wetting and drying of soil barriers associated with precipitation and evapotranspiration could lead to crack formation and eventual failure. Temporal changes in the water content of compacted-soil barriers in representative landfill operations in a humid environment have been simulated with computer modeling. This modeling is used to evaluate possible long-term changes in barriers at shallow land burial facilities following closure.

Three landfill designs were simulated by using the Unified Transport Model (UTM) hydrologic code. Input data for the Oak Ridge area were assembled to represent a humid-region site where annual evapotranspiration is less than annual precipitation. Such sites have a net excess of soil water drainage that needs to be diverted around landfill wastes by the cap and liner barriers. In the first series of simulations, mean soil properties were used to simulate an ideal landfill built to specifications. Soil heterogeneity was next introduced into the modeling by propagating a lognormal frequency distribution of soil hydraulic properties through the UTM by using the Latin hypercube sampling method. Published field studies have shown that several orders of magnitude of variation in the hydraulic conductivity of soil barriers can occur. In the last series of simulations, soil macropores (cracks and channels) were introduced into the barriers.

Simulations of ideal landfills did not show any significant change in barrier water content and very little leakage for the two designs without root invasion of the cap. Root penetration into the compacted-soil cap resulted in significant drying due to transpiration, and the original water content of the soil cap decreased by 10%. Simulations with two orders of magnitude of variation in barrier hydraulic conductivity showed a small increase in drainage through the landfill; however, the barriers were still effective. Cap water content, however, decreased by 36% in some cases, and this could lead to crack formation by soil shrinkage. Simulations that included barrier macropores showed complete failure of the landfill and high leachate production.

Macropore formation during construction of barriers or by shrink-swell processes associated with drying and wetting is a concern in the long-term performance of shallow-land burial facilities in humid environments. Macropores may also be formed by vegetation with deep roots or by burrowing animals that may invade a landfill facility after termination of institutional control.

19

Calcium Availability and Forest Decline: Has the Future Arrived?

S. B. McLaughlin, E. A. Bondietti,[1] and W. K. Roy

The decline in vigor of red spruce at high-elevation sites across the Appalachian Mountains has been a focal point of concerns that eastern forests were being adversely affected by acidic deposition.

These concerns were addressed at ORNL in several projects as a part of the National Forest Response Program sponsored primarily through the National Acid Precipitation Assessment Program (NAPAP). One of the significant findings from this work has provided evidence indicating that growth of high-elevation red spruce forests currently is being adversely impacted by acid deposition through ecosystem level changes in nutrient cycles. The nutrient that appears to be a pivotal component of these changes is calcium, and evidence suggests that changes in calcium cycling in high-elevation forests were being induced by acid deposition well before NAPAP began to study the problem.

Forest decline research at ORNL began with documentation and analysis of growth decline of mature red spruce on a regional scale at sites extending from Maine to Tennessee. This work, based on tree-ring analysis, led to the documentation of a regional growth decline that was unprecedented during the previous 200 years of record. Decreased growth occurred over a 5- to 10-year time window across nearly all high-elevation sites beginning ~30 years ago. Analyses showed that stand competition was not a causal factor and responses were not predictable based on past climatic influences on growth. In the northern Appalachians, growth reduction was more severe, started 5–10 years earlier than in the South, occurred at all elevations, and was accompanied by severe and progressive mortality (>60% in some stands). In the southern Appalachians, growth decline occurred only at elevations above ~5000 ft and has been accompanied principally by visual deterioration of tree crowns. The elevational gradient in effects in the South has provided us with an opportunity to explore the physiological basis and hence the causes of the growth decline.

A series of studies conducted in the Smoky Mountains has identified a reduced efficiency of carbon metabolism that occurs at high elevations in association with low levels of foliar and soil calcium and high levels of available soil aluminum. Both the increased loss of calcium from foliage and the inhibition of calcium uptake from soils have been shown to be induced by acidic deposition. Controlled experiments have now documented that acidic deposition at levels occurring along the cloud-impacted high mountains can reduce efficiency of carbon metabolism as observed in the field.

Tree-ring chemistry studies have documented that changes in aluminum and calcium content in wood began to occur in eastern red spruce forests 30–40 years ago at approximately the same time SO_2 and NO_X emissions rapidly increased across the region. Historical analysis of soil chemistry data indicated that calcium levels in the upper organic horizons of eastern red spruce soils are now reduced ~50% from pre-1950 levels. The importance of calcium to a wide variety of forest physiological processes and its apparent susceptibility to depletion and interference by acidic deposition have led us to conclude that the "future effects" of acid deposition on forest soils predicated by process models[2] have already arrived in the red spruce forest.

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[1] *Deceased.*

[2] *National Acid Precipitation Assessment Program,* 1989 Annual Report, *NAPAP, Washington, D.C., 1990.*

20

Hydrogeochemical Studies on Walker Branch Watershed Indicate That Streamflow Is Generated via Three Subsurface Flowpaths

P. J. Mulholland and D. Genereux[1]

The issues of acidic deposition and contaminant transport have resulted in increased interest in forest hydrology. Efforts to identify the dominant flowpaths generating streamflow in low-order streams and the mechanisms controlling flux of cations and anions along these flowpaths have intensified. Hydrometric measurements and mixing analyses using naturally occurring chemical and isotopic tracers have been used to determine the dominant hydrologic flowpaths in small catchments. Spatial and temporal analyses of groundwater and surface-water chemistry have been used to determine differences in solute chemistry along different subsurface flowpaths. Stream chemistry is then determined by the mixing of water from the different flowpaths, the proportions of which vary over space and time.

A combination of hydrometric measurements (streamflow and groundwater levels), natural chemical

Lee Cooper changes amplifier heads on a stable isotope mass spectrometer to allow measurement of deuterium:hydrogen ratios in natural water samples. Very slight changes in natural abundances of deuterium, a rare form of hydrogen with one neutron, can be used as a diagnostic tool for studying oceanographic, hydrologic, geologic, and plant physiological processes.

tracers (Ca and SO_4), and a newly developed technique involving naturally occurring ^{222}Rn were used to determine the importance of different flowpaths in generating streamflow in the Walker Branch Watershed over a range of hydrologic states (base flow and storm flows). These techniques were applied across a nested set of catchments, ranging in size from 0.5 to 38.4 ha. The results indicate that streamflow can be viewed as a mixture of geochemically distinct water from three subsurface flowpaths that vary in importance with hydrologic conditions. These flowpaths are (1) bedrock fracture flow with relatively high concentrations of Ca, moderate levels of ^{222}Rn, and low concentrations of SO_4 and dissolved organic carbon (DOC); (2) saturated-zone groundwater with high levels of ^{222}Rn and low concentrations of Ca, SO_4, and DOC; and (3) vadose-zone groundwater (including temporary zones of perched saturation) with high concentrations of SO_4 and DOC and very low concentrations of Ca and ^{222}Rn.

During base-flow periods, fracture flow dominates streamflow resulting in stream chemistry dominated by Ca, Mg, and HCO_3, with relatively low concentrations of SO_4 and DOC. At higher flows, contributions from vadose-zone groundwater increase sharply and can dominate streamflow, resulting in substantial dilution of Ca, Mg, and HCO_3 and sharp increases in SO_4 and DOC concentrations. Importance of saturated-zone groundwater also increases at high flow, but this component is less important than vadose-zone groundwater.

This research indicates that mobilization and transport or retention of materials through watersheds depends on hydrologic processes that route water along different flowpaths and on vertically stratified biogeochemical processes that regulate solute concentrations in different soil or bedrock zones.

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21

Concept of Landscape Equilibrium Is Revised Regarding Disturbance, Pattern, and Stability on Scaled Landscapes

M. G. Turner, W. H. Romme,[1]
R. V. O'Neill, and R. H. Gardner

Concepts of landscape equilibrium are confounded by problems of scale. A broader context was developed for the description of landscapes that incorporates the space and time scales of disturbance and predicts the resultant dynamics of a landscape at any scale of observation. Five major factors controlling the dynamics of landscapes are considered: (1) disturbance frequency, or its inverse, the interval between successive disturbances; (2) rate of recovery from disturbance, or its inverse, the length of time required for a disturbed site to recover; (3) disturbance intensity (i.e., the amount of damage inflicted on the biota); (4) the size or spatial extent of disturbance events; and (5) the size or spatial extent of the study landscape.

Because the functional effects on the landscape of these five factors are interrelated, we reduce them to two key parameters representing time and space that can be used to describe potential disturbance dynamics. The temporal parameter, T, is defined by the ratio of the disturbance interval to the recovery time. The intensity of a particular disturbance is incorporated in the recovery time such that a low-intensity disturbance would be

associated with rapid recovery and a high-intensity disturbance with slow recovery. The spatial parameter, S, is defined by the ratio of the disturbance size to the landscape size. The use of ratios in both parameters permits the comparison of landscapes across a range of spatial and temporal scales.

A simple simulation model was developed to explore the implications of various combinations of the parameters S and T. The landscape is represented as a square grid of 100 × 100 cells. Eight vegetation classes representing sequential seral stages are included in the model. Initially, the entire landscape is covered with mature vegetation (seral stage 8). At a fixed interval, square disturbances of a fixed size are imposed at random locations on the landscape. Disturbed sites recover deterministically through succession, passing through a seral stage at each time interval and achieving full recovery eight time steps following disturbance. The

Moist tropical forests such as this in the Brazilian Amazon are being burned at an alarming rate by farmers to create cropland. Virginia Dale, Bob O'Neill, and Marcos Pedlowski, along with Frank Southworth of the ORNL Energy Division, are studying the effects of the deforestation on the local economy and social structure as well as on the environment.

disturbance-recovery process is continued for 100 time intervals in each simulation.

Where the disturbance interval is long relative to recovery time and a small proportion of the landscape is affected, the system is stable and exhibits low variance over time (e.g., northeastern hardwood forests). These are traditional *equilibrium* systems. Where the disturbance interval is comparable to recovery interval and a large proportion of the landscape is affected, the system is stable but exhibits large variance (e.g., subalpine forests in Yellowstone National Park). Where disturbance interval becomes much shorter than recovery time and a large proportion is affected, the system may become unstable and shift into a different trajectory (e.g., arid ecosystems with altered fire regimes). This framework permits the prediction of disturbance conditions that lead to qualitatively different landscape dynamics and demonstrates the scale-dependent nature of landscape equilibrium concepts.

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22

Multivariate Analysis of North American Fish Life Histories Provides Framework for Predicting Responses to Disturbances

K. O. Winemiller[1] and K. A. Rose

Life history theory provides a conceptual framework for comparisons among different species and settings in population simulation models. To evaluate a general demographic model of life-history evolution, life cycle data was gathered for 225 species (24 orders, 57 families) of North American freshwater and marine fishes for analysis of relationships among variables and ordination of species.

Principle components analysis (PCA) was performed on a merged data set (225 species, 16 variables) and on separate data matrices containing species classified as either freshwater or marine. In the merged and freshwater data sets, high scores on the first orthogonal axis (PC1) were associated with late maturation, high fecundity, small eggs, and few bouts of reproduction during a short spawning season. High scores on PC2 were associated with parental care, large eggs, and extended breeding. PCA results from the marine data set were similar, except that egg size was positively associated with PC1. Phylogeny significantly influenced all 16 life history variables (Nested ANOVA, Canonical Discriminant Function), and higher taxa were associated with particular subregions within multidimensional life history space. Large egg size in salmonids influenced the results of PCA for marine vs freshwater and merged data sets.

The brief summer growing season appears to favor large egg size in inland waters at high latitudes. Canonical correspondence analysis based on 12 life history and 7 ecological variables showed a positive association between the high fecundity suite of life history characteristics and large ranges within the marine environment. Late maturation, rapid adult growth, long lifespan, and large egg size were positively correlated with anadromy and piscivory. Parental care were negatively correlated with median latitude.

A triangular, two-dimensional continuum predicts many of the intercorrelations among traits for North American fishes. The continuum represents an adaptive surface with a quantitative basis in essential demographic tradeoffs. Review of the life history literature indicates that (1) seasonally variable environments or

large-scale spatial variation favors late maturation, large batch fecundity, and pulsed bouts of reproduction; (2) saturated habitats with relatively stable resources favor smaller clutches and increased investment in individual offspring; and (3) stochastically varying environments favor early maturation and other traits associated with opportunistic reproduction and frequent recolonization of habitat patches. This general model has important implications for predicting the response of populations to different kinds of natural and anthropogenic disturbances and provides a basis for comparing the response of divergent populations to the same disturbance.

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Environmental Analyses

Introduction

The Environmental Analyses Section of the Environmental Sciences Division (ESD) at Oak Ridge National Laboratory (ORNL) develops theory and methods, analytical tools, and numeric data bases to evaluate environmental problems and issues and prepares interdisciplinary assessments of environmental issues at spatial scales ranging from the individual site to the regional landscape and the globe. The section also provides technical assistance for the development of policy concerning compliance with environmental regulations. These objectives are accomplished by the three groups into which the section is divided.

Environmental Assessment

The Environmental Assessment Group prepares impact analyses for use by sponsors within the U.S. Department of Energy (DOE), the Federal Energy Regulatory Commission (FERC), the Nuclear Regulatory Commission (NRC), and the U.S. Department of Defense (DOD) as part of their compliance with the National Environmental Policy Act (NEPA). These analyses assess impacts on terrestrial and aquatic ecological resources, land and water use, and water quality for environmental impact statements and related documents.

Staff members also provide technical reviews and analyses of NEPA documents and related issues for the DOE Office of NEPA Oversight and technical support to the Environmental Protection Agency (EPA) Office of Federal Activities. The goal of the Environmental Assessment Group is to apply state-of-the-art assessment tools to complex issues at individual plants, at sites that are large geographically, and in areas that are programmatic in scope.

In FY 1991, staff provided NEPA training for DOE managers and, as members of Tiger Teams, played an important role in assessing NEPA compliance at DOE facilities. The group is also analyzing the environmental implications of the development of multiple hydroelectric power plants, the relicensing of nuclear power plants, disposal of the U.S. stockpile of chemical agents and munitions, and continuing the U.S. Antarctic Program. In addition, staff have cochaired an international task force on the application of environmental impact assessment (EIA) to government policy, plans, and programs for EPA. New initiatives for EPA include the development of an EIA sourcebook/manual.

Environmental Compliance

The Environmental Compliance Group conducts a variety of regulatory analysis and environmental compliance activities in support of a number of sponsors, such as the DOE Office of Environmental Guidance and the U.S. Air Force. Intense pressure to clean up and protect the environment at federal sites is currently being exerted by Congress, the regulatory authorities, and the public. The regulatory programs that implement the major federal environmental statutes—including the Resource Conservation and Recovery Act (RCRA) and the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA)—are complex mazes of rules, procedures, and technical requirements that change frequently as the regulatory authorities respond to changes in law.

The Environmental Compliance Group is composed of professional regulatory specialists who maintain an up-to-date working knowledge of the existing federal environmental laws and regulations, as well as of legislative and regulatory actions now under consideration by Congress and the regulatory agencies. The group tracks and analyzes new regulations both to facilitate sponsor understanding of technical requirements and to determine their impact on the facilities and programs of DOE and other sponsors. The group also performs environmental compliance audits and provides training in environmental laws and regulations.

Regional Water Resources Group

The Regional Water Resources Group conducts basic and applied research on the management and analysis of water resources and related natural systems (e.g., fish populations affected by water allocation or land-use practices as they interact with water quality). The group specializes in the development and application of quantitative assessment techniques to solve environmental problems over a variety of spatial scales ranging as large as river basins and national boundaries.

Relevant water resource issues include the environmental effects of hydroelectric development, instream flow needs, multiple-use tradeoff analyses, cumulative impact assessment, contaminant transport, surface and groundwater monitoring, acidic deposition, and climate change. Scientists in the group maintain unique capabilities in simulation and optimization modeling, sensitivity and uncertainty analysis, geostatistical applications, geographic information systems, and scientific data base management.

In FY 1991, the group completed its support to the National Acidic Precipitation Assessment Program (NAPAP) with several publications, including NAPAP's 1991 Integrated Assessment and the State of Science Report on biological effects. The environmental effects of hydroelectric development were the focus of several different projects, with sponsorship from DOE, the Electric Power Research Institute, and the Federal Energy Regulatory Commission. The major products related to hydropower were (1) a DOE report on mitigation practices for instream flow needs, dissolved oxygen protection, and fish passage; and (2) development work on a new generation of instream flow assessment models that predict fish population response to altered flow regimes.

The group also provided continued support to the EPA Environmental Monitoring and Assessment Program in the area of spatial statistics and to the Environmental Restoration Program on the Oak Ridge Reservation in the areas of groundwater data management and analysis and application of geographic information systems. Staff worked with the President's Council on Environmental Quality (CEQ) in Washington, D.C., to produce a plan for national environmental trends assessment, the result of which was a report to CEQ entitled "Environmental Trends Assessment: Concepts, Approaches, and Strategies."

Technical Summaries

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Two Applicable or Relevant and Appropriate Requirements for Cleanup of Tritium Are Identified

C. F. Baes III

In 1988 the Oak Ridge Reservation location of ORNL was placed on the National Priorities List (NPL). Placement on the NPL establishes requirements for the cleanup of hazardous substances released to the environment in accordance with policies set forth in the Comprehensive Environmental Response, Compensation and Liability Act of 1980 (CERCLA) as amended by the Superfund Amendments and Reauthorization Act of 1986. CERCLA requires that cleanups achieve a level or standard of control for hazardous substances that attains all legally applicable or relevant and appropriate requirements (ARARs) of other federal and state laws. A study was initiated to examine potential ARARs for tritium (^3H), an isotope of hydrogen with a half-life of 12.28 years. Tritium is a CERCLA hazardous substance that contaminates soils and water in the vicinity of ORNL at levels as high as 800,000 pCi/L.

To determine potential ARARs for the cleanup of soils and water contaminated with ^3H, federal, state, and local radiation protection standards and guidelines were reviewed. A number of federal standards and guidelines were identified. Only one state standard was found, and no local standards or guidelines were identified.

One potential federal ARAR legally applicable to ^3H remedial activities is the Federal Guidance on Occupational Exposures to Radiation of January 27, 1987, which establishes a limit of 5 rem per year for workers over age 18. For the cleanup of groundwaters and surface waters in the vicinity of ORNL, another potential ARAR that undoubtedly will be applied is the federal (and state) drinking water standard that sets a maximum contaminant level (MCL) of 20,000 pCi/L (740 Bq/L) for ^3H. CERCLA requires that MCLs be achieved in the cleanup of groundwaters and surface waters that are actual or potential sources of drinking water. Groundwaters in the vicinity of ORNL currently are not sources of drinking water. However, many contain <10,000 mg/L total dissolved solids and may be hydrologically connected to other sources of drinking water (e.g., the Clinch River). For these groundwaters, CERCLA requires that the 20,000 pCi/L MCL be a cleanup goal.

Compliance with ARARs is required only on completion of CERCLA remedial action. Therefore, remedial actions involving ^3H could take advantage of its relatively short half-life in achieving the 20,000 pCi/L level in groundwaters and surface waters. For example, a 200-year institutional control period, as an integral part of a remedial action, would ensure that even the most contaminated groundwaters at ORNL would achieve the ^3H MCL at the end of the remedial action.

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Impacts to Aquatic Resources Are Assessed for Nuclear Power Plant Relicensing Rule

G. F. Cada, V. R. Tolbert, and
S. W. Christensen

More than half of the 118 licensed commercial nuclear power plants in the United States will have reached the end of their original 40-year license period by the year 2020. Because the nuclear utility industry has expressed considerable interest in operating these facilities beyond their initial term, the Nuclear Regulatory Commission is developing a rule for relicensing commercial nuclear power plants. This rule will specify the types of environmental information that would be required in the relicensing applications. ORNL was contracted to prepare an Environmental Impact Statement (EIS) on this proposed action to comply with the National Environmental Policy Act.

A wetland area such as this one at the Umatilla Army Depot in Oregon could be adversely affected by the deposition of chemical nerve agents if an incineration accident were to occur. Roger Kroodsma, Virginia Tolbert, and Julie Watts are assessing the potential environmental impacts that the construction of incinerators could have at eight continental U.S. Army storage sites.

Analysis of impacts to aquatic resources in the EIS focused on the effects of continuing power plant operation on water quality, water use, and aquatic biota. The potential impacts on all of these resources stem mainly from operation of the cooling water systems, although possible effects of construction and modifications that accompany continued operation during the relicense period were also examined. Monitoring data and other published information were examined for evidence of past or ongoing impacts. In addition, both nuclear utilities and regulatory and resource agencies were consulted to ascertain the level of concern regarding impacts on aquatic resources at operating plants. If no impacts had occurred during the initial operating period of the plant, continued operation under similar circumstances during the relicense period would not be expected to result in significant impacts.

The study results indicate that, despite many early concerns, impacts on aquatic resources have not been significant at any facility. In some cases, adverse effects on water quality or aquatic biota were corrected and have not recurred. Certain issues, such as the entrainment and impingement of large numbers of fish or the discharge of large volumes of heated water, continue to warrant monitoring and occasionally mitigation. Regulatory mechanisms (e.g., the periodic renewal of the plant's water quality permit by state or federal permitting agencies) have been sufficient to minimize impacts on aquatic resources. This study synthesizes information about the effects of licensed nuclear power plants that will be used to determine relicensing requirements.

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Scope and Intensity of ESD Participation in Environmental Auditing Expand

G. K. Eddlemon, T. L. Ashwood, G. F. Cada, C. Heckman, M. B. Hyder, L. L. Sigal, C. F. Sigmon, V. R. Tolbert, and J. W. Webb

Formal participation of ESD staff in environmental compliance auditing began with the multimedia assessments of four U.S. Air Force bases of the Tactical Air Command during the summer of 1985. The interdisciplinary teams for these efforts included only two ESD members along with staff from other ORNL divisions. Since that time, the scope of environmental compliance activities involving ESD staff has expanded to include at least nine staff members, who participate as needed in compliance audits of major bases and facilities at other commands of the U.S. Air Force (e.g., Space Command), U. S. Navy facilities, DOE national laboratories and other facilities, and the Food and Drug Administration (FDA).

The number of compliance areas examined by ESD staff at each of these facilities ranges from one [a comprehensive evaluation of compliance with the National Environmental Policy Act (NEPA) at DOE facilities as part of a full multimedia Tiger Team)] to ten or more at most Air Force bases (e.g., air and water emissions, PCBs, solid wastes, hazardous materials and wastes, pesticides, oils and lubricants, and management of natural resources).

Environmental settings include the arctic tundra of Greenland; the tropical lagoons of Oahu; the deserts of southern Nevada; the warm, humid swamps of south Georgia; and numerous points between.

More environmental audits of naval facilities, Air Force bases, and DOE facilities are planned for the remainder of FY 1991. Among these are DOE Tiger Team assessments of NEPA compliance at Sandia and Los Alamos national laboratories and the Idaho National Engineering Laboratory and multimedia audits of four Navy inactive ship maintenance facilities and three Air Force bases. Each facility or group of facilities has its own special needs concerning environmental compliance, and the audit of each facility is therefore tailored to meet those needs. Our audits of relatively small naval facilities, for example, focus on the management of PCBs, lead, and hazardous materials, whereas audits of nearly 200 individual laboratories and storage rooms in an FDA facility in Washington, D.C., center on the management of hazardous wastes and materials, air emissions, radionuclides, and carcinogens.

Continued participation by ESD staff in expanded auditing activities has proved valuable for both the auditors and the audited facilities. For example, significant or major compliance findings have been identified at nearly all facilities audited to date, thereby alerting workers and management to the need for corrective action before serious harm, to human beings or the environment, or penalties from regulators are incurred. Participating ESD staff have increased their understanding of environmental laws and regulations and the implementation of those measures at federal facilities that have widely differing missions, hazards, and environmental characteristics.

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Geographic Information System Provides a Quality Control Tool for Groundwater Well Data

M. A. Faulkner

The ORNL groundwater monitoring plan for environmental restoration is organized into waste area groupings (WAGs), which have been determined by both the nature of the waste and the hydrology of the area. Because of the number of wells (more than 1400, including the 89 hydrofracture wells) and the involvement of multiple contractors in installing the new water quality wells, any data base used to track these operations must include quality assurance and quality control (QA/QC) procedures.

A geographic information system (GIS) is used to institute the QA/QC procedures for the ORNL groundwater monitoring plan. The well names, which must be unique, are mapped to coordinates by the electronic transfer of the data directly from the official environmental restoration data base to a point coverage in the GIS. A GIS coverage is a collection of digital data that defines topology in terms of points, arcs, and polygons. The topological manipulation of data permits the use of mapping as a model rather than simply as an illustration. The point coverage of wells is plotted onto layers of arc coverages from the S-16A map for reference information such as roads, streams, and buildings.[1] The WAG boundaries, digitized into a polygon coverage from the best available Oak Ridge Operations maps, are plotted over the other layers of geographic information. A number of mistakes in the official data base were identified through the use of this technique. For example, in one case, the reported northing and easting coordinates were interchanged.

Furthermore, in WAG 11, the Oak Ridge Y-12 Plant Site coordinates were reported as the Oak Ridge X-10 Plant Site coordinates. Elsewhere, a typographical error in the one-thousandth position caused a WAG 3 well to plot 4000 ft east of WAG 3. In another case, the nameplates of two neighboring wells were interchanged during installation, but the preliminary records did not reflect the change.

The accurate positioning of wells on the base map allows the planner to study spatial relationships of the wells with confidence that the wells are at the plotted locations. The various thematic levels of the S-16A map provide a consistent frame of reference for both large and small scales. Seasonal water table elevations and chemical water quality parameters may also be associated with the well location. GIS then permits geographic visualization of the values of specified variables. The expense involved in well construction, sampling, and chemical analyses mandates quality assurance of location data. Accurate spatial display makes better decisions possible for remediation.

[1] *"Oak Ridge Area, Oak Ridge, Tennessee" (topographic), Map S-16A, Mapping Services Branch, Tennessee Valley Authority, U.S. Geological Survey, Reston, Virginia, December 1987.*

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A Spatial Model of Smallmouth Bass Populations Is Developed for Streams

H. I. Jager, D. L. DeAngelis, and M. J. Sale

Water resource development, such as hydroelectric projects, can adversely affect fish resources in streams. The effects of variations in streamflow on fish population size are currently evaluated indirectly by predicting changes in the availability of suitable habitat. The purpose of this research is to gain a detailed, mechanistic understanding of how the stream habitat influences fish populations through the study of individual fish responses to local conditions during each life stage and process. The goal is to describe the relationships among streamflow, habitat features, behavioral strategies of fish, and, ultimately, population response.

The model that has been created links an individual-based model of a smallmouth bass population with a spatially explicit description of the stream habitat that responds to temporal changes in streamflow. The new model describes the response of each life process experienced by individual fish to daily changes in physical habitat quality and streamflow. Individual fish in the model can move daily if conditions in the current stream cell deteriorate or if the energetic condition of the fish deteriorates. Because this model is spatially explicit, the movement of individual fish acts as the principal mechanism for adapting to changes in habitat condition and population density.

Individual responses to habitat and flow have been built into modules of each major life process (spawning, movement, feeding, growth, and mortality). In the spawning module, large males are energetically capable of spawning earlier and usually secure the best nesting sites. The model simulates nesting failures caused by episodes of high flow but permits males to attempt renesting at a later date. The foraging module allows daily prey densities to respond to habitat depth and velocity in each stream cell, and thus the influence of streamflow on feeding behavior can be simulated. For example, high flows increase the rate at which prey are

encountered and permit fish to conserve energy by feeding passively on drifting prey. However, as flows increase, prey densities are diluted, and foraging activity is curtailed by increased turbidity. The growth module incorporates the energetic cost of locating in cells with higher velocities and considers the amount of time spent in high-cost activities such as active foraging and movement. The mortality module incorporates flow impacts by modeling the loss of juvenile fish because of high current velocities. These effects of streamflow are neglected by existing flow assessment methods.

This modeling effort is supported by field studies in the North Anna River of Virginia and the Cloquet River of Minnesota. These field studies play an important role by providing site-specific measurements needed to parameterize the model and to test model results. Other field studies are designed to answer basic questions about the life processes of smallmouth bass. The next phase of development and testing will evaluate whether the model is reasonably accurate in predicting population response to streamflow. If so, the model will provide a useful tool for assessing the response of stream populations to alternative hydropower operating procedures.

Arnold Hunley checks the location and characteristics of a groundwater well on a map produced by Mary Alice Faulkner through the use of the geographic information system. Such surveys help researchers verify and update the ORNL well data base, which supports environmental restoration projects at the Laboratory.

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Environmental Trends Analysis Is Planned for the President's Council on Environmental Quality

R. J. Olson

As a basis for adequate monitoring, prudent environmental policy requires a scientific understanding of environmental processes and recognition of their natural variability, as well as a knowledge of the ways in which human activities may have negative impacts on environmental systems. The National Environmental Policy Act of 1969 requires that the President's Council on Environmental Quality (CEQ) report on the status and condition of the environment; current and foreseeable trends in the quality, management, and use of the environment; and effects of environmental trends. ORNL is assisting CEQ in developing concepts and implementing of a new, more comprehensive program to meet the goals of this mandate.

Determining the condition of the nation's environment is truly a mission that builds on the expertise, resources, and cooperation of many federal agencies, and the task cannot easily be performed by any one agency. Components of the project include initiating an interagency process; developing a conceptual framework for trends analysis; crafting a strategic plan for implementation of the program; and addressing technical issues such as integrated data bases, statistical analyses, and graphical display. Developing a conceptual framework includes setting up a process to define environmental quality in terms of specific issues with endpoints that are relevant to societal concerns and to policy actions. In addition, methods to incorporate data must be identified, and scientific understanding must be cultivated. Such activities will help to integrate environmental data with socioeconomic, demographic, energy-related, and other trends to give improved insight into possible relationships among these factors, and ultimately the information will be valuable in decision making.

This project establishes a process that will improve decision making for national environmental issues. It also identifies needs for continued monitoring, data analysis, and research related to trends analysis and reporting. These needs provide opportunities to apply results from ongoing regional ecological risk assessment research within ESD.

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Recent Trends in Minimum Flow Practices at Hydroelectric Projects Are Quantified

S. F. Railsback

Hydroelectric projects alter streamflow rates and the physical habitat available for fish. Projects that store water in a reservoir and release it through a powerhouse alter the temporal pattern of flows. Projects that divert flow around a segment of stream and then through a powerhouse reduce the flow in the bypassed stream segment. Minimum-streamflow requirements are imposed on such projects to provide physical habitat (a sufficient area of stream with adequate depths and velocities) to maintain fish populations. Minimum-flow requirements are imposed by the Federal Energy Regulatory Commission (FERC), which licenses nonfederal projects, but the requirements are often developed and recommended by fish and wildlife agencies. These agencies use a number of methods for determining minimum-flow

requirements. A study was made of the different objectives, methods, and monitoring practices used in setting flow requirements at nonfederal hydroelectric projects. A study under the DOE Hydropower Program was conducted to identify practices currently used to provide instream flows for fish. The study results are being used to determine hydropower research priorities and, at a few sites, to study the costs and benefits of instream flows in detail.

Information on environmental mitigation practices (also including mitigation for water quality and other fisheries issues) was obtained from 301 of 690 projects determined from FERC data to have been issued licenses containing these mitigation requirements since 1980. Of the 301 projects providing information, 170 had minimum-flow requirements. Extrapolated to the population of 690 projects, these data indicate that 394 projects ($\pm$14 projects) nationwide have been licensed since 1980 with minimum-flow requirements. The information obtained from these projects was uniformly distributed among geographic regions so that stratifying the analysis of results by region did not alter the results.

This study looked primarily at minimum flows that are designed to protect fish populations, but the results indicated that temperature, recreation, riparian vegetation, and protection of water quality are also important to consider in setting minimum flows. Of the established and documented methods used to determine minimum flows, the most frequently reported (at $\sim$25% of projects) was the Instream Flow Incremental Methodology (IFIM), a relatively expensive and sophisticated method. A number of other methods were reported; each was used at $<$10% of projects. At 28% of the projects, the judgment of agency biologists was the only method reported for setting flow requirements.

Monitoring the effects of minimum flows on fish populations appears uncommon. The study results indicate that measurement of the flow rate is conducted at $\sim$50% of the operating projects with minimum-flow requirements. Fish population measurements are necessary to determine whether minimum flows designed for fisheries are successful (although fish population data alone cannot be used to determine conclusively that flows are sufficient or inadequate). Yet few of the projects conduct routine long-term fish population monitoring, perhaps because these measurements are expensive to make, relatively variable and uncertain, and difficult to relate directly to flow rates. The high cost of minimum-flow requirements may limit the development of renewable energy at many hydropower projects. However, improved methods for determining flow requirements may reduce such costs.

Conclusions of this study that will help direct research on flow requirements include the following: (1) the IFIM is the most commonly used assessment method, so research should focus on improving it; (2) many projects are licensed without any formal assessment of flow needs or collection of data to show if flows are higher or lower than necessary; and (3) many benefits of minimum flows other than those to fisheries are important, and methods for assessing flow needs for these other resources need to be developed. These conclusions will be used, along with others developed from analysis of case studies, to identify minimum-flow assessment methods that are most successful and to direct future research on flows under the DOE Hydropower

Program. The goal of such research is to ensure that instream water uses and hydropower development can be compatible.

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Draft Supplemental Environmental Impact Statement on U.S. Antarctic Program Is Published

R. M. Reed, R. B. McLean,[1] E. J. Liebsch,[1] D. B. Hunsaker,[1] S. F. Railsback, C. L. Hardy,[2] and J. W. Saulsbury[1]

In a project funded through Energy Division's Integrated Analysis and Assessment Section, an interdisciplinary team from ESD and the Energy Division has assisted the National Science Foundation (NSF) during FY 1991 in preparing a supplement to its 1980 Programmatic Environmental Impact Statement (PEIS) on research and logistics efforts conducted by the United States in Antarctica. The draft Supplemental Environmental Impact Statement (SEIS) updates information and analysis of U.S. efforts and evaluates alternative programmatic actions to improve the safety, environment, and health of the U.S. Antarctic Program (USAP).

Significant environmental issues addressed in the SEIS revolve around concerns that the pristine Antarctic environment be preserved for scientific study. In addition, U.S. research and support activities should not create environmental impacts that would limit the value of Antarctica as a region in which research could be conducted. The area's preservation also is important in terms of the monitoring of global systems (i.e., weather systems and marine ecosystems), global climatic change, unique physical and biological resources present on the continent, and atmospheric and astronomical phenomena (e.g., the thinning of the ozone layer). Potential environmental impacts of particular concern include those that could result from solid waste disposal, the import of materials into Antarctica, the disposal of wastewater, the handling and storage of fuel, and energy use and conservation.

The four alternatives evaluated in the draft SEIS define a range of environmental protection measures that USAP could implement. The proposed action would complete the implementation of planned safety, environment, and health initiatives and would reduce the number of support personnel in the Antarctic by streamlining operations and consolidating facilities.

The analysis showed that current environmental impacts of U.S. activities and facilities in Antarctica are localized, and initial steps to improve safety, environment, and health will further reduce these impacts. It was concluded that under the proposed action, NSF could continue its research activities at current or increased levels and minimize risks to the environment.

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Environmental Compliance Group Assists DOE in RCRA Compliance

C. F. Sigmon

Compliance with the Resource Conservation and Recovery Act (RCRA) is difficult to achieve even for relatively simple operations. Large DOE facilities, however, experience an even greater challenge because their activities tend to

Kaye Sigmon presents material from the Management Training Course in Environmental Laws and Regulations to ESD staff members. The course is offered to midlevel managers and project leaders at ORNL to clarify their roles and responsibilities in complying with laws and regulations that apply to DOE facilities.

be diverse, complex, and complicated by the presence of radionuclides in some waste streams. The Environmental Compliance Group (ECG) is involved in a variety of activities that assist DOE in RCRA compliance. Among other things, ECG comments on proposed rules, assists in developing guidance for implementing final rules, provides training, and evaluates compliance through on-site inspections and assessments of activities.

A recent support task for the Nevada Operations Office (NEVOO) provided an opportunity to apply several of these activities to specific RCRA compliance needs. The primary compliance concern was a Notice of Violation (NOV) regarding administrative issues associated with the storage of mixed transuranic waste at the Nevada Test Site (NTS). NTS is an important receiving facility for a variety of wastes generated in the DOE system. The inability of NTS to store such wastes could,

therefore, have an impact on activities that occur outside NTS. NEVOO assembled a team of compliance specialists from DOE Headquarters' Office of Environmental Compliance, NTS, NEVOO, and ECG. The group reviewed NOV, actions taken in response to NOV, and potential alternative actions. The group, providing a fresh look and approach to old issues that NEVOO had long attempted to deal with, contributed in a small way to making progress toward solutions. Another important outgrowth of the group's activities, the need for more in-depth review of RCRA waste generated at NTS, became an additional arena in which ECG's expertise in training and compliance assessment was used.

A more in-depth look at RCRA waste generation at NTS involved two additional activities. First, training was conducted for NEVOO and its subcontractor personnel who were knowledgeable about site activities but not about RCRA's requirements or compliance assessment techniques. Second, several weeks of surveys were conducted for NTS. ECG personnel provided guidance the first week, and after gaining experience in compliance assessment and RCRA, NEVOO personnel completed the assessment. The combination of training and compliance assessment provided by ECG helped NEVOO better understand important RCRA compliance issues. This knowledge should aid NEVOO in reducing the number of future NOVs.

Thus, ECG assisted NEVOO in addressing specific compliance issues that were beyond the manpower available locally. The effort drew upon ECG's regulatory, compliance assessment, and training expertise and provided the sponsoring office with new perspectives that could lead to more productive actions to prevent future compliance concerns.

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Environmental Biotechnology

Introduction

The Environmental Biotechnology Section of the Environmental Sciences Division (ESD) at Oak Ridge National Laboratory (ORNL) is involved in basic and applied research concerning the mechanisms through which contaminants affect the response of biological systems to contaminants, the ways in which receiving systems affect the availability and distribution of materials to which they are exposed, and the modification of biological systems to enhance degradation or immobilization. Research is conducted from the subcellular and biochemical level to the ecosystem level by means of experimental, observational, and simulation studies. Section activities are supported by the U.S. Department of Energy (DOE) Headquarters; the U.S. Environmental Protection Agency; the U.S. Department of Defense; the Electric Power Research Institute; and the remedial action and waste disposal projects at ORNL, the Oak Ridge Y-12 Plant, the Oak Ridge K-25 Site, the Paducah Gaseous Diffusion Plant, and the Portsmouth facilities.

Biomonitoring

Activities of the Biomonitoring Group include studies to assess the responses of aquatic populations and communities to radiological and nonradiological contaminants in existing point-source (effluent) discharges and nonpoint-source discharges associated with past waste disposal operations at DOE facilities in Oak Ridge, Tennessee; Paducah, Kentucky; and Portsmouth, Ohio. These studies focus on identification of appropriate parameters for evaluating the impacts on and recovery of stream ecosystems. Projects in the group incorporate a variety of techniques ranging from laboratory toxicity tests and manipulative field experiments to comprehensive ecological surveys. Established protocols combined with innovative, state-of-the-art techniques are used to document regulatory compliance and to ensure environmental protection and restoration.

The Environmental Chemistry Group investigates the transport, transformation, and accumulation of materials in surface water environments, including sediments and biota. Additionally, the dispersal of contaminants through the subsurface environment is being examined, especially with respect to the role of organic and inorganic colloidal particles in enhancing the mobility of hazardous chemicals in groundwater.

Ecotoxicology

The Ecotoxicology Group uses laboratory bioassays of fish, daphnids, snails, and algae to quantify toxicity, identify toxic constituents in wastewaters, and verify the efficacy of changes in treatment operations. The group also conducts diverse laboratory and in situ toxicity tests and uses field manipulative experiments to identify and quantify toxic conditions in contaminated streams. Experimental studies of community structures and food webs in contaminated and noncontaminated streams, ponds, and wetlands show how contaminants modify aquatic communities or indirectly alter populations, communities, or ecological processes.

Biological Markers

The Biological Markers Group assists in the assessment of the health of the environment by identifying and evaluating biological responses induced in biota

exposed to contamination. Biological responses are studied at the molecular, biochemical, and physiological levels, both to understand the basic toxicological mechanisms elicited by exposure to environmental contaminants and to relate these changes to effects observed at higher levels of biological organization.

Reservation Data Systems

The role of the Reservation Data Systems Group is to provide data management support for environmental restoration projects conducted at all Martin Marietta Energy Systems, Inc. (Energy Systems) facilities. The group has assumed data management responsibilities for the ORNL remedial action activities and for the Clinch River Resource Conservation and Recovery Act Facility Investigation. Emphasis is placed on developing for Energy Systems a consolidated environmental data base in which environmental restoration and compliance monitoring data will be easily accessible to various users.

Microbial Interactions

The Microbial Interactions Group uses powerful new techniques of molecular biology to complement traditional microbiological methods in attempting to understand the processes by which microorganisms transform hazardous chemical contaminants in soils, surface water, and groundwater. The goals of these investigations are to optimize microbial degradation of hazardous chemical contaminants and to demonstrate application of innovative microbial techniques and bioremediation approaches to the solution of contamination problems at DOE sites.

Off-Site Environmental Restoration Programs

The Off-Site Environmental Restoration Program, which is conducted for the Energy Systems Environmental Restoration Program, addresses the transport, fate, and effects of contaminants in surface waters beyond the boundaries of the DOE Oak Ridge Reservation. Ongoing investigations focus on (1) determining the nature and extent of off-site surface water contamination, (2) assessing potential contaminant transport and exposure pathways and the associated risks to human health and the environment, and (3) evaluating and implementing appropriate remedial actions.

Technical Summaries

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Radioactive Contaminants in Migratory and Resident Waterfowl Inhabiting White Oak Lake on the Oak Ridge Reservation Are Assessed

B. G. Blaylock and A. E. Waters[1]

White Oak Lake (WOL) has served as the final settling basin for low-level radioactive effluents from ORNL since the lake was created in 1943. Biota in the lake, which has a surface area of ~6.8 ha, contain elevated levels of radionuclides, primarily ^{60}Co, ^{137}Cs, and ^{90}Sr. Migratory waterfowl use the lake as a resting area, and several hundred ducks have been observed on the lake during peak migration periods. A major concern is that hunters who harvest and consume migratory ducks that have accumulated radioactivity in their tissues during their residency on WOL will receive a significant dose of radiation.

To determine the accumulation of radionuclides in waterfowl tissue, an experiment was conducted in which two groups of domestic wing-pinioned mallards were released on WOL. Thirty-eight birds were released in May 1989, and 38 were released in October 1989. The second release of birds paralleled the arrival of fall migrants on the lake and provided a basis for evaluating seasonal differences in tissue concentrations of radionuclides. Ducks were collected at intervals during a period of 77 and 95 d for the first and second groups, respectively. Birds were sacrificed, and the concentration of radionuclides in their tissues was determined.

Cesium-137 was the primary radionuclide detected in all mallard tissues except bone, where levels of ^{90}Sr exceeded the concentration of ^{137}Cs. Low levels of ^{60}Co were also found in several whole-body, gastrointestinal tract, gizzard content, and liver samples.

For the first group of mallards, maximum concentrations of ^{137}Cs in the breast tissue increased from below detectable on day 2 to 354 Bq/kg on day 77. For the second group, mean concentrations of ^{137}Cs increased from 5.2 $\pm$ 1.1 Bq/kg on day 2 to 277 $\pm$ 29 Bq/kg on day 61. The concentration of ^{137}Cs in breast tissue over time was not significantly different in the two groups. Because most migratory ducks spend only a few days on WOL, they would be expected to have lower concentrations of radionuclides in their tissues than would domestic mallards, which spent from 77 to 95 d on the lake. Assuming that the mallard, with the maximum concentration of ^{137}Cs (354 Bq/kg), was taken by a hunter shortly after leaving the lake, the potential effective dose equivalent from consuming the edible tissue (350 g) is 1.7 μSv (0.17 mrem) or a lifetime risk of 1.4×10^{-7}. Because the concentration of ^{60}Co was very low or less than detectable in the mallards and because ^{90}Sr concentrates in bone, which is usually not consumed, the radiation dose from these two radionuclides was considered insignificant. Although results from the mallard experiment indicate that migratory ducks should not accumulate significant levels of ^{137}Cs during their stay on WOL and therefore would not present a significant risk to human beings who consume one or more of them, the possibility exists for waterfowl to remain on WOL for much longer periods.

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Replacement of Cobalt by Iron in EDTA Complexes Promotes Degradation of EDTA by *Agrobacterium radiobacter* and Immobilization of ^{60}Co

P. A. Boerman, A. V. Palumbo, and S. Y. Lee

At numerous DOE sites, including ORNL, organic compounds in groundwater chelate radionuclides, thus increasing the mobility of these radionuclides. It has been well documented that ^{60}Co is mobilized via chelation to ethylenedinitrilotetraacetic acid (EDTA). EDTA is also found in association with uranium and plutonium that were disposed of in the same areas and is probably increasing the mobility of these radionuclides as well. The objective of this research is to develop methods to stimulate microbial degradation of the organic constituent EDTA, which would result in immobilization of the associated ^{60}Co.

No organism capable of degrading the Co-EDTA complex directly has been identified. However, addition of ferrous chloride to Co-EDTA under the proper conditions should result in displacement of the cobalt with ferrous iron and formation of iron(III)-EDTA. For this reason, a known iron-EDTA-degrading bacterium, *Agrobacterium radiobacter*, has been selected for preliminary biodegradation studies.

Initial experiments verified the ability of *A. radiobacter* to degrade iron(III)-EDTA. Degradation was followed by quantifying ^{14}C-labeled CO_2 produced from 10 m*M* iron-[2-^{14}C]EDTA (17% ^{14}C in CO_2) and by the loss of nonlabeled iron(III)-EDTA as measured by high-pressure liquid chromatography (up to 64.5% of iron(III)-EDTA, at an initial concentration of 30 m*M*, was degraded within 66 h).

After determining the conditions under which iron(III)-EDTA degradation occurred, Co-EDTA degradation experiments were initiated. No degradation was observed at an initial Co-EDTA concentration of 20 m*M*. Neither did degradation occur when 0.01% *N*-laurylsarcosine was added to permeabilize the cell membrane, nor when yeast extract and peptone were added to the medium. However, following addition of 100 m*M* ferrous chloride under conditions found to enhance displacement of cobalt by iron, 38% of the EDTA was degraded within 13 d, indicating that the newly formed iron(III)-EDTA complex was susceptible to microbial degradation.

Results to date indicate a strong potential for the use of *A. radiobacter* in immobilization of Co-EDTA in soil and groundwater. Although this organism appears incapable of degrading Co-EDTA directly, remediation schemes based upon the formation and subsequent degradation of iron(III)-EDTA may prove effective. Microbial degradation of EDTA may have an additional application in the treatment of waste decontamination solutions for which no such technology currently exists.

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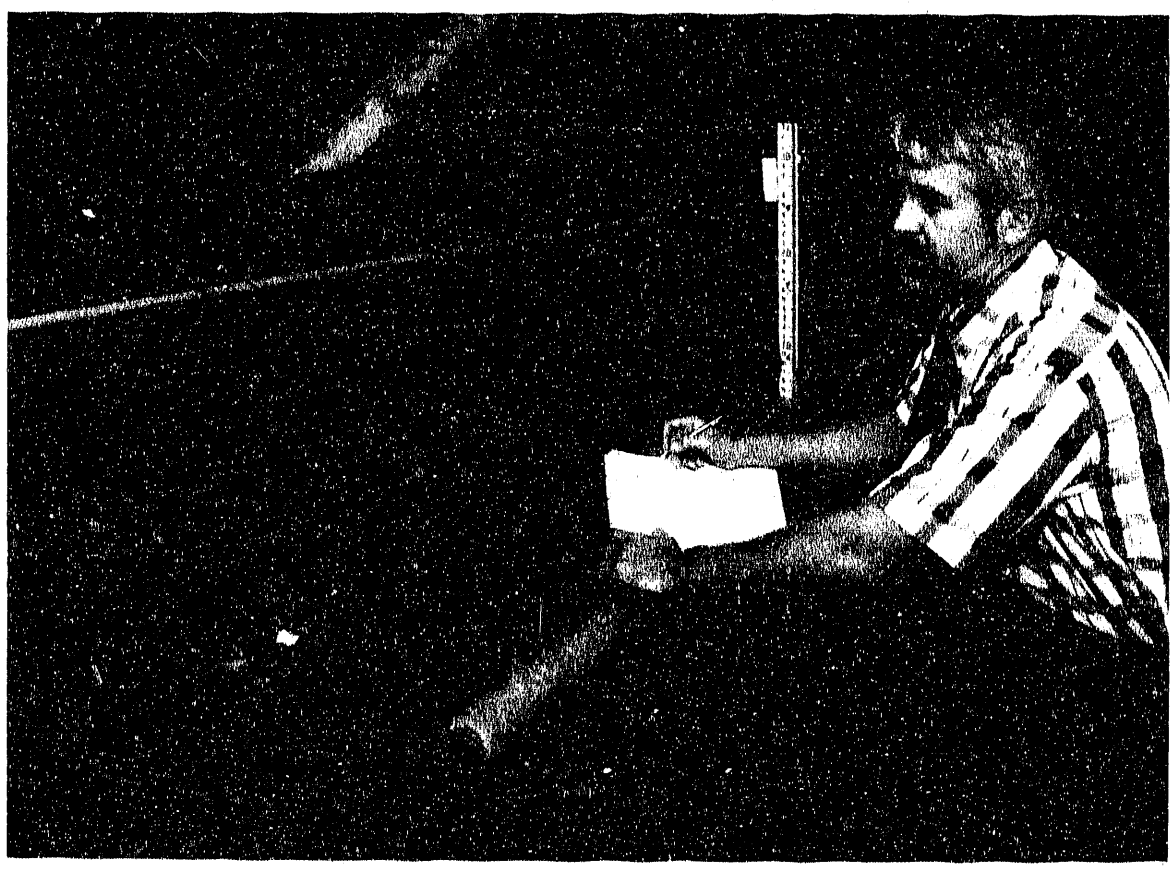
Attached Algal and Microbial Communities Provide Insight into Natural and Anthropogenic Factors Influencing Aquatic Systems

H. L. Boston, W. R. Hill, and A. J. Stewart

Periphyton is a complex matrix of algae and heterotrophic microbes attached to submersed surfaces in aquatic systems.

The periphyton photosynthetically fixes carbon, processes organic matter, and is important for nutrient cycling in many flowing water systems. Periphyton communities are sensitive to anthropogenic stress and can be entry points for contaminants into aquatic food chains. For several years, studies involving the periphyton communities in streams in the Oak Ridge vicinity have been conducted.

Because periphyton is ubiquitous and ecologically important, it is useful for toxicity assessment. In systems where toxicity is intermittent or subtle, community photosynthesis (PS) is an easily measured, ecologically meaningful process that responds to stress. Analysis of covariance was used to compare PS rates as an indicator of physiological condition for communities having different biomass from



Bruce Kimmel, manager of the Off-Site Environmental Restoration Program, notes environmental conditions in one of the many streams on the Oak Ridge Reservation that drain into the Clinch River system. He and numerous other ESD staff are involved in DOE-sponsored efforts to determine the nature and extent of on-site and off-site contamination, assess the potential risks to human health and to the environment, and identify appropriate remediation measures to reduce those risks.

different environments. The data were well correlated with information for fish and invertebrate communities that allowed us to characterize and document biotic conditions in streams receiving effluents from DOE facilities.

The periphyton at sites near industrial discharges had high concentrations of potentially toxic metals. Because several taxa of periphyton-grazing invertebrates were coincidentally absent from those sites, a 5-week laboratory experiment to assess the effects of metals on the growth of two species of invertebrates was conducted. Invertebrates grazing on contaminated periphyton accumulated metals; however, their growth was correlated with algal biomass and apparently was not influenced by the metals in the periphyton that they consumed.

The PS response to irradiance for periphyton communities has been measured, and PS rates for algae from different depths within the matrix have been evaluated . The PS responses of periphyton from light or shade conditions are fundamentally different from those for phytoplankton and may reflect the influences of the matrix on community PS. Experimental manipulations in streams addressed the effects of grazing by fish and invertebrates on periphyton biomass, turnover, and primary production. Grazing could either stimulate or decrease the rate of algal growth and alter the potential food available, depending on the grazer, grazer density, and environmental conditions.

Recently, the use of lipid analysis to investigate the microbial component of the periphyton was begun. Methods are being developed to identify sources of organic carbon (energy) for the microbes, measure rates of carbon flow through the community, and evaluate and track the condition of the microbes.

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A TOL-lux Transcriptional Fusion Plasmid Is a Sensitive Bioreporter of Toluene and Xylene Contamination in Environmental Samples

R. S. Burlage[1] and A. V. Palumbo

One of the greatest challenges to the successful biodegradation of hazardous wastes in situ or in bioreactors is the optimization of conditions for the expression of the genes responsible for the catabolic activity. Many reports have demonstrated biodegradation without investigating the key parameters that allow this activity to take place. Other literature has demonstrated the potential for biodegradation in environmental samples (through the use of gene probes) without determining whether the genes are actually functional. The objective of this research is to construct a bioluminescent reporter strain that responds to an important contaminant and to use this construction to optimize conditions for the catabolic process.

This project has been successful in creating a fusion between two gene fragments. A fragment of the upper pathway of toluene degradation from the well-known TOL plasmid that contains the promoter and other control elements of expression was identified and cloned into the vector plasmid called pUCD615. This plasmid contains a gene cassette from the *lux* operon of *Vibrio fischeri* and produces visible light when the *lux* genes are expressed. The resulting plasmid fusion permits the expression of the *lux* genes and production of light when the promoter of the TOL operon is active. This event occurs in the presence of either toluene or xylene, two important contaminants of groundwater. This fusion plasmid was

introduced into a strain of *Pseudomonas putida* that degrades these substrates. The resulting strain, called RB1401, is able to both degrade toluene and xylene and report on their presence and bioavailability in an environmental sample.

Strain RB1401 is a sensitive bioreporter, producing significant levels of light when toluene is present at a concentration as low as 15 μM (i.e., ~1 ppm). The background bioluminescence is also very low and is essentially undetectable with the photomultiplier equipment currently in use.

This strain has been used to determine the presence of toluene and xylene in contaminated soils from a Department of Defense site. Proposed applications of this technology include identification of contaminants from sample sites and optimization of in situ bioremediation. RB1401 will also be used in the Director's Fund project as an index of trichloroethylene (TCE) degradation because these same catabolic enzymes co-metabolize TCE when the pathway is induced. Process optimization can be achieved by using the bioluminescence as a monitor of proposed key parameters in gene expression.

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Research Assesses the Damage of Enhanced UV-B Radiation on the DNA of Soybeans and Other Plants

S. J. D'Surney[1] and L. R. Shugart

Research on the biological effects of enhanced UV-B radiation (>32% increase) was conducted during and after the 1990 growing season on two varieties of soybean, two varieties of poplar trees, and pine trees to assess changes in leaf biochemistry, electron transfer in photosynthesis, leaf gas exchange, transpiration, and deoxyribonucleic acid (DNA) integrity. The role of the Laboratory was to develop bioassays to measure DNA damage in plants from enhanced UV-B.

Leaf samples that were located at a specified distance from the UV-B exposure source were collected at particular time intervals. Prior to being archived, samples were pooled by variety, frozen in liquid nitrogen, and ground to a powder while frozen. Whole-cell DNA was extracted from powdered leaf tissue by cell lysis with detergent and proteinase K digestion followed by phenol/chloroform/ isoamyl extraction to remove proteins. DNA samples from two varieties of soybean were analyzed by an alkaline unwinding assay to measure strand breaks. Photoproducts induced by UV-B were measured with the use of denaturing agarose gel electrophoresis of DNA pretreated with a photodimer-specific, single-strand endonuclease.

The results of alkaline unwinding analysis at early, middle, and late exposure (10, 30, and 52 d) showed an unusual increase in F values (percentage of DNA in double-strand form after a given period of alkaline unwinding) early in exposure for soybean Essex (F value = 126 $\pm$ 4.1) and soybean Forrest (F value = 115 $\pm$ 6.3). After longer exposures, F values declined to near control levels in soy Forrest, but remained elevated in soy Essex. Analysis of photodimers in the two soybean varieties revealed a higher ambient level of dimers in soy Forrest relative to soy Essex in experimental controls exposed to natural sunlight plus some unscreened UV-A (UV-B was filtered out). In the group exposed to enhanced UV-B, both soybean

varieties had increased levels of photoproduct damage, and soy Forrest showed a greater sensitivity to enhanced UV-B than that observed for soy Essex. DNA photoproduct damage was cumulative, with soy Forrest showing greater cumulative sensitivity to elevated UV-B.

The elevation in *F* values in soybean exposed to UV-B is similar to the increased resistance to alkaline unwinding seen in other organisms and may represent a phenomenon associated with induced protein synthesis and activity in chromatin of stressed organisms. Soybean Forrest showed reduced biomass and seed production in plants exposed to UV-B, a finding that may partially explain its greater UV sensitivity.

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Toxicity Tests Justify Modification in Precipitation Process at the Coal Yard Runoff Treatment Facility

L. A. Kszos and P. A. Taylor[1]

Toxicity tests of effluents discharged from ORNL are required as part of the Laboratory's National Pollutant Discharge Elimination System (NPDES) permit. Tests conducted since 1986 have shown that effluent from the Coal Yard Runoff Treatment Facility (CYRTF) is consistently more toxic than effluent from either the Sewage Treatment Plant (STP) or the Nonradiological Wastewater Treatment Facility (NRWTF). Typically, a concentration of 3 to 25% of full-strength CYRTF effluent decreases the number of young produced by *Ceriodaphnia dubia*, and a concentration of 20 to 100% of full-strength effluent reduces the growth of fathead minnows. In contrast, a 12 to 100% concentration of full-strength STP effluent reduces the reproduction of *C. dubia*, and a 50 to 100% concentration of full-strength effluent reduces the growth of fathead minnows. Effluent from the NRWTP has never been toxic to either species.

Treatment at CYRTF consists of pH adjustment with lime (CaO) to precipitate metals, subsequent flocculation to promote settling of sludge, and final pH adjustment of the supernate prior to discharge to White Oak Creek. This treatment effectively lowers the concentration of iron, copper, and zinc to $\leq$1 mg/L, as required by the NPDES permit, but it yields an effluent that is very high in calcium, usually 400 to 900 mg/L.

Toxicity tests with *C. dubia* using bench-top-treated coal yard runoff and pure chemical solutions were used to evaluate (1) the source of toxicity in the CYRTF effluent and (2) the question whether neutralization of coal yard runoff with MgO rather than CaO would effectively remove metals and reduce toxicity. Seven-day, static renewal *C. dubia* toxicity tests with $CaSO_4$ and $CaCl_2$ were used to estimate the toxicity of calcium. Results showed that with either salt, a calcium concentration of about 110 mg/L was toxic to *C. dubia*. Evaluating the no-observed-effect concentration levels for CYRTF in terms of calcium produced similar results: a concentration of about 100 to 150 mg/L was toxic to *C. dubia*. Thus, the calcium present in the CYRTF effluent accounted for most of the toxicity.

In another experiment, two separate bench-top treatments of coal yard runoff were conducted using CaO and MgO. In both cases, metal removal with MgO was as effective as or more effective than metal

removal with CaO, and the runoff treated with MgO was 5 to 10 times less toxic to *C. dubia*. Toxicity tests with $MgSO_4$ also indicated that magnesium was 3 to 4 times less toxic than calcium. Our results show that neutralization of coal yard runoff with MgO would reduce the toxicity of the discharged effluent without sacrificing effective removal of metals. We have also illustrated that, in addition to ensuring compliance with NPDES permit limits, toxicity tests may also be used to justify changes in waste treatment processes, thereby reducing the load of chemicals discharged to the aquatic environment.

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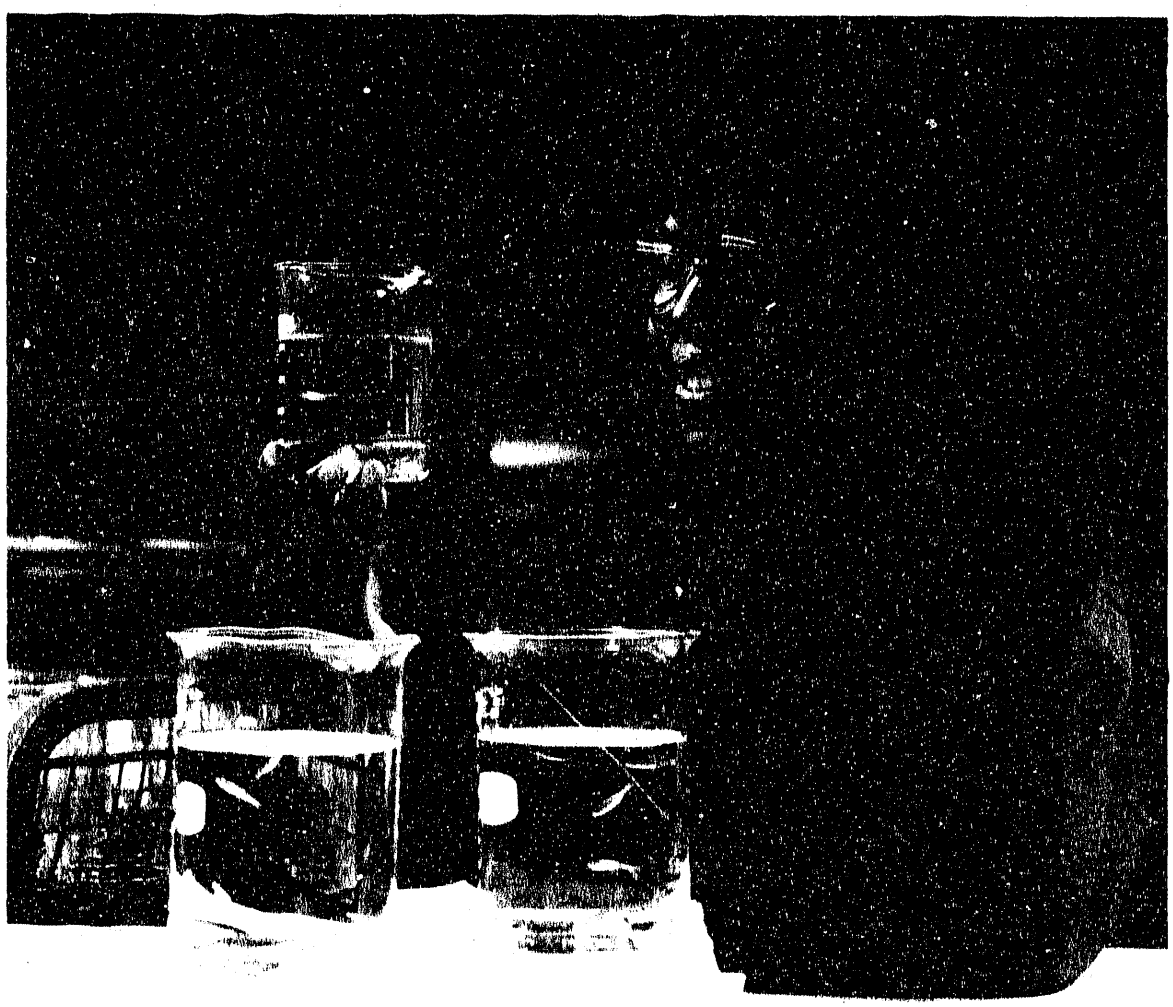

Gail Morris of ESD's Aquatic Toxicology Laboratory inspects juvenile male and female fathead minnows. When mature, these fish produce young that are used in tests to determine the biological quality of wastewater at major DOE facilities in Oak Ridge, Tennessee.

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Mobility of Natural Organic Matter and Inorganic Colloids Was Manipulated in a Sandy Aquifer

J. F. McCarthy, L. Liang, P. M. Jardine, A. V. Palumbo, and T. M. Williams[1]

The transport of natural organic matter (NOM) in groundwater is being studied to improve capabilities to predict the subsurface transport of contaminants that sorb to mobile sorbents such as NOM. The research objectives are (1) to determine if NOM is mobile in subsurface environments and (2) to elucidate the chemical and hydrological properties of aquifers that influence the transport of NOM as well as inorganic colloids. A large volume (80,000 L) of surface water with 66 mg/L of NOM was injected into a suboxic, Fe(II)-rich sandy aquifer. Concomitant effects of the injection on inorganic colloids and on the abundance of groundwater bacteria were also monitored. Sampling wells were located in three horizons at 1.5 m and 3 m from the injection well. A nonreactive tracer (Cl^-) was injected with the first 4000 L of NOM solution to provide information on the average pore-water velocity and dispersion characteristics of the media.

Although significantly retarded compared to a nonreactive tracer (Cl^-), the NOM moved rapidly through the aquifer. The apparent retardation was somewhat less than predictions that were based on laboratory studies using NOM and aquifer material from the site. The NOM breakthrough did show many features predicted from laboratory studies, including evidence of a slow kinetic component to NOM sorption and very slow desorption kinetics.

Both laboratory and field results support the hypothesis that NOM migration can be described as a multicomponent transport process. In laboratory column studies and in the field experiment, hydrophilic subcomponents of NOM were rapidly transported, compared to hydrophobic subcomponents of the NOM. Likewise, differences were observed in the mobility of different subcomponents of NOM defined on the basis of molecular size. Although the NOM injection solution contained a majority of solutes in the size range of 3 to 100 kilodaltons (by filtration using Amicon hollow fiber filters), the early portion of the NOM breakthrough curve comprises primarily small NOM (<3 kilodaltons); the higher molecular weight material is retarded relative to the <3-kilodalton fraction. A portion of the rapidly transported NOM is >0.1 μm and appears to be sorbed to, and cotransported with, iron colloids; the iron colloids were approximately 200 nm in size (by photon correlation spectroscopy and scanning electron microscopy) and were negatively charged (by microelectrophoretic mobility), suggesting that the NOM coating altered the surface properties of the iron colloids (expected to be positive at pH 6.5) and stabilized them in the mobile groundwater.

Although the NOM injection solution contained 2–3 mg/L of dissolved oxygen (DO), there was little change in DO in most of the sampling wells. The consumption of oxygen did not appear to be the result of NOM-induced increases in microbial respiration since there was no consistent increase in bacterial abundance. We postulate that DO was consumed by Fe(II)/Fe(III)-catalyzed oxidation of NOM

within the aquifer. The experiment illustrates the complexity of field manipulations and the interacting effects of chemical, hydrological, and microbiological processes.

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The Oak Ridge Field Office Environmental Information System Is Being Developed

R. A. McCord and L. D. Voorhees

A large investment of time, resources, and money is being made on designing and implementing a variety of environmental monitoring and restoration programs at DOE facilities. Data from these programs are often collected for a single purpose and are not readily useful for other applications because of inaccessibility, poor documentation, incompleteness, and lack of standardization with respect to format and nomenclature. However, the increasing costs of data acquisition make it imperative that maximum use be made of historic and current DOE environmental data bases. A Federal Facility Agreement between DOE, the U.S. Environmental Protection Agency, and the Tennessee Department of Environment and Conservation addresses this need by calling for the development of a consolidated environmental data base for the DOE Oak Ridge Reservation facilities, which would include all data resulting from environmental restoration activities and compliance with federal and state environmental permits. The Oak Ridge Field Office Environmental Information System (OREIS) is being developed and implemented to meet these data management needs.

The objectives of OREIS are to (1) ensure long-term retention and accessibility of data collected at all facilities; (2) support the development of a common format for reporting environmental monitoring data; (3) generate well-documented, standardized data products; and (4) facilitate the sharing of data in support of environmental compliance and restoration assessments. OREIS staff are addressing the following issues: (1) defining data management needs; (2) identifying the types and sources of data to be maintained; (3) characterizing the hardware and software capabilities at each facility; (4) developing a standard data base scheme; and (5) setting standards for the contents, quality, and documentation of the data sets and products. Major areas being addressed include software standards, data collection procedures, data entry, data exchange formats and procedures, variable naming conventions, units of measurement, levels of precision, date and time formats, spatial coordinates, missing values, quality assurance elements, and security.

The initial phases of development and implementation of the system includes (1) the establishment of a prototype system with a limited range of data types, analytical functions, and user support and (2) the development of standardized procedures for data management. The prototype will be used to evaluate data management and software integration issues. The success of the system is dependent, in part, on the implementation of standardized procedures for all data activities. The value of a robust and integrated system is limited by the documentation and quality assurance of each of these phases of environmental information management.

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Organic Contaminants Commonly Found in Association with Trichloroethylene (TCE) Can Significantly Influence the Degradation of TCE by Methane-Utilizing Bacteria

A. V. Palumbo, W. Eng,[1] P. A. Boerman, and S. E. Herbes

In preparation for field demonstrations of biodegradation of chlorinated solvents at a DOE site in Oak Ridge, Tennessee, the impact of mixtures of organic contaminants on the biodegradation of trichloroethylene (TCE) by methane-utilizing bacteria is being assessed. The contaminants at DOE sites in Oak Ridge include anaerobic degradation products of TCE [e.g., dichloroethylenes (DCEs)] and compounds disposed of with the TCE, including tetrachloroethylene (PCE), toluene, other aromatics, and numerous chlorinated and nonchlorinated compounds. The ability of additions of carbon and energy sources other than methane to increase microbial degradation rates was also tested.

Both 1,1-DCE and PCE, at concentrations of 6 μM, were found to significantly decrease degradation rates of other chlorinated ethylenes (e.g., *trans*-1,2-DCE at 50 to 800 μM) by *Methylosinus trichosporium* strain OB3b. These compounds are also either very slow to degrade (1,1-DCE) or are not degraded at all (PCE). Estimated maximum velocities (V_{max}) for 1,1-DCE; *cis*-1,2-DCE; *trans*-1,2-DCE; and TCE degradation were 16, 28, 21,250, and 14 nmol·h^{-1}·mg^{-1} of protein, respectively. Preliminary experiments with mixed methane-utilizing batch cultures have indicated that low concentrations (2 μM) of toluene do not significantly reduce TCE degradation.

Methanol was found to relieve growth inhibition of OB3b at high (106.5 μM) TCE concentrations. However, the addition of methanol to cultures grown on methane significantly reduced the rate of TCE degradation. Although methanol reduces the toxicity of TCE to the cultures, biodegradation of TCE cannot be sustained in methanol-grown cultures. Because high TCE concentrations appear to inhibit methane uptake and growth, the primary toxicity of TCE appears to be directed toward methane monooxygenase (MMO). Future work will evaluate the addition of formate, which should provide energy to the cells without inhibiting either MMO production or degradation of TCE.

These results demonstrate that other organic contaminants in water can significantly alter the rate of TCE degradation by the methanotrophs. Examination of the effects of additional aromatic compounds and chlorinated ethenes found in groundwater at the demonstration site is planned prior to initiation of the field demonstration. The effects of the contaminants in the actual site water will be evaluated by the use of molecular probes being developed as indicators of methanotroph biomass and activity as well as by measurements of TCE degradation. These studies will enable the rates of degradation of the field bioreactor demonstrations to be optimized and will increase the understanding of the factors that affect TCE degradation in the bioreactor system.

[1]*The University of Tennessee, Knoxville.*

Todd Anderson, a graduate student at The University of Tennessee, collects soil samples at the Miscellaneous Chemical Basin at the Savannah River Site. He and Barbara Walton, an ESD toxicologist, have found that chemically contaminated soils may be cleaned up more rapidly by soil microorganisms if vegetation is present.

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A Rapid Method for Screening Bacterial Cultures for Biodegradation of Volatile Contaminants Is Developed and Applied

A. V. Palumbo and J. Strong-Gunderson

The DOE Subsurface Science Program has isolated over 4500 bacterial strains with many more to be isolated as activities continue. The unique nature of these bacteria, the vast majority of which do not match known species and may have been separated from surface strains for long periods of time, offers potential for organic contaminant degradation. Much of the carbon that has been available to these organisms may have been compounds that are considered recalcitrant to degradation. Although these isolates represent a potential source of bacteria and genetic material for the degradation of contaminants of interest to DOE, their ability to degrade complex or unusual substrates has not been examined and needs to be assessed regarding their potential in the remediation of contaminated sites.

In a project originating in the DOE Office of Health and Environmental Research

Subsurface Science Program and continuing with funding from the DOE Office of Technology Development, we are collaborating with Idaho National Engineering Laboratory to screen these isolates for their degradative capabilities. The large number of bacteria in the collection represent a significant challenge in efficiently screening for degradative capabilities. The method we have developed for use with semivolatile and volatile compounds depends on an existing innovative, commercial system utilizing Microplates™ by Biolog, Inc., that was developed for the detection of bacterial respiratory activity. This system is based on the use of substrates, nutrients, and tetrazolium dyes in 96 well plates. When a bacterial species metabolizes the carbon substrate supplied in the well, the tetrazolium dye turns purple and a spectrophotometric plate reader is used to quantify the response. This system is normally used for bacterial identification, but plates can be designed to test for specific compound degradation. Many of the contaminants found at DOE sites are either semivolatile or volatile; prior to this project their utilization with the present system design had not been demonstrated.

The system was evaluated for compatibility with volatile compounds. *Pseudomonas putida* (Mt2), a known toluene degrader, was incubated using two treatments: one in the presence of toluene vapors and the other in atmospheric air (no other carbon source was supplied). Exposure to toluene produced a strong color change indicating this species could utilize toluene vapors. Exposure to atmospheric air produced no color change. Thus, the Biolog system has the potential to work with volatile compounds.

The bacterial concentration and incubation time and temperature have been optimized, and *P. putida* (Mt2) will be used as a positive control in future assays. In preliminary screening for toluene degradation, 4 to 5 strains of the 30+ subsurface isolates showed a stronger reaction over controls that had been incubated in atmospheric air, indicating an ability to degrade the toluene. Additional experiments are currently determining the compatibility of other volatile organics with the Biolog system. This technique should allow rapid testing of bacteria from contaminated and uncontaminated environments for their ability to degrade a broad range of volatile organic contaminants. Both the techniques developed and the cultures identified as having significant degradative abilities in this project can be transferred to environmental remediation activities in DOE and to users other than DOE.

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Study of Reproductive Biology of Tennessee Dace Provides Data for Management Options on Reservation Streams

M. G. Ryon and E. M. Schilling[1]

The Tennessee dace (*Phoxinus tennesseensis*) is a fish that was recently recognized as a distinct species from the more widely distributed mountain redbelly dace, *P. oreas*. Localized populations of Tennessee dace have been found in only 28 streams, including Bear Creek and other streams on the Oak Ridge Reservation (ORR). Indeed, the highest population densities may occur in ORR streams. The Tennessee dace has been classified as a species "deemed in need of management" by the state of Tennessee. Under this classification it is illegal to knowingly destroy their habitat, and a special permitting process must be followed before any significant habitat alteration can occur. Because life history information on the

Tennessee dace is not available, a study was initiated to describe its reproductive biology. This information is important because habitat changes associated with environmental restoration activities can potentially disrupt spawning and adversely affect larval survival.

Fish were collected monthly from a 5-km section of Bear Creek between October 1988 and September 1989 using a backpack electrofisher. The fish were measured for total length, body weight, ovary weight, egg numbers, and egg size. A gonadal somatic index (GSI) was calculated as a measure of reproductive readiness. Field observations of spawning behavior were made, and nest sites were evaluated for size and structure.

Changes in mean monthly GSI and egg size indicated that spawning in 1989 occurred from late March through early May and was completed by the end of May. GSI values increased from December to March and peaked in April and early May (GSI = 13.0). Mean egg diameter increased gradually from the fall sizes (0.3 mm) through early spring and rapidly thereafter to early May (1.2 mm). Egg size-frequency distributions indicated at least two clutches with a mean clutch size for the more developed eggs (>0.8 mm) of 506 eggs per female.

Behavioral studies observed spawning aggregations consisting of 8 to more than 100 individuals. Males maintained positions over a nest, and one or two females would swim into the aggregation. Surrounded by males, the female was forced toward the gravel where a broadcast spawning occurred. The released eggs settled into gravel interstices within the nest. Any disturbance that increased sediment loading to the nest dispersed the spawning aggregation, and spawning did not resume until clean gravel was reestablished.

Nests used by the Tennessee dace were constructed by creek chubs and other minnows. These nests were gravel depressions, cleared of fine sediments and located in open, shallow areas where the current was sufficient to prevent siltation. There was a distinct difference in the degree of embeddedness between the inside (5-25%) and outside (25-50%) of the nests.

The data obtained on the reproductive biology of the Tennessee dace suggest potential vulnerabilities. Observations indicate that they are sensitive to siltation; they actively seek out nest areas with clean gravel and cease spawning when these areas are covered by silt. Because the nest sites are in shallow water, any reduction in the total discharge of the stream may reduce the available spawning habitat. Also, the low number of mature eggs per female combined with a short life span (2-3 years) implies that the existence of Tennessee dace populations may be dependent on a successful reproductive effort at least once every 2 years. Consequently, remedial action alternatives that involve a reduction in stream discharge (e.g., pumping and treating contaminated groundwater without returning the water to the original stream) or an increase in the amount or duration of sediment runoff to streams because of inadequate measures to control soil erosion could have a significant adverse impact on local populations of the Tennessee dace.

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[1]*Automated Sciences Group, Inc., Oak Ridge, Tennessee.*

Marshall Adams (far right) and his team of researchers and students examine the tissues of sunfish from polluted streams. Biochemical and physiological analyses of the tissues will help researchers determine the effects of contaminants on aquatic life in streams and reservoirs

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Sunlight and Periphyton Drive Chlorine Dynamics in Area Streams

A. J. Stewart, W. R. Hill, and K. D. Ham[1]

Previous studies have shown that chlorine is an important toxicant in six streams near DOE facilities in Oak Ridge, Tennessee. The major source of this chlorine is chlorinated drinking water, which is used as a once-through coolant. We conducted 7-d laboratory tests with *Ceriodaphnia* to estimate instream toxicity, made instream measurements of total residual chlorine (TRC) with an automated amperometric titrator, and used streamside and laboratory experiments to identify processes controlling TRC in upper East Fork Poplar Creek (EFPC) at the Oak Ridge Y-12

Plant and in a midreach section of White Oak Creek (WOC) at ORNL, where TRC concentrations are sometimes high enough to be toxic to fish and invertebrate communities.

A failure-frequency analysis of toxicity-test results from upper EFPC demonstrated that TRC was toxicologically important: stream water samples dechlorinated with sodium thiosulfate were not toxic (only 1 of 16 tests failed), but untreated water samples were frequently toxic (14 of 18 tests failed). The outcomes of nearly 80% of the *Ceriodaphnia* toxicity tests of upper EFPC (37 of 47 tests) were correctly predicted using a simple pass-or-fail response model with a critical TRC value of 0.22 mg/L. Bankside experiments using flow-through aquaria also showed that the elimination of TRC from EFPC water by addition of sodium thiosulfate greatly enhanced the survival of fathead minnows.

The monitoring of TRC in EFPC and WOC revealed strong daily cycles in TRC concentration: In both streams, TRC concentrations were approximately three times higher at night than during the day. In contrast, TRC concentrations in drinking water at ORNL and stream discharge in WOC and upper EFPC changed very little over day-night cycles. Thus, differences in instream processes, not loading rates, controlled TRC levels in both streams. Laboratory and field experiments showed that the daily cycles in TRC in WOC were caused by sunlight and periphyton and that those two factors were additive; TRC losses due to volatilization were minor in comparison.

Many studies emphasize that toxic chemicals can adversely affect biological communities in streams. Our studies demonstrate the opposite point: Stream periphyton communities, which consist of algae, bacteria, and associated protozoans, can strongly influence toxic chemicals such as TRC. The ability of periphyton to lower concentrations of TRC leads us to predict that flood events that scour periphyton from stream substrates will also temporarily increase vulnerability of fish and invertebrate communities to TRC inputs. Similarly, extensive riparian vegetation may increase vulnerability of stream communities to TRC during the spring and summer, even if stream flow remains constant.

Laboratory experiments conducted concurrently with these studies demonstrated that TRC levels in water from EFPC and WOC declined rapidly with exposure to pure UV light. This finding suggests that commercially available UV treatment systems (used by some municipalities to control fecal coliform bacteria in sewage treatment operations) may help lower the concentration of TRC and reduce the toxicity in TRC-contaminated waters.

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Microbial Degradation of Trichloroethylene Occurs Faster in Soils Containing Plant Roots

B. T. Walton and T. A. Anderson[1]

The possibility that vegetation may be used to actively promote microbial restoration of chemically contaminated soils was tested by using rhizosphere and nonvegetated soils collected from a field site contaminated by trichlorethylene (TCE). The field site was used as a chemical disposal site where, from ca. 1956 to ca. 1974, chlorinated solvents were poured directly into a shallow basin that had been excavated from the soil. Fill was added, and an area of ~100 by 100 m was graded for the site.

Several characteristics of the site made it a favorable location for exploring the potential for vegetation to be managed as an integral part of site remediation. Specifically, the area is small and inaccessible to the public, TCE and other hazardous chemicals are present in relatively low concentrations, and no imminent hazard exits. Moveover, the site has become vegetated naturally during the 10 or more years since chemical disposal stopped; thus, sufficient time has passed for the populations or consortia of TCE-degrading microorganisms to be enriched in the rhizosphere.

Soil samples were collected from the rhizospheres of the four predominant plant species [a grass, *Paspalum notatum* var. *saurage* Parodi; a legume, *Lespedeza cuneata* (Dumont); a composite herb, a *Solidago* sp.; and loblolly pine, *Pinus taeda* L.] and from the nonvegetated (edaphosphere) soils. Biomass determinations of microorganisms, disappearance of TCE from the headspace of spiked soil slurries, and mineralization of [^{14}C]-TCE to $^{14}CO_2$ all showed that microbial activity is greater in rhizosphere soils than in edaphosphere soils and that TCE degradation occurs faster in the rhizosphere than in the edaphosphere. These studies indicated that vegetation may be an important variable affecting microbial degradation of hazardous organic compounds and can be managed to achieve biological restoration of chemically contaminated surface and near-surface soils.

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Municipal Sewage Sludge Is Applied to Land to Improve Soils and Provide Nutrients for Trees Grown for Energy Production

A. E. Walzer,[1] H. L. Boston, and H. Van Miegroet

Land application of sewage sludge is an economical and environmentally safe method of disposal when done according to regulations. Approximately 30% of the U.S. municipal sewage sludge is currently disposed of by land application. Sludge is a nutrient-rich organic material that can improve soil fertility and increase plant growth. In addition to the organic components of sludge, there are also metals and, in the case of Oak Ridge sludge, radionuclides released from private industry. The City of Oak Ridge has applied its municipal sewage sludge to DOE's Oak Ridge Reservation land since 1983. Beginning in 1986, a monitoring program was initiated to evaluate the fate of sludge and sludge constituents within the environment and to identify application strategies that have the greatest benefits for soil improvement and tree growth.

Environmental monitoring in association with sludge application has included sampling and analysis of soil, groundwater, soil water, surface runoff, and vegetation to determine the fate of metals, radionuclides, and the organic constituents of the sludge. During and for several months following sludge application, surface runoff contained

NO_3, P, BOD, and fecal coliform bacteria at concentrations similar to runoff from cow pastures. The runoff quality improved rapidly after application ended. It was also found that metals were diluted and immobilized in the upper 15 to 20 cm of the soil and generally did not concentrate in vegetation or move off-site. For a time, Oak Ridge municipal sludge was contaminated with low levels of ^{137}Cs, ^{60}Co, and depleted uranium. The fate of these radionuclides was studied when the sludge

Municipal sewage sludge from the City of Oak Ridge is applied to pastures on the Oak Ridge Reservation. Harry Boston and Helga Van Miegroet are studying the benefits of using the sludge to improve soil fertility and tree growth. In addition, they are assessing the potential environmental impacts of sludge applications.

was applied to land, and it was found that they were largely immobilized in the upper soils and did not move off-site nor accumulate in the vegetation. The monitoring program has shown that when sludge is applied in moderation (<5 tons per acre per year) to improve soils rather than simply to dispose of sludge, adverse environmental effects are minimal.

The nutrients in sewage sludge can greatly increase the fertility of marginal farm lands. Nitrogen and phosphorus, which are frequently the limiting factors in tree growth, were found to be significantly increased in soils treated with sludge. Our studies have shown elevated nitrogen levels for 10 years after sludge application, whereas nitrogen from synthetic fertilizers is lost within 2 or 3 years. These findings indicate that sludge application can play a significant role in soil improvement for tree farming.

The benefits of sewage sludge application are being examined for tree biomass production, a technology which produces high-yield energy crops. These biomass crops, which produce liquid fuels for energy, also recycle CO_2, unlike fossil-fuel burning. To further study the use of sludge application for this technology, a biomass plantation was begun this year on a retired sludge application site to assess the growth rates on four hardwood varieties: tulip poplar, sycamore, silver maple, and black walnut. This study will provide new information on sludge application for biomass production.

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Consortial Microbial Activity and Resilience in the Westinghouse Savannah River Site Bioremediation Integrated Demonstration Are Defined

D. C. White, T. J. Phelps,[1] and D. B. Ringelberg[1]

Objectives of this study were (1) to define the base-line microbial community structure and nutritional status of the endogenous microbiota recovered from the plume in the horizontal-well system at Westinghouse Savannah River Site (WSRS) prior to the initiation of warm air and the introduction of methane co-metabolite through the use of the in situ signature biomarker system developed with the subsurface science program and (2) to establish microbial consortia recovered from contaminated plumes at WSRS in bioreactors to test for substrate specificity, biogradation capacity, and resiliency to stresses.

Subsurface samples were recovered from between the horizontal wells in the WSRS integrated demonstration by using proper anticontamination procedures. The sediments were lyophilized; extracted by means of the reversed serial one-phase solvents extraction; fractionated into neutral lipids, glycolipids, and polar lipids; and derivatized from capillary gas chromatographic separation with detection by chemical ionization-extracted ion mass spectrometry. Phospholipid ester-linked

fatty acids (PLFA) provide in situ community structure and nutritional status definitions that shift with manipulation and contamination. The initial predemonstration base-line samples show an in situ low biomass of ~1 pmol PLFA per gram of dry wt ($<10^5$ microbacteria per gram), with evidence of nutritional stress—an ideal community for manipulation for fortuitous biodegradation.

Microbial consortia have been recovered from contaminated plumes at the WSRS site and used in gas-tight recycling bioreactors for aerobic fortuitous metabolism of mixtures of organic halogenated hydrocarbons and benzene-toluene-xylene (BTX) recovered from Y-12 Plant wells utilizing methane and propane as co-metabolites. Decreases of one to three orders of magnitude in chlorinated hydrocarbons, trichloroethylene (TCE), dichloroethylenes, vinylchloride (VC), and BTX were demonstrated. Mineralization of ^{14}C TCE to ^{14}C CO_2 established biodegradation. Slow aerobic breakdown of perchloroethylene and rapid inducible VC mineralization have been demonstrated.

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Geosciences

Introduction

Staff of the Geosciences Section of the Environmental Sciences Division (ESD) at Oak Ridge National Laboratory (ORNL) engage in basic and applied research and conduct demonstration projects directed toward understanding and controlling the physical and chemical mechanisms that influence the movements of material through the lithosphere, hydrosphere, and atmosphere. Whereas most activities are highly interdisciplinary, the major areas of emphasis in the section involve geochemistry, geology, geophysics, environmental chemistry, soil science, hydrology, atmospheric chemistry, oceanography, and environmental engineering. The scope of the studies includes field characterization, testing and demonstration of innovative remedial action alternatives, laboratory experiments, and mathematical and computer modeling. Throughout its efforts, the section is substantially involved in science education at all levels, from precollege to graduate and postgraduate. The section consists of six groups, each designated by a disciplinary title that reflects the training of the staff.

The section strives to maintain a balance between basic and applied studies. The common theme of most section activities is the study of waste materials and by-products from energy production. Activities span major portions of the energy cycle. For instance, a significant part of the research involves characterization of past and future disposal sites, whereas another major part is directed toward an understanding of the physical and chemical factors that lead to migration of materials away from disposal sites in groundwater, surface water, and the atmosphere. Closely coupled with this effort are projects that deal with the development of quantitative capabilities for predicting the behavior of natural systems. Another part of the energy cycle—also related to waste—involves in situ treatment of disposed materials in the ground to mitigate their movement into the environment.

In the area of site characterization, the section has been involved in the study of fracture and fault systems that dominate the rock strata underlying many sites at Oak Ridge; these fractures are a major influence on groundwater flow. In addition, considerable site work has been conducted at other U.S. Department of Energy (DOE) and U.S. Department of Defense (DOD) facilities, such as the Paducah Gaseous Diffusion Plant, and at various U.S. Air Force bases.

With regard to the movement of energy-related by-products and wastes in the environment, we have been heavily engaged in studies of acid deposition and its impact on forest systems and soils, as well as studies of the movement of radioisotopes in marine and freshwater systems. The scope of predictive investigations ranges from geostatistical models for estimating groundwater elevations to geochemical studies of mineral solubilities and sorption characteristics.

Innovative waste treatment technologies that have been developed include bioremediation of organic contaminants and mercury, as well as oxidation and venting of organic contaminants that occur in soils and groundwater. The staff of the Geosciences Section are heavily committed to investigating many of the critical issues essential in dealing with the cleanup of

DOE facilities to bring them into environmental compliance. The staff are also addressing issues that are necessary to understand the impact of energy technologies on the environment.

During the year, two major new activities were initiated through the section: The Energy Systems Office of Groundwater Management and the Oak Ridge Hydrology Support Programs (ORHSP). Both entities support proper groundwater studies, in parallel with compliance directives, at all five Martin Marietta Energy Systems, Inc. (Energy Systems) facilities. A significant part of ORHSP is the highly challenging study of the hydrology of the Oak Ridge Reservation (ORR), the most complex hydrology at any DOE site.

The Geosciences Section is fortunate to have a wide variety of sponsors. The single greatest area of support reflects the need for on-site characterization of geologic and hydrologic conditions on ORR, at other DOE facilities (such as the Paducah Gaseous Diffusion Plant), and at DOD sites. Much of this support is through the Environmental Restoration and the Office of Technology Development (OTD) programs, as well as through direct funding from some of the facilities; activities funded through DOE's Hazardous Waste Remedial Action Program are included. The Office of Health and Environmental Research provides some of the fundamental support for the section's basic research on subsurface transport phenomena, as well as for work in marine and arctic environments. Funding for geophysical and geochemical research came from the Office of Basic Energy Sciences. In addition, staff in the section generated support from other national laboratories for geochemical research. The section also performed research for a number of non-DOE sponsors, including the Environmental Protection Agency, U.S. Geological Survey, and Tennessee Valley Authority.

During FY 1990 the section had a number of significant achievements:

- ORHSP was developed for technical support to the groundwater coordinators at Energy Systems sites.
- A field site of the in situ vitrification waste treatment technology was successfully completed using simulated tracer-level radioactive waste.
- Research toward field validation of a three-dimensional multiregion contaminant transport model was completed.
- Paper recycling at ORNL was initiated through efforts of section staff.
- A new model of atmospheric mercury behavior showed that dry deposition is significant in the summer.
- The complete synthesis of the Integrated Forest Study was published.
- Independent ^{35}S studies in Scotland confirmed ORNL research that throughfall fluxes of sulfate can predict atmospheric sulfur deposition.
- The Energy Systems Office of Groundwater Management was established to help ensure compliance with the federal and state statutes related to groundwater.
- A field demonstration for in situ soil mixing and treatment of TCE and other organic compounds was initiated at the Portsmouth facility.
- Fundamental work on tritium and helium isotopes for defining

groundwater travel times and recharge rates into shallower aquifers was completed.

- Benchmark documents on the hydrology and geology of ORR were issued; they reflect the conceptual model of groundwater flow and transport in this highly fractured and very complex system.
- Risk assessment calculations were made through the use of uncertainty analysis to rank ORNL waste sites.
- Use of West Bay down-hole sampling systems was shown to be highly effective at the Oak Ridge Y-12 Plant.
- Innovative research on matrix diffusion of contaminants was undertaken at a site on ORR; the research shows a linkage between a disposal trench and a nearby spring.
- A portable ground-penetrating radar unit was demonstrated for identification of subsurface heterogeneities.
- Borehole flow meters were demonstrated to be effective in identifying fracture flow zones and colloid transport in the subsurface.
- An analytical system for ultratrace concentrations of mercury in environmental media was developed.
- A staff member served on the staff at OTD and took the lead in developing much of the 5-year plan.
- A shallow, high-resolution seismic reflection survey at the Paducah Gaseous Diffusion Plant was undertaken.
- A geochemical modeling study of the evolution of groundwaters in Bear Creek Valley at the Oak Ridge Y-12 Plant was completed.

Technical Summaries

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Hydraulic Head and Hydrochemistry Anomalies Are Observed in Borehole GW-134 During Monitoring Activities at the Oak Ridge Y-12 Plant

T. O. Early, R. B. Dreier, and H. L. King[1]

For several months, extensive pressure and hydrochemical data have been obtained from a Westbay multiport system installed in borehole GW-134 at the Oak Ridge Y-12 Plant. Thirty-seven monitoring intervals are available over the 809-ft depth of this borehole. Preliminary results of these monitoring activities suggest that contaminated groundwater associated with the S-3 ponds, located ~500 ft north of borehole GW-134, has migrated downward in the vicinity of this well to a depth of at least 762 ft. Available data have been examined and a working hypothesis developed that provides a mechanism for both the hydrochemical and hydraulic head anomalies.

Pressure profiles obtained at borehole GW-134 on April 19, 1990 (~1 month after installation of the multiport system), and March 18–20, 1991, show that the most prominent feature is a large pressure bulge that occurs in the middepth range (350–600 ft) of the profile. This anomaly lies downdip from the S-3 ponds, located in the Nolichucky Shale. The natural gamma log for borehole GW-134 indicates that the pressure anomaly corresponds to a more limestone-rich interval (lower gamma counts) within this formation.

Hydrochemical data, including the major cationic and anionic species, have been obtained from groundwater samples taken from selected intervals at borehole GW-134. These results indicate that groundwaters at all levels are contaminated with nitrate. On the basis of the researchers' understanding of historical disposal activities at the S-3 ponds, it was concluded that the ponds are the likely source of the nitrate. Interestingly, the sample with the highest concentration of nitrate (5520 mg/L) is in the region of the pressure anomaly (424 ft). The deepest sample obtained (762 ft) also contains significant nitrate (3070 mg/L) in addition to sodium (2600 mg/L) and chloride (3370 mg/L). The elevated concentrations of sodium and chloride in this sample are indicative of the dominant type of groundwater that exists at this depth and are not evidence of a surface source for these components. From the data the maximum depth to which contaminated groundwater has migrated could not be defined.

Nitric acid wastewaters were disposed of in the S-3 ponds. Infiltration of this water through the unlined base of the ponds resulted in immediate reactions (primarily with calcite) in the weathered bedrock and the limestone intervals of the Nolichucky Shale. For this reason, shallow groundwater in this region frequently is characterized to be of the calcium-nitrate type. (The uppermost sample at GW-134 is of this type.) It is further hypothesized that the very reactive water from the S-3 ponds was able to preferentially and aggressively attack limestone beds within the Nolichucky Shale and proceed to migrate downdip. This process would create a high-conductivity, dip-parallel reaction pathway. The depth to which this pathway extends is unknown, but contaminated groundwater in this well has been observed at a depth of 762 ft.

In a sense, this mechanism results in the development of a high-conductivity cul-de-sac in an otherwise low-conductivity matrix. However, it is likely that ancillary migration of contaminants will occur beyond this relatively small reaction zone because of the significant hydraulic gradients associated with it and the presence of fractures within the host rock. This process may explain the high level of contamination observed in the deepest zone sampled.

These preliminary results suggest several potential avenues for additional study that should be pursued. First, it is important to determine if contaminants other than nitrate that were present in the S-3 Ponds (e.g., uranium and ^{99}Tc) have migrated downdip in the manner hypothesized. Additional samples and more extensive chemical analyses will be performed to resolve this question. Second, geochemical and reaction path modeling should be conducted to ascertain how well the observed chemical evolution of groundwater in this system can be explained. Finally, the researchers are attempting to develop a groundwater flow model that adequately describes the local hydrologic system.

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A Nondestructive Technique Has Been Developed to Determine Void Volumes of Radioactive Burial Trenches

C. W. Francis and P. J. Hanson

Void volumes of low-level waste trenches have been previously determined by filling the trenches with water and taking into account losses due to seepage into the surrounding soil (water pump-in tests). This practice may result in serious leaching of radionuclides, hazardous wastes, or both into groundwater and induce the premature settling of soil overburden into the trench. Because such a practice is no longer acceptable, an alternative technique was developed.

The technique is based on the principle that small pressure differentials (<0.1 psi) can be monitored within the trench as gas is pumped into the trench at a known rate. The technique assumes that the void volume of the trench is constant and air leaking from the trench occurs across a constant resistance to airflow. The measurement is based on the ideal gas law, where Eq. (1) describes conditions in the trench before pressurization and Eq. (2) describes conditions in the trench after

$$V_o = \frac{n_o RT}{P_o} \qquad (1)$$

$$V_o = \frac{n_x RT}{P_c} \qquad (2)$$

pressurization to a constant pressure. The variables in Eqs. (1) and (2) are defined as follows: V_o = void volume of trench; R = ideal gas constant; T = ambient absolute temperature in trench; P_o = pressure initially present in trench (assumed to be 1 atm); P_c = pressure in trench after pressurization to constant pressure; and $n_x = n_o + n_1$ (where n_x = moles of gases after pressurization, n_o = moles of gas initially present, and n_1 = net moles of gas added to cause increased pressure to P_c). The volume of gas added (V_1) to result in P_c is defined by Eq. (3). Combining Eqs. (1) and (2), assuming no difference in temperature on pressurization, and substituting Eqs. (1) and (3), respectively, for n_o and n_1 result in

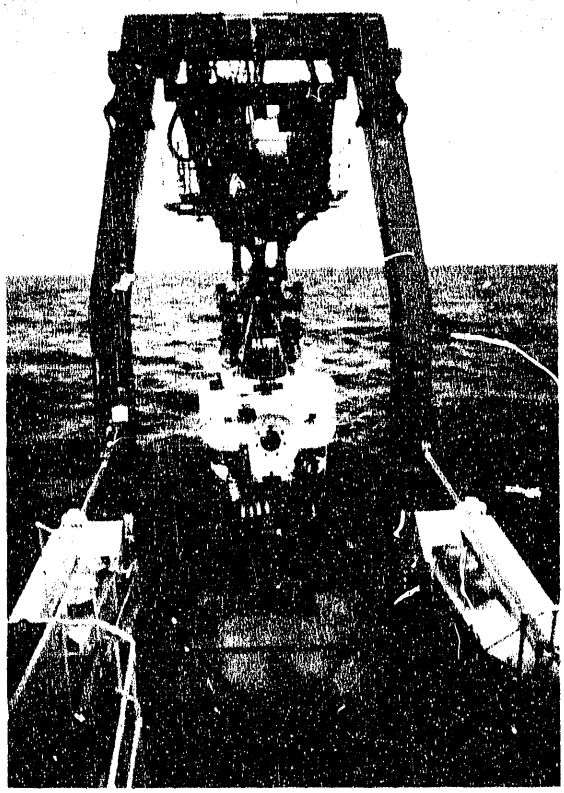
Eq. (4). V_1 can be determined by monitoring the pressure increase in the trench

$$V_1 = \frac{n_1 RT}{P_c} \qquad (3)$$

$$V_o = \frac{V_1 P_c}{P_c - P_o} \qquad (4)$$

over the time it takes to develop a constant pressure from a constant flow of air pumped into the trench. The net inflow into the trench is proportional to the pressure increase over time, and when the trench is at a constant pressure, the outflow (leak rate) is equal to the inflow rate.

Trench void volume determined in this manner was ~60% higher than void volume determined from pump-in water tests. The method provides a means to estimate trench void volume that is fast, inexpensive, and environmentally superior to the previously used pump-in water test.



The research submarine Alvin *is poised for a deep-sea dive. ESD's Karen Von Damm and Jackie Grebmeier participated in* Alvin *dives to study the volcanic and hydrothermal systems of the East Pacific Rise ~1.5 miles below the water surface. The rise is part of the global system of volcanic ridges from which magma erupts to create new seafloor.*

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Unsaturated Transport Studies in Undisturbed Soil Columns Are Useful for Quantifying In Situ Contaminant Mobility at the SWSA Sites

P. M. Jardine, G. K. Jacobs, and Z. Kooner

Prolonged disposal of organic and inorganic waste in shallow burial sites of eastern Tennessee has prompted detailed investigations of contaminant transport processes in upper subsurface media. The radionuclides ^{90}Sr and ^{60}Co are of significant concern because of (1) the large inventories present in existing waste sites, (2) their relatively long half-lives (~29 and ~5 years, respectively), (3) the large health risks associated with each isotope, and (4) their high mobility at many waste sites. Transport processes present at these sites are spatially complex because of preferential flow in fractured media and the presence of massive saprolite with variable size and permeability.

The purpose of this research was to investigate the thermodynamic and kinetic processes controlling the transport of nonreactive and reactive contaminants in variably saturated, heterogeneous soils. Large undisturbed soil columns were carefully isolated in the C-horizons of the proposed burial grounds of Solid Waste Storage Area 7. The columns were fitted with two fritted glass endplates, and variably saturated conditions were imposed with a mariotte device at the column inlet and a vacuum chamber at the column outlet. Single and multispecies injections of nonreactive Br and reactive Sr and Co were initiated on the columns to simulate a leaky burial trench during storm events.

Tracer studies were conducted under a variety of moisture conditions in order to assess the importance of solute mass-transfer limitations during in situ transient storm events. Significant mass-transfer limitations among pore classes occurred during saturated transport, and a multipore-domain model was required to describe the data. Mass-transfer limitations became increasingly negligible with unsaturated conditions because of a decrease in pore-class heterogeneity involved in the transport process.

The classical convective-dispersive equation was found to adequately describe observed effluent concentrations for these unsaturated conditions. Observed breakthrough curves for Sr and Co were delayed relative to nonreactive Br breakthrough curves, which indicated that the former tracers were adsorbed by the soil. Cation exchange equilibria relationships obtained from tests on disturbed samples using batch methods could describe the thermodynamic processes that were prevalent during unsaturated transport. These results suggest that the massive saprolite within the soil columns was a chemically active constituent during unsaturated reactive tracer transport. However, significant bypass of the porous media occurs during saturated flow.

In situ contaminant transport processes are driven by transient storm events that impart variable soil moisture conditions with time. Quantifying the thermodynamic and kinetic controls on solute transport during these conditions is critical for the successful utility of field-scale subsurface transport models.

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Field Test Kit for Petroleum Hydrocarbons Is Successfully Tested and Modified for Use in Remote Locations

N. E. Korte and D. A. Pickering[1]

Friedel-Crafts acylation, a classical preparative reaction in organic chemistry, involves the reaction of an aromatic compound with an acid chloride catalyzed by a Lewis acid such as aluminum chloride. With an appropriate choice of reagents, a colored product is formed. The hue and intensity of the color are determined by the nature and concentration of the aromatic compounds in the sample. The aromatic fraction of a petroleum spill is typically of greatest interest because such compounds are the most toxic and the most water-soluble components of the fuel. A recently marketed test kit employs the Friedel-Crafts reaction for estimating the concentration of fuel in soil and water samples.

The test kit was obtained for use in a biotreatment feasibility study for hydrocarbon-contaminated soil remediation at a remote island in the southwest Pacific. It proved impossible, however, to ship the kit's extraction solvent, carbon tetrachloride (CCl_4), to the island because of CCl_4's status as a poison and a carcinogen. Disposal would also have been difficult. Consequently, the test kit procedure was modified by substituting 1,1,2-trichloro-1,2,2-trifluoroethane for the CCl_4.

Samples from six test pits were extracted and analyzed on-site with the test kit and infrared spectrometer (IR). Out of 12 samples deemed contaminated on the basis of on the IR method, the test kit yielded only 1 false negative and no false positives. The IR indicated a low level of contamination, and a hand-held photoionization detector (PID) yielded a false negative for the sample. Natural organic matter or simply an absence of aromatics may explain the apparent contamination observed with the IR.

Upon returning from the field, diesel fuel standards were prepared in CCl_4 and Freon. Color development in the two solvents was identical. A literature search revealed that the extraction efficiencies of CCl_4 and Freon are comparable.

As a final demonstration of the test kit's utility, exposure to salt spray resulted in failure of PIDs used for field screening by a group performing a site characterization. Instrument repair was impossible because of the site's remote location. The field crew was given the remaining Freon and test kit materials following the biotreatment study. The test kit proved to be acceptable for field screening, enabling the crew to continue working despite the absence of PIDs.

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Bed-Load Transport in White Oak Creek Is Modeled by Using ^{137}Cs Inventories

I. L. Larsen, R. W. Sobocinski,[1]
T. E. Cerling,[1] and S. J. Morrison[1]

Bed load sediments of White Oak Creek (WOC) below the Process Waste Treatment Plant have been labeled by historical releases of ^{137}Cs to a depth of >25 cm. The streambed of WOC acts as a sink for ^{137}Cs because of irreversible sorption onto bed-load sediments. During major storm events streamflow develops

sufficient competency to initiate transport of bed-load sediments downstream. Because the bulk of ^{137}Cs in WOC moves downstream fixed to sediments, the rate of sediment transport becomes an important parameter in assessing the dispersal of ^{137}Cs through the fluvial system. The net downstream transport of several different streambed sediment size fractions in WOC was quantified.

Laura Toran and Libby Reyes confer about a groundwater transport model for use on the ORNL supercomputer. Through the supercomputer's increased power, they can create more sophisticated models to describe the transport of hazardous waste on the Oak Ridge Reservation. The two researchers are working with the Engineering Physics and Mathematics Division to create their model, which will help determine effective remediation strategies.

To accomplish this, streambed cores were collected from several locations within a 550-m study reach of WOC, sectioned into 2-cm intervals, and wet-sieved into various size components (1–2 mm to 8–16 mm). This size range comprises the bulk of sediments in WOC. The separated size fractions were then analyzed for ^{137}Cs, and an inventory for each size fraction and core location was performed. The integrated ^{137}Cs activity is the total activity of the core to depth of bed-load scour for a particular size fraction. This inventory is due both to contaminated sediment transported to that location and to subsequent ^{137}Cs sorption directly from streamwater. A model of ^{137}Cs transport and distribution in the streambed of WOC was formulated that incorporates bed-load celerity, as well as sorption, dispersion, advection, and radioactive decay of ^{137}Cs.[2]

Results indicated that the bed load of WOC undergoes several transport events per year when threshold velocities exceed base flow (~ 0.22 m^3/s) by a factor of 5. Sediment transport velocities decrease with increasing grain sizes. The model indicated mean sediment velocities of 265, 215, 170, and 160 m/year for the 1- to 2-, 2- to 4-, 4- to 8-, and 8- to 16-mm fractions, respectively, are similar to rates observed elsewhere. On the basis of these transport rates, a 30-cm scour depth, and a normal number of storm events per year, bed-load transport will flush the contaminated 1- to 16-mm fraction out of the study reach within 1–6 years after the sources of ^{137}Cs contamination are eliminated. This has important implications for predicting downstream transport of contaminants in this system.

[1]*University of Utah, Salt Lake City.*
[2]*R. W. Sobocinski, T. E. Cerling, S. J. Morrison, and I. L. Larsen, "Sediment Transport in a Small Stream Based on ^{137}Cs Inventories of the Bed Load Fraction,"* Water Resour. Res. *26(6), 1177–87 (1990).*

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Dry Deposition Contributes Significantly to the Atmosphere–Surface Exchange of Mercury in a Forest and Has Important Implications for the Global Metal Cycle

S. E. Lindberg, T. P. Meyers,[1] and R. R. Turner

A complete understanding of the fate and effects of mercury in the environment is again a major concern of the scientific community. In vast numbers of lakes around the world, mercury continues to accumulate in fish tissue at levels potentially harmful to consumers, and this mercury is influenced by emissions from energy production. Recent data confirm the importance of the atmosphere in the cycling of mercury in aquatic and terrestrial ecosystems. However, there are few data on the role of dry deposition. Wet deposition alone cannot account for all of the mercury apparently accumulating in lakes in forested watersheds.

Concentrations of mercury aerosol and vapor in air have been measured at Walker Branch Watershed (WBW) for 2 years. These data confirm that airborne mercury is dominated by vapor species that exhibit a strong seasonal cycle, and summer maxima correspond to elevated air temperature. The concentration data have been combined with a recently developed model to estimate dry deposition fluxes to the forest at WBW. Weekly mean modeled values for the deposition velocity of mercury range from <0.01 cm/s (winter) to >0.1 cm/s (summer). Dry deposition fluxes range from 80 $ng \cdot m^{-2} \cdot d^{-1}$ in the winter to 230 $ng \cdot m^{-2} \cdot d^{-1}$ in the summer.

These data, plus limited measurements of wet deposition, indicate that dry deposition may be the dominant input process in this forest, particularly during summer. Preparations are being made to apply the gradient method to estimate dry deposition of mercury during short-term experiments. To date, these profiles indicate that the canopy is a sink for mercury vapor during some periods, but the canopy/soil system is a source during other periods.

The data have interesting implications for the role of possible changes in the earth's physical and chemical climate in the tropospheric cycle of mercury. The atmospheric concentration of mercury vapor is strongly related to air temperature, which suggests the importance of surface soil emissions. A similar relationship exists between the dry deposition of mercury and air temperature, with modeled dry deposition velocities increasing with temperature because of the strong physiological control over the mesophyll pathway for mercury uptake. Global warming would also imply increased mean surface temperatures of foliage. If these relationships are universal, a general increase in global temperature would have profound implications for the global biogeochemical cycle of mercury, possibly resulting in increased rates of transfer of mercury from the geosphere to the biosphere. Because of the unique chemistry of mercury and its compounds, it may be the trace metal whose cycling is most sensitive to global change.

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SWSA 4 Bathtubbing Trench Contributes Fission Products to White Oak Creek

J. D. Marsh, Jr., R. B. Clapp, and N. D. Farrow

From 1951 to 1959, 2 million ft^3 of low-level radioactive waste containing 90,000 to 120,000 Ci of ^{137}Cs, ^{90}Sr, ^{60}Co, and ^{239}Pu was buried in Solid Waste Storage Area (SWSA) 4. As trenches fill up during rainstorms, they overflow (bathtub) and bring soluble radionuclides that were buried there to the surface. The overflow from the "bathtubbing trench" runs into White Oak Creek. There the radionuclides are either (1) adsorbed to the bottom sediments of the creek, (2) incorporated into vegetation growing along the creek banks and then eaten by wildlife, or (3) transported to White Oak Lake, where they add to the burden of radioactivity already present. The objective of this research was to assess the importance of the bathtubbing effect in bringing radionuclides to the surface, where they can then be transported to White Oak Creek.

Seven groundwater wells were installed both inside and around a bermed area surrounding the bathtubbing trench. The wells ranged in depth from 10 to 16 ft. There was no pattern to the radioactivity as a function of either well depth or spatial relationship with well locations.

An iron floc observed in the bermed area had a radiation reading of 10 to 20 mR/h at the surface. Gamma analysis of the bermed water and the ferric hydroxide precipitate gave a K_D of 2.6×10^4 for ^{137}Cs. This high K_D indicates that some ^{137}Cs coprecipitates with the ferric hydroxide, resulting in above-background radiation readings on the surface of the bermed area. For comparison, the suspended matter from the wells, which consisted mainly of silty clay, had a K_D ranging from 30 to 125. Strontium-90 was not appreciably adsorbed.

In two wells the iron concentrations were low, and the dissolved ^{137}Cs activity was undetected. It is possible that the iron had precipitated and scavenged the ^{137}Cs from these well waters in situ. It is not known why these two wells would have a more oxidizing environment than the other wells. The dissolved ^{137}Cs activity in the other wells ranged from undetected (with 21 mg/L of iron) to 20,700 pCi/L. In well 14, located inside the bermed area, ^{3}H values were more than 10^6 pCi/L, which was two to three orders of magnitude higher than the other wells. No dissolved or particulate ^{60}Co was detected in any of the wells. Strontium-90 was found in all the wells sampled and ranged from 42 to 72,200 pCi/L.

A statistical comparison of the gross beta with the sum of the individual beta emitters indicated the presence of one or more beta emitters not reported by the isotopic analysis regimen. The excess gross beta could be a result of the beta-emitting daughters of ^{238}U that may be buried at the site. The presence of uranium would also help explain the gross alpha activity, which ranged from 119 to 865 pCi/L. This alpha activity needs further characterization to determine what transuranics are present.

Thus, although iron scavenging may remove most ^{137}Cs from solution, the SWSA 4 bathtubbing trench could be a source of ^{3}H, ^{90}Sr, U, and some ^{137}Cs in White Oak Creek. Further characterization is required to identify the radioactive components buried in SWSA 4 to assess the potential for transport of radionuclides into White Oak Creek so that effective remedial actions can be evaluated.

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Subsurface Stormflow Is Measured near ORNL

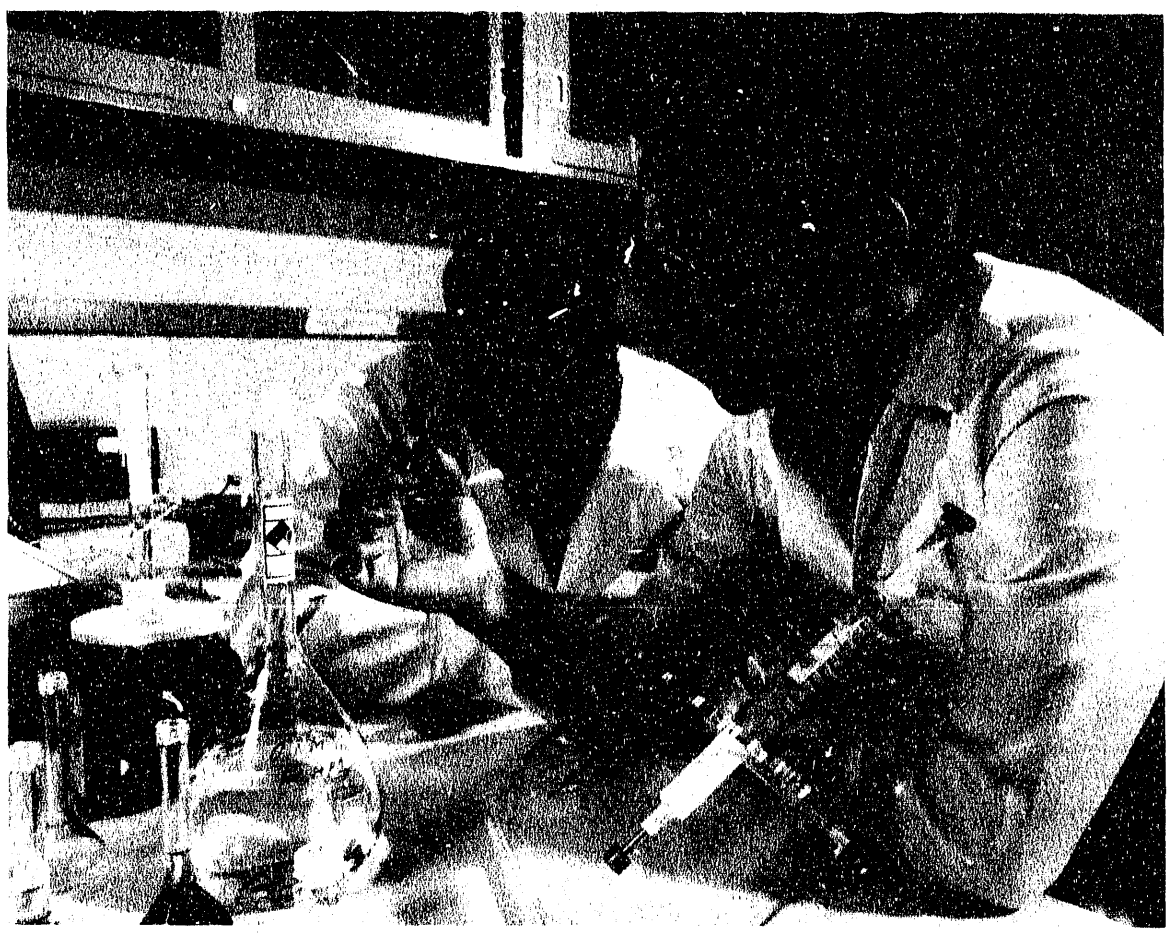
G. K. Moore[1] and R. B. Clapp

The stormflow zone approximately corresponds to the root zone of vegetation and is 10 to 1000 times more permeable than the underlying vadose zone. Because of this large difference in permeability, many precipitation events produce a transient perched water table in the stormflow zone, and water is then transmitted downslope, above the water table, toward nearby streams. The stormflow zone may thus prove to be an important pathway for the subsurface flow of water beneath clay caps and into waste trenches.

Monitoring tubes consisting of 1.9-cm plastic pipe, sealed at the bottom and slotted from land surface to depths of 79 cm, were installed at 17 locations in proposed Solid Waste Storage Area (SWSA) 7. All tubes had some water inflows, indicating saturated soils and downslope flows of water. Tubes on steep slopes and in gullies generally had water inflows during small precipitation events, whereas larger or more intense events were required to produce inflows on smooth and shallow slopes. During periods of intense precipitation, overland flow was observed near some monitoring tubes in

gullies and swales, but overland flow apparently occurs only after the storm-flow zone fills to overflowing. All water samples obtained from the monitoring tubes were cloudy to muddy, and the suspended sediment was mostly colloidal. Subsurface erosion and sediment transport in colloidal form may be a significant geomorphic process in proposed SWSA 7.

The recession rates of water levels in stormflow monitoring tubes and in wells were related to discharge from these zones, and they were used to calculate streamflow components in proposed SWSA 7 for February 15-25, 1990. During this period, measured streamflow was 71% of precipitation and consisted of 40% overland flow, 48% subsurface stormflow,



S. Y. Lee (foreground) performs a phosphate analysis of a soil solution as Stan Cash, a SEED project student from Fulton High School in Knoxville, Tennessee, observes. Lee and Cash are quantifying the amount of phosphate remaining in solution after it is mixed with radiostrontium-contaminated soil. The analysis will help researchers determine the optimal concentration of phosphate necessary to immobilize radioactive strontium in soils at DOE facilities.

and 12% groundwater flow. Stormflow discharge is a larger percentage of streamflow during events when overland flow is minimal. From 1800 h on February 18 to 0800 h on February 22, for example, streamflow consisted of 5% overland flow, 77% stormflow, and 18% groundwater flow. Subsurface stormflow is a major part of the water budget during a part of each year.

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Conventional Methods for Sample Collection and Handling Yield Negatively Biased Results for Concentrations of Trichloroethylene and Other Volatile Organic Compounds in Soils

R. L. Siegrist, R. A. Jenkins,[1] and M. P. Maskarinec[1]

ORNL staff have been spearheading research to advance the state of knowledge and improve the measurement of soil volatile organic compounds (VOCs) such as trichloroethylene (TCE). A recent field investigation confirmed the results of prior laboratory research, which demonstrated substantial and significant negative bias (up to 100%) in measurements of VOCs as a result of inadequate sample collecting, handling, and preserving. This field study was conducted at a waste oil and solvent landfarm located at the Portsmouth Gaseous Diffusion Plant in Ohio. Soil samples were collected from two depths in each of three borings by two conventional methods [i.e., RCRA (Resource Conservation and Recovery Act) Facility Investigation (RFI)] and by two enhanced methods. The enhanced methods were developed in part at ORNL and are currently being considered for implementation by the U.S. Environmental Protection Agency (EPA) and the American Society for Testing and Materials. All laboratory samples were analyzed by gas chromatography/mass spectrometry (EPA methods SW5030 or 3580, and SW8240).

Thirteen VOCs were detected; TCE was predominant. As expected, VOC concentrations measured by the commonly used RFI methods were 50 to 90% lower than those measured by the ORNL methods [infield modified purge and trap vial (MP&T) and infield methanol immersion (IMI)]. IMI consistently provided the highest soil VOC concentrations. The differences between the conventional RFI and the enhanced MP&T methods could be attributable to volatilization losses induced by disturbance (i.e., during sample collection, containerization, or laboratory subsampling). The differences between the MP&T and the IMI methods may be attributable to VOC losses due to vapor leakage from the containers, VOC degradation, or poor VOC extraction efficiency. VOCs detected by the field headspace screening were correlated with the IMI method.

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Analytical Approximations Have Been Developed to Model Depths During In Situ Vitrification

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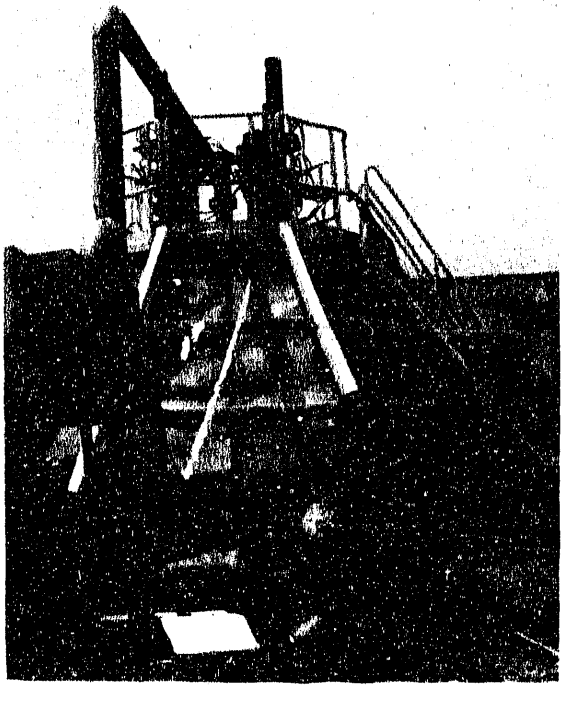
S. M. Lenhart[3]

In situ vitrification (ISV), developed by Pacific Northwest Laboratories (PNL) and patented for DOE, is one method used to stabilize contaminated soils in place. Because ISV is concerned with immobilizing highly hazardous wastes, a precise quantitative knowledge of the process is desirable to determine where the melt zone is at a given time and whether hazardous materials are being released to the surrounding soil or the atmosphere during melting.

Previous models of ISV have been based on an assumed interface profile linked to heat and mass balances. They accurately predicted the ISV process in some cases but not in others. These models are limited because they do not take into account all of the important and complex heat transfer processes occurring in the



Nelia Dunbar samples gases released from the surface of an in situ vitrification (ISV) melt on the Oak Ridge Reservation. The ISV process uses electricity to transform soil into a mixture of glass and crystals. Gary Jacobs, Brian Spalding, Mike Naney, and Nelia Dunbar are evaluating the feasibility of ISV for stabilizing contaminated soil sites. They also study gas samples from the ISV melt to learn more about natural volcanic emanations.

melt and the effect they may have on the temporal and spatial development of the melt front. The current study identified key parameters and processes in the ISV melt cycle and developed analytical approximations for several properties of molten soil from available data. Using a simplified geometrical approximation (a cylinder) for melt geometry, an analytical approximation for the rate of melting (depth) vs time was derived that is consistent with data from field experiments

$$Melt\ depth = \sqrt{\frac{kbP_o t}{\pi h R_c \rho \lambda}},$$

where

k = melt thermal conductivity (kJ/m·s·°C);
P_o = power (kJ/s);
t = time (s);
ρ = density (kg/m^3);
λ = $c\Delta T + L$;
c = specific heat (kJ/kg·°C);
ΔT = temperature drop (°C);
L = latent heat (kJ/kg);
R_o = cylinder radius (m);
h = film coefficient (kJ/s·°C·m^2);

$$b = \sqrt{\frac{2\pi R_0 h}{A_0 k}},$$ for A_o = cylinder cross-sectional area (m^2).

For small t values, the depth of melting increases linearly with time. After ~10 h in large-scale tests, however, the depth increases as the square root of time. Existing data are also consistent with a relationship that shows the volumetric growth rate of the melt to be directly proportional to time. These conclusions suggest that heat transfer processes controlling the ISV process may be at the transition between weak convection and conduction.

Continued interpretation of additional test data and derivation of analytical models should lead to an improved understanding of controlling processes during ISV. In parallel, it is important to improve existing three-dimensional heat transfer models that can account for heat transfer, phase changes, convection and conduction, electric field and power distributions, bubble formation and transport, chemical reaction, and vapor transport. Such a model would be useful in optimization studies of ISV designs and would provide added confidence in the application of ISV to contaminated sites.

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Tritium and Helium Isotopes Have Been Used to Define Groundwater Travel Times and Recharge Rates in a Shallow Unconfined Aquifer

D. K. Solomon and R. J. Poreda[1]

Radioactive ^{3}H, which has a half-life of 12.4 years, in precipitation (arising primarily from aboveground testing of thermonuclear devices) has been entering groundwater systems since the mid-1950s, with peak values occurring in the mid-1960s. Tritium activities in precipitation are temporally and spatially variable; and hence, it is difficult to use ^{3}H alone to determine groundwater ages and recharge rates. However, combined measurement of ^{3}H and its stable daughter helium-3 (^{3}He) can be used to determine groundwater ages without knowledge of the ^{3}H input activity.

Vertical profiles of ^3H and ^3He isotope ratios have been measured in groundwater from the well-characterized Borden aquifer, Ontario. The sum of ^3H and tritiogenic ^3He ($^3He^*$) is used as an equivalent nondecaying tracer, whereas the ratio of $^3He^*$ to ^3H is used to compute groundwater ages. The sum of ^3H and $^3He^*$ clearly defines the mid-1960s ^3H bomb peak at several locations. The accuracy of the ^3H:^3He dating method depends on the ability of the saturated zone to retain $^3He^*$ against diffusive loss at the water table and on the amount of dispersive mixing that occurs within the saturated zone of shallow unconfined aquifers. Helium-3 confinement is strong and dispersive mixing is weak in the Borden aquifer, resulting in an excellent delineation of groundwater travel times.

Computed ^3H:^3He age profiles are compared with travel times predicted from a previously calibrated flow model. Although the ^3H:^3He age profiles are vertically offset from the modeled travel times, the travel time and ^3H:^3He age gradients compare exceptionally well. Recharge rates have been computed using the ^3H:^3He age gradients and vary from 62 cm/year beneath the Borden landfill to 14 cm/year north of the landfill. The ^3H:^3He-computed recharge agrees well with the recharge function used in previous flow modeling. The results of this study indicate that the ^3H:^3He dating method is extremely promising for (1) defining baseline recharge values in the context of global climate change, (2) evaluating groundwater flow patterns in complex shallow aquifers (e.g., waste sites), and (3) evaluating the scale dependence of transport processes in the subsurface.

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In Situ Grouting of Burial Trenches with Polyacrylamide Improves Hydrologic Isolation of Low-Level Radioactive Waste

B. P. Spalding and T. A. Fontaine

As part of a burial ground stabilization and closure technology demonstration project, a group of 19 burial trenches in ORNL Solid Waste Storage Area (SWSA) 6 was selected as a demonstration and test area. Because of the large inventory of radioactivity in some burial trenches in SWSA 6, additional assurance of hydrologic isolation of trench contents from groundwater intrusion and/or percolation, beyond that provided by an infiltration barrier or cover, may be warranted for particular trenches. In situ grouting is a technique with the potential to provide hydrologic isolation of burial trench contents, regardless of infiltration barrier integrity or performance.

Demonstrations of in situ grouting with polyacrylamide were carried out on two unperturbed burial trenches and one dynamically compacted burial trench in SWSA 6. The objective of these demonstrations was to evaluate the effectiveness of grouting in converting burial trenches from their ambient condition of high permeability to one in which they become considerably less permeable than the surrounding soil formation.

The injection of polyacrylamide was quite facile for the two unperturbed burial trenches, and the trenches were filled with grout in several batches injected over several days. The compacted burial trench failed to accept grout at a rate of >0.5 gal/min even when pressure was applied. Thus, it appears that burial

trenches that have been stabilized by dynamic compaction are converted to sufficiently low permeability and that they are no longer groutable.

Sampling of undisturbed soil cores around both of the uncompacted trenches, after filling with grout, revealed that minimal quantities of polymerized grout had permeated into the surrounding soil formation. A lack of response of the water table in the area of the grouted trenches was indicative of a lack of hydrologic connection between fluid grout and the water table. Because grout set times were adjusted to <60 min, the lack of hydrologic connection was not surprising.

Postgrouting penetration testing revealed that the grout had changed the stability of the burial trenches from 25 to 79% of the undisturbed soil formation. In situ permeation tests on the grouted trenches have indicated a significant reduction in hydraulic conductivity of the trench contents from a mean value of 2.91×10^{-3} cm/s to 1.85×10^{-5} cm/s. Dynamic compaction, in contrast, reduced the mean hydraulic conductivity to only 2.08×10^{-4} cm/s. However, both dynamic compaction and grouting produced wide variability in the range of hydraulic conductivities measured.

Minor contamination (<1 mg/L) of groundwater at the site by acrylamide has been confirmed, but spatial and temporal patterns are not apparent. Sampling of groundwater at the site will continue over the next year to determine whether contamination by residual grout constituents persists. Preliminary observations indicate that grouting with polyacrylamide is a good method for both improved stability and hydrologic isolation of radioactive waste and its incidental hazardous constituents.

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Statistical Analysis of Fracture Spacing on the Oak Ridge Reservation Shows Clustered Distribution and Wider Spacing for Thicker Beds

L. E. Toran, P. J. Lemiszki,[1] and J. J. Beauchamp[2]

Fracture spacing is one of about a dozen parameters needed for fracture flow modeling to make predictions about contaminant transport. As part of the characterization effort of the Oak Ridge Reservation, data on fracture spacing were collected from ~600 surface outcrops, with ~1100 measurements on different fracture sets at each station. The fracture spacing varied from <1 in. to ~60 in., with a geometric mean of 2 in. and a standard deviation of 12 in. However, the data failed tests for lognormal and exponential distributions commonly assumed for fracture spacing. Thus, these distributions are inappropriate for generating fracture spacing in fracture flow modeling of the shallow subsurface. The lack of statistical fit is indicative of clustered spacings. The means reported herein assume a lognormal distribution.

As expected, the lithologies that fracture as massive units have larger mean fracture spacing and larger variation. Shale units, interbedded shale and limestone units, and other interbedded units had mean spacing from 0.5 to 2 in. and a smaller variation. The limestone has a mean spacing of 11.5 in.; dolomite, 5 in.; and sandstone, 5.75 in. These mean spacings include data from various bed thicknesses, although thicker beds are more common in the massive units. The Youngs modulus, which relates stress to strain in a rock, generally decreases from limestone to dolomite to sandstone. Thus, the stiffness of the

limestone may lead to the wider fracture spacing, assuming similar stress histories between the different lithologies. Some differences have been observed between stratigraphic units; the Rome Formation tends to lower spacing, which may be related to proximity to major thrust faults.

The data on fracture spacing for various bed thicknesses fell into three statistically distinct groups, a large mean fracture spacing and variation occurred in the thickly bedded group. Although differences were statistically significant, the mean values varied only by inches. The mean value was 2 in. for thin beds, 3 in. for the medium-thickness bed, and 10 in. for the thick beds. The mean spacing for the two perpendicular fracture sets was not significantly different.

In summary, although fracture spacing varies from inches to feet over the reservation, in surface outcrop the dominant spacing is <5 in. At the scale of measurement, neither lithology, bedding, nor fracture orientation causes variations more than a few inches in the mean-fracture spacing.

However, more information is needed to establish whether the trend continues at depth and whether fracture filling (which cannot be easily established in outcrop) will lead to wider effective spacing. The next step is to use this information to design hydrologic field tests, such as pressure-response between two wells, which can determine the hydrologically important fractures.

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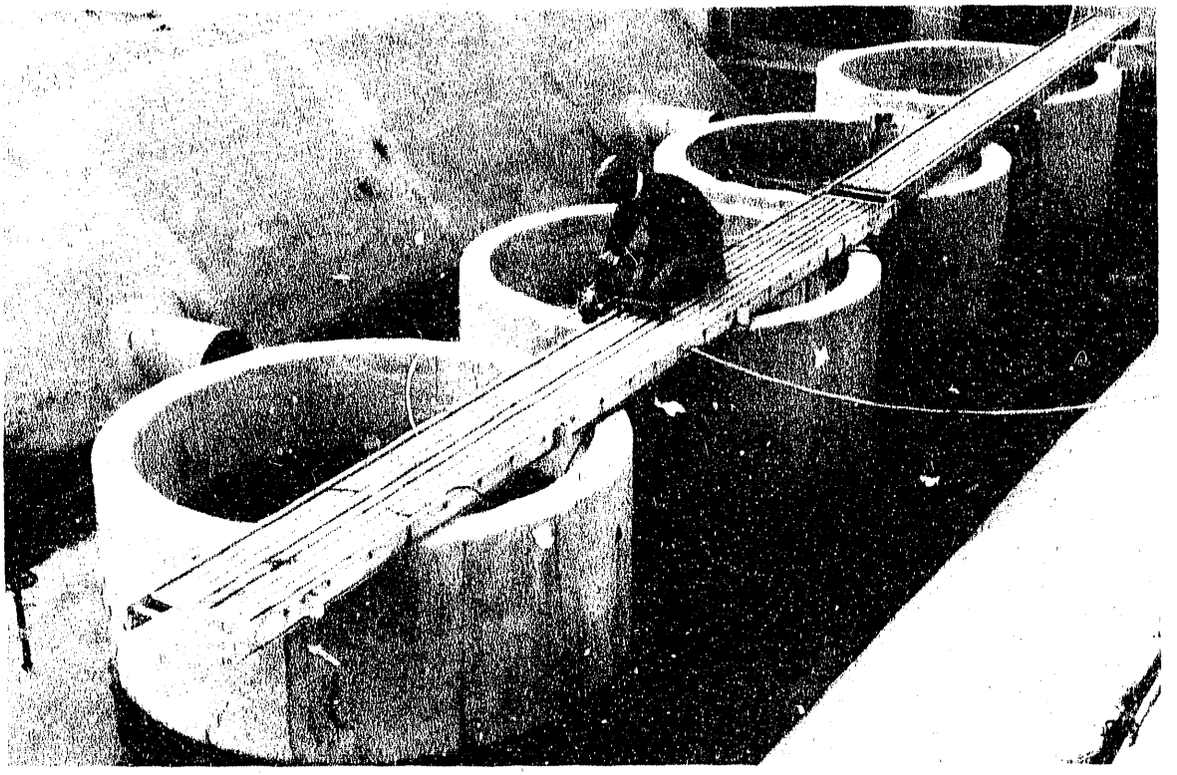
Evidence for Fracture Flow Is Found in Groundwater with Old ^{14}C and Young ^{3}H

L. E. Toran, D. K. Solomon,
W. M. McMaster,[1] and C. M. Morrissey

The presence of both ^{14}C, indicating water thousands of years old, and ^{3}H, indicating water <50 years old, in groundwater samples collected on the Oak Ridge Reservation must be explained with a fracture flow model that incorporates matrix diffusion. Seven groundwater samples were collected from 200-ft-deep wells in Melton Valley, and the goal was to better interpret flow paths in the deep groundwater zone.

Several corrections are needed to date ^{14}C in groundwater from fractured sedimentary rocks; because of uncertainties it is better to refer to such dates as ^{14}C dates rather than groundwater dates. The first correction to the data made use of ^{13}C to estimate the amount of dead carbon (no ^{14}C activity) introduced from the dissolution of carbonate rocks. For example, the well in the recharge area had an uncorrected ^{14}C date of about 8000 years, but the ^{13}C value indicated nearly one-half of the carbon resulted from the dissolution of carbonate rocks. The ^{13}C-corrected age, using a thermodynamic model, is only 2500 years. The oldest date in the discharge area was 39,000 years, with a ^{13}C correction to 28,000 years.

Another correction to the data was undertaken to determine whether the groundwater contains a mixture of old and young waters. The primary indicator of mixing is ^{3}H. All but one well had



Ralph Turner checks the water temperature in experimental enclosures at Reality Lake near the Oak Ridge Y-12 Plant. Researchers have placed fish in the enclosures and are measuring their uptake of mercury as part of an investigation into the relative importance of sediment and water as mercury sources.

measurable ^{3}H, indicating the presence of water <50 years old. Five wells had from 1 to 5 ^{3}H units, and one well had 100.

The presence of ^{3}H can be explained by understanding flow in fractured rock. The ^{3}H may travel along fast flow paths in fractures. The ^{14}C, whose input began many thousands of years ago, has diffused from fractures into the matrix to reach a steady-state concentration in the deep system (rather than a modern concentration, which would result if fracture transport were the only pathway). Thus, the leading edge of a solute plume could migrate hundreds of meter per year as given by the ^{3}H data, whereas the peak contaminant concentrations (i.e., the center of the contaminant mass) would migrate at a rate of only centimeters per year as given by the ^{14}C data.

These processes, matrix diffusion and fracture flow, can be modeled using a simple parallel fracture model. Little is known about fracture characteristics at the depths sampled, so a wide range of parameters was tested. This testing was accomplished by using a Monte Carlo driver that selected values for aperture,

spacing, velocity, and matrix porosity with a random number generator, conducting several thousand runs at a time.

The model reproduced ^{14}C data from a well in the recharge area to a well in the discharge area. The derived values for fracture spacing (>30 m) were consistent with estimates from a borehole flowmeter at somewhat shallower depths, whereas, the derived apertures (<10 μm) had not been previously estimated. The same set of parameters explains the observed ^{3}H value in the recharge area only if ^{14}C is retarded to reduce its concentration. Retardation factors as high as 10 have been hypothesized to explain ^{14}C-rock exchange in some systems. In the recharge area, the retardation factor would reduce the ^{14}C age from 800 to 300 years and from 15,000 to 4000 years in one discharge area well modeled . Although the water is still old, these are large corrections. Tritium can be transported to the discharge area but not without requiring retardation factors higher than previously reported.

In summary, the presence of both recent ^{3}H and old ^{14}C in the same well has implications for contaminant transport and groundwater age-dating in fractured sedimentary rocks. The rapid migration of small amounts of contaminants may offer an early warning of transport pathways, provided the detection limit is low enough to monitor the leading edge of the plume. Carbon-14 ages alone cannot be used to date groundwater in fractured rock since they do not exclude the possibility of recent water traveling in fractures; and age correction for carbonate dissolution, matrix diffusion, and possibly retardation result in groundwater ages significantly younger than ^{14}C dates.

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Behavior and Aqueous Chemical Speciation of Mercury Are Characterized in East Fork Poplar Creek

R. R. Turner, M. A. Bogle, and N. S. Bloom[1]

Environmentally significant quantities of mercury continue to leak out of the Oak Ridge Y-12 Plant. This facility used many millions of pounds of elemental mercury in the 1950s to separate lithium isotopes. Current losses (30 g/d) from the facility originate in the extensive subsurface drainage system of the plant, enter the headwaters of East Fork Poplar Creek (EFPC), and then exit the plant site through Reality Lake (a 1-ha plastic-lined impoundment constructed in 1988). EFPC is posted against fishing because of the occurrence of mercury at concentrations approaching or exceeding the U.S. Food and Drug Administration Limit of 1.0 μg/g in edible fish in the upper reaches of the creek below the lake. Although the creek has been exhaustively studied, there has been no previous effort to characterize the aqueous chemical speciation of mercury and particularly the occurrence and behavior of monomethylmercury, the species which bioaccumulates and accounts for 100% of the mercury in fish muscle.

Systematic surveys of total mercury (TM), dissolved mercury (DM), particulate mercury (PM), mercury-on-suspended matter (SSM), dissolved gaseous mercury (DGM), total monomethylmercury (MM), and selected other constituents in EFPC water (nonstormflow) were begun in January 1989. Three sites upstream and six sites downstream of Reality Lake, representing EFPC km 23.8 through 6.8, were typically included in each survey. All analyses were performed at ORNL except

the MM analyses, which were performed at Brooks Rand Ltd. An ultrasensitive technique involving ethylation, cryogenic gas chromatography, and atomic fluorescence spectrophotometry was used.

Survey results showed significant spatial and temporal patterns in the aqueous chemistry of mercury. The concentration of all species of mercury decreased with distance downstream of Reality Lake. Although Reality Lake had little effect on TM entering the lake (inflow = 1.9 μg/L; outflow = 1.8 μg/L), DM consistently decreased between the inflow (0.84 μg/L) and the outflow (0.28 μg/L). MM consistently increased in the lake (inflow = 0.00021 μg/L; outflow = 0.0015 μg/L). Mass-balance calculations revealed that MM was being generated and released from the lake at an average rate of $\sim 2\ \mu g \cdot m^{-2} \cdot d^{-2}$. Release of MM by the lake was highest in summer. This observation of a net source for MM in the lake is consistent with the favorable conditions for methylation of mercury provided by abundant influx of soluble inorganic mercury and the accumulation of anaerobic sediments in the lake. DGM typically accounted for <10% of DM in water and was always highly supersaturated with respect to elemental mercury in ambient air, which this measured form of mercury probably represents. The latter was especially true of sites upstream of the lake and suggests active reduction of mercury by the abundant mercury-resistant bacteria known to be present in this system.

Average PM concentration also increased between the inflow (1.0 μg/L) and the outflow (1.5 μg/L) of the lake, indicating a shift toward greater association of mercury with the suspended phase. However, this increase in particle-associated mercury was offset by a significant increase in autochthonous suspended matter in the lake, which resulted in the average SSM decreasing from 640 to 173 μg/g between the inflow and outflow.

Overall, these results demonstrated the important role of continuing releases of mercury from the plant, and the active methylation process in Reality Lake in sustaining mercury in resident fish. This study also revealed that Reality Lake has essentially no effect on the quantity of mercury leaving the plant under nonstormflow conditions but significantly affects the chemical form of that mercury.

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Division Operations

Introduction

The Division Operations Section of the Environmental Sciences Division (ESD) at Oak Ridge National Laboratory provides support to ESD in the following areas: administration; environment, safety, and health; finance; information; and operations. At the close of FY 1991, ESD employed 204 staff; over 350 guests and other-division staff worked on ESD projects during the fiscal year. ESD is housed mainly in five facilities, which contain offices, research laboratories, and special purpose rooms. In addition, ESD is responsible for two large field installations and several other field locations on the Oak Ridge Reservation.

Administrative support includes personnel and staffing-related functions, education efforts, and day-to-day oversight of activities in the ESD facilities. It also includes interactions with DOE representatives, Energy Systems organizational units, and other ORNL divisions and offices.

Environment, safety, and health support focuses on helping the division meet the multitude of environmental, safety, and health requirements that are intended to ensure that work is conducted in a manner that is safe for staff and the environment. This group helps the division decipher requirements relating to these concerns such as safety reviews and documentation, waste-related activities, training, and radiation protection.

Finance support is provided under the coordination of a Finance and Materials Division staff member. Assistance is provided in tracking budgets and meeting reporting requirements, in establishing subcontracts, and in estimating costs for work proposals.

Information support comes in the form of editing, graphics, library, and publications activities. The publications activities include assistance with publication clearance forms, division statistics, and the production of division-level reports and other information. It also includes support for special projects as they arise.

Operations support includes computer networking support, as well as support from Plant and Equipment Division, Instrumentation and Controls Division, and Analytical Services Division. These activities include scheduling work priority for other-division staff and ensuring that the division receives the best possible research and maintenance support possible. Computing support provides a network backbone for the division and fulfills administrative requirements such as inventories and security-related concerns.

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DOE Program Activities 2

Biofuels Feedstock Development Program

Introduction

The Biofuels Feedstock Development Program (BFDP) in the Environmental Sciences Division (ESD) at Oak Ridge National Laboratory (ORNL) manages a national program of research on biomass production for the U.S. Department of Energy (DOE). In the past it has included two programs, the Short Rotation Woody Crops Program and the Herbaceous Energy Crops Program. Both are now managed as a single national program.

BFDP's major sponsor is the Biofuels System Division in DOE's Office of Transportation Technologies. In 1991 the U.S. Environmental Protection Agency provided additional support for assessment of biomass energy technologies and the economics of energy crop productions.

The objective of BFDP is the development of cost-effective production systems for dedicated energy crops. The DOE Biofuel Systems Division emphasizes technologies for producing liquid transportation fuels from lignocellulosic biomass. To complement that research, BFDP is developing wood and grass species, primarily, whose total aboveground biomass becomes an energy feedstock. BFDP's crop development research is closely coordinated with research at the National Renewable Energy Laboratory and involves the development of the technologies for converting wood and grass biomass to transportation fuels. BFDP also participates in International Energy Agency (IEA) activities related to woody and herbaceous biomass production.

Research and analysis for BFDP are performed within ESD, in other ORNL divisions, and at cooperating institutions. In FY 1991 the program supported 2 research projects at ORNL, 15 projects at universities, 4 at U.S. Department of Agriculture research stations, 1 at another national laboratory, and 1 at a private company. Major efforts included genetic improvement research for woody and herbaceous species; related studies on physiology, nutrient cycling, silviculture, and agronomics; environmental research and analysis; and economic analysis. The genetic improvement, silvicultural, agronomic, and physiologic studies were performed primarily at cooperating institutions, supported by subcontracts and interagency agreements. Supporting studies, including nutrient cycling research and stress physiology, were performed in ESD. Division or ORNL staff also primarily performed resource and environmental assessment, studies on CO_2 cycling in biomass-based energy systems, and economic analysis.

In FY 1991, BFDP had four major research components: Model Wood Energy Species, Model Herbaceous Energy Species, Environmental Research and Analysis, and Economic Analysis and Integration. Other program efforts included IEA activities, Data and Information Handling, and Fuel Cycle Analysis. The current status of each of these areas is described briefly in the following sections.

Model Wood Energy Species

The goal of the Model Wood Energy Species component is to develop wood

energy crops for U.S. regions where land availability and climate are favorable for the establishment of biomass-based energy systems. Model species have been selected on the basis of their potential to be highly productive on a broad range of sites under environmentally sound management practices.

The primary area of research in this component is the improvement of *Populus* species and hybrids. *Populus* research subcontracts have been strategically placed within the United States on the basis of the natural range for each species and of potential productivity levels within the region. Activities currently include regional interactive *Populus* breeding programs in the north central and Pacific Northwest regions. In the north central region, efforts are continuing on the development of early selection procedures for resistance to *Septoria* canker and cottonwood leaf beetle. In the Pacific Northwest region, first-year efforts on the development of a *Populus* molecular map have been completed. In other regions, an initial version of a *Populus* growth model (ECOPHYS) has been validated. First-year field testing of herbicide-tolerant poplars has been completed. In addition, a final report on the evaluation of the "woodgrass" culture system has been completed; the report concludes that wider spacings favor cumulative biomass yields over time over that achievable under woodgrass systems.

Other model species include silver maple, sycamore, and black locust. Using material propagated in a tissue culture, a study of silver maple seed sources was established at two locations in southern Illinois. Three additional locations are scheduled for establishment in 1992. Research has continued on developing effective clonal propagation techniques, improving rooting success, and improving breeding and genetic selection techniques for sycamore. Staff continued research on black locust, particularly in connection with improvements in productivity, nitrogen fixation, and pest resistance. Genetic transformation techniques have also been investigated for black locust.

Model Herbaceous Energy Species

The goal of the Model Herbaceous Energy Species component is to develop herbaceous energy crops that are attractive to both growers and processors. In 1991, new research studies were designed for switchgrass (*Panicum virgatum*). The new work will consist of genetic selection of new and improved varieties suitable for sustained and extensive biofuels production, development of physiological indicators to be used in breeding and evaluation strategies, development of tissue culture techniques for rapid propagation of varieties, and documentation of cultural and genetically based improvement of yield level and stability for existing and newly developed varieties under representative field conditions. The regional focus of this new switchgrass research will be the southeastern and south central United States, where switchgrass yield potential appears quite high. Projects will be selected through a competitive solicitation scheduled for release in November 1992.

A study on biomass production by fescue and switchgrass alone and in mixed swards with legumes will be completed in 1992. Iowa State University and North Dakota State University will continue research in the north central United States on screening and selection of herbaceous energy crops. Studies on the effects that storage has on switchgrass composition and on the development of winter rapeseed varieties for double-cropping in the Southeast were completed in 1991. Auburn University will complete two studies in 1992—one on the variability for

biomass and plant composition in sericea lespedeza germ plasm and one evaluating the biomass potential of switchgrass, napiergrass, and energy cane.

Environmental Research and Analysis

Dwindling clean coal supplies, the requirements of the Clean Air Act, and concern over greenhouse gas emissions have drastically increased the need for quantifying the environmental implications of lignocellulosic energy crops. If millions of acres are converted from agriculture to energy crops, habitat changes and chemical emissions will also be of significant national concern.

In response to these needs, BFDP has greatly expanded its efforts in environmental evaluations. These activities have three major emphases. The first involves land-use analyses in connection with geographic information system (GIS) resource data and economic modeling to determine specific resources that would most likely be affected by energy crop deployment. These assessments can help researchers evaluate the degree to which policy affects land use, environment, agriculture, energy, forestry, and energy crops. Evaluations of this kind are being completed for six locations in the United States.

The second major emphasis involves the quantification of environmental effects from energy crops on the basis of existing literature, various agricultural analogies, and theories on such topics as chemical transport and fate, habitat qualities and biodiversity, and carbon cycling. These efforts are enabling researchers to set clearer priorities related to the third major environmental emphasis.

The third emphasis is on the collection of new data from energy crops, their analogues, and control environments. Studies have already examined a number of related aspects, including small mammals, carbon, soil bacteria, and nitrogen cycling. Further evaluations will focus on avian populations, erosion, chemical fates, and gas exchange. The entire environmental effort incorporates the interests and capabilities of a complex network of research groups including the U.S. Department of Agriculture (USDA), the USDA Forest Service, other national laboratories, conservation groups, utilities, and academic institutions.

Economic Analysis and Integration

The goal of the Economic Analysis and Integration component is to ensure that all linkages affecting the overall viability of biomass-based fuel cycles are understood and considered in program research and planning. This component includes the translation of research results into projections of estimated biomass production costs. Because low production costs alone will not ensure the economic viability of energy crops, this component also includes investigations of the economic consequences of energy crops, both for the producing farmer and for the agricultural sector as a whole. This year the program began a modeling effort to incorporate farm-level constraints into a national farm sector model.

Economic Analysis and Integration staff are also responsible for coordinating the input on biomass production systems needed in DOE and National Renewable Energy Laboratory planning and analysis efforts.

International Energy Agency Activities

IEA biofuels activities are designed primarily for information exchange among participating countries. BFDP gives technical support to DOE for IEA tasks on energy crop production. In 1991 the United States participated in eight such tasks—Energy Forestry Production Systems, Energy Forestry Ecophysiology, Dedicated Agricultural/Herbaceous Crop Systems, Pest/Disease Management,Wood Feedstock Qualities, Tree Ideotypes, Exchange of Genetic Materials, and Joint Trials. Activities included the direct involvement of ESD staff and BFDP subcontractors in cooperative evaluations and joint efforts to summarize and synthesize research results.

Total Energy Cycle Analysis

Participation in an effort to analyze the total energy cycle was an additional task taken on by BFDP in response to a request from the office of Michael Davis, Assistant Secretary for Conservation and Renewables. ORNL's role was to analyze total emissions from the production, harvest, storage, and delivery of energy crops. This analysis was performed in concert with the National Renewable Energy Laboratory and Pacific Northwest Laboratories, who addressed conversion and system integration issues, respectively.

The participants jointly decided to tackle the problem by looking at site-specific land use and environmental effects at five sites located in five different regions of the United States: Peoria, Illinois (Midwest); Lincoln, Nebraska (Great Plains); Tifton, Georgia (Southeast); Rochester, New York (Northeast); and Portland, Oregon (Pacific Northwest). The National Resources Inventory data base was used to develop information on the characteristics and uses of the land and on the erosion potential for each site. On the basis of research experience of BFDP, staff developed plausible scenarios for energy crop types, management strategies, and potential yields. From these scenarios, they made estimates of biomass production, land-use changes, chemical use, and fuel use. Literature reviews and personal contact with various experts were used in estimating air and water emissions.

This type of site-specific analysis of land distribution and use provided insights into energy crop requirements and transportation requirements. For instance, staff originally assumed that 100% of the feed-stock in the Northeast would be trees. However, analysis of the land base together with knowledge of expected yields on different land classes suggested that incorporation of perennial grasses into the feedstock mixture would be required to minimize the distance that crops are hauled. In regions with a narrow corridor of suitable land such as the Pacific Northwest, haul distances as great as 210 miles would be required to supply a single 2000-ton/d ethanol conversion facility.

Literature on biogenic hydrocarbon emissions was of particular interest. ESD's Paul Hansen conducted a review of the literature. The data were very incomplete, but they indicated that hardwood species emit isoprenes, some at relatively high levels in comparison to average background forest levels. Sorghum was the only herbaceous crop for which information was available, and it appears to be a monoterpene emitter along with pines and sweetgum. To understand the implications of the average chemical emissions from energy crops, it will be necessary to compare the emissions from

energy crops with those expected from other agricultural options in the year 2010. These comparisons should be included in a future follow-up effort.

Data and Information Handling

The goal of the Data and Information Handling component is to coordinate, collect, organize, and disseminate information to a wider audience in order to promote the acceptance of the concept and feasibility of energy crops. The demand for information has increased with the emergence of concerns about climate change, greenhouse gases, and USDA set-aside policies.

A technical data base containing the results of the short-rotation woody crops research is available; a similar data base is under development for the herbaceous energy crops. In addition, ORNL staff have developed bibliographic data bases for programmatic-sponsored publications and presentations, related materials, and conversion of woody and herbaceous crops to biofuels. Data management activities included the addition of recently collected data to the technical data base and new materials to the bibliographic data bases. The data bases are used to develop reports and sythesize data and are made available to the public upon request.

To identify a target audience for information dissemination activities, the Data and Information Handling staff developed a computerized inventory containing the names of more than 1200 federal, state, and municipal government contacts; regional program managers and staff; research scientists at universities; extension agents; energy crop researchers in academia; members of Congress; representatives of private industry and trade associations. In addition, the first issue of *Energy Crops Forum*, a newsletter devoted to fostering communications among members of the worldwide research community, policy makers, entrepreneurs, and landowners went to press. The newsletter contained articles about energy crop research, operational experiences with similar crops, environmental concerns, and policy issues, most of which highlighted BFDP activities. Future issues will also feature relevant research and commercial ventures not connected with the program.

Technical Summaries

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A Large Land Base Is Suitable for Biomass Energy Crop Production in the United States

R. L. Graham

A two-phase approach is taken in researching the potential of biomass energy crops in the United States. The first phase examines the issues from a national perspective and attempts to define at a national scale the acreage and location of land that could grow biomass energy crops and the expected yields. The second phase addresses the economic, social, and environmental constraints to biomass energy crop development through the use of site-specific case studies of potential biomass energy production facilities and the feedstock demands of those facilities.

The first phase is almost completed. The U.S. Department of Agriculture's 1982 National Resource Inventory (NRI) data base was used to characterize the potential land base for biomass energy crops. This data base contains ~800,000 geographically specific point observations about current land use and agricultural capability on nonfederal lands in the United States. Each of these observations has an extension factor that allows calculation of the acreage of land associated with an observation. The sum of all point acreages is the total area of nonfederal land in the United States. Leading researchers in biomass energy crop production were queried so that an empirical model (look-up table) could be developed to predict potential biomass energy crop yield on the basis of site attributes found in the NRI. With the use of this model, the NRI was queried to determine the acreage, potential biomass yield, and location of land suitable for biomass energy crops.

In the coterminous United States 392 million acres are capable of growing biomass energy crops. Of this total 78% is currently used for growing crops, and 13% is used as pasture. The remaining 9% comes from a variety of other land uses. Short-rotation woody crops (SRWC) with expected annual yields of 5 or more tons dry standing woody biomass per acre could be grown on 225 million of these acres by using current best-management practices. Herbaceous energy crops (HEC) with similar expected yields could be grown on 324 million acres. Most of the suitable land for growing SRWC lies in the north central region of the United States (Illinois, Indiana, Iowa, Kansas, Michigan, Minnesota, Missouri, Nebraska, North Dakota, South Dakota, and Wisconsin). In this region 817 million tons of dry woody biomass could be produced annually on 128 million acres. This region is also the most likely location for HEC production, with 167 million suitable acres potentially yielding 1338 million dry tons of herbaceous biomass per year. The south central region (Alabama, Arkansas, Louisiana, Mississippi, Oklahoma, Tennessee, and Texas) contains the second-largest amount of acreage suitable for woody and herbaceous energy crops.

Land that has severe restrictions for growing conventional annual crops but is suitable for energy crops may be the most likely land for conversion to energy crops. There are 37 million acres of such land suitable for SRWC and 134 million acres for HEC. If planted to energy crops, these acreages could yield 229 million tons of dry woody biomass or 767 million tons of herbaceous biomass each year. If current biomass energy conversion technologies

were employed, this amount of woody biomass could annually produce ~15 billion gal of ethanol (10% of current U.S. gasoline consumption) or 296 million MWh of electricity (11% of current U.S. electric power consumption). This amount of herbaceous biomass could annually produce ~45 billion gal of ethanol or 630 million MWh.

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Environmental Policy and Effects of Biofuel Feedstock Production Are Considered

J. W. Ranney

Because the production of biomass for energy may involve tens of millions of acres, environmental information is needed on the changes and conditions generated by this new land use. Practically no information is available, although major environmental improvements have been credited to energy crops. Significant efforts have been taken to identify important environmental issues, scope preliminary data, and plan an environmental monitoring program on biomass energy crops for FY 1992. The public and environmental groups often confuse forest-cutting issues with those of energy crop production on agricultural land and the use of biomass wastes and residues. These biomass sources have quite distinct issues.

The major issues fall into two groups: those concerning environmental effects and those concerning environmental policy. The environmental-effects issues involve greenhouse gas exchange, biodiversity, sustainability, and air quality. More specifically they involve CO_2; habitat quality, especially for bottomland and wetlands; measures of species composition; the use and fate of chemicals; erosion; general landscape changes; and full-cycle (biomass production, conversion, and use) biofuel emissions for ethanol and electricity, especially compared with emissions from reformulated gasoline and coal (e.g., CO_2, CO, nitrogen oxides, sulfur oxides, CH_4, and volatile organic compounds).

Environmental groups are interested in influencing policies to correct past forestry and agricultural concerns. Forest clearcutting, riparian zone and wetland protection, wilderness expansion, chemical controls, general wildlife habitat improvement, and erosion control are some of the issues. Congressional and administrative interests involve specific full-cycle gas balances of biofuels compared with fossil fuel and agricultural policy on the use of set-aside or conservation land. Credits, payments, regulations, and monitoring requirements, which will affect both the environmental effects and competitiveness of energy crops, are under consideration.

The first energy crop environmental data are favorable with respect to habitat improvement and gas emissions and mixed on erosion and chemical use. Habitats most vulnerable to possible negative effects of energy crops are still being defined but are believed to be privately owned bottomlands and wetlands. Environmental monitoring plans call for several workshops, coordination with the Environmental Protection Agency and environmental groups, and the use of many existing experimental and scale-up sites around the country to develop a network for environmental data collection.

A harvester cuts down 8-year-old hybrid poplars planted by the James River Corporation in the Columbia River Valley in Oregon. ESD's Biofuels Feedstock Development Program funded the research that developed the fast-growing clones used in this commercial operation.

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Biomass Energy Strategies for CO_2 Mitigation in the United States Are Being Assessed

L. L. Wright

The U.S. Environmental Protection Agency (EPA) Office of Policy Analysis has requested background information and preliminary strategy options for using biomass energy technologies to reduce CO_2 emissions in the United States.

In response to the request, background information papers are being prepared on six topics: (1) status of production technology concerning herbaceous and wood energy crops; (2) regional analysis of land suitability for biomass energy crops in the United States; (3) regional analysis of land availability as determined by consideration of economic constraints; (4) status of conversion technologies suitable for use of biomass energy crops; (5) summary of potential environmental issues associated with production of woody and herbaceous energy crops; and (6) summary of available information on current and projected energy use, needs,

and costs for several regions of the United States. These topics will be integrated in a summary paper outlining national research and policy options for increasing the use of biomass energy. Additionally, a workshop was planned as a means of gathering information and recommendations from a cross section of groups in government and the private sector.

The first drafts of all the papers (except the summary chapter) are finished and are being technically reviewed. The goal is to produce papers for publication in the open literature. The workshop was conducted in early November 1990. The 40 attendees included representatives from ORNL, EPA, DOE, the U.S. Department of Agriculture, the Solar Energy Research Institute, the Tennessee Valley Authority, the Audubon Society, paper products industries, power companies, universities, and small businesses. The Biofuels Feedstock Development Program staff presented the initial session, which provided an overview of technological and environmental considerations in regard to energy crop production. Working groups drew up lists of constraints and solutions associated with commercializing energy crop production and with generating electricity and producing liquid fuels from biomass. General group discussions provided recommendations on priorities for research and development (R&D) and policy changes required to stimulate commercialization of biomass energy in the United States. There was a general consensus that demonstrations were needed to assure the private sector of the feasibility of biomass energy technologies. Other recommendations included (1) the continuation of R&D concerning production and conversion technologies, (2) the application of siting studies to characterize infrastructure requirements and potential environmental impacts, (3) the use of economic and risk assessments, and (4) the implementation of more aggressive technology transfer involving the feasibility and benefits of biomass technologies.

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ORNL Center Activities 3

Center for Global Environmental Studies

Introduction

Many of the decisions that will determine our direction in the next millennium hinge on issues that are complex, interwoven and global in scale: greenhouse gases, climate change, ozone breakdown, deforestation and desertification, resource depletion, and the spread of pollution. These and other global environmental issues must now be explored far more seriously—far more comprehensively—than ever before.

The Center for Global Environmental Studies, established at Oak Ridge National Laboratory (ORNL) in 1989, provides a unique interdisciplinary base for such explorations. The center has three main goals:

1. improving the understanding of the global-scale workings of environments in air, on land, and in water;

2. developing capabilities to anticipate the long-term, large-scale effects that human actions have on the biosphere; and

3. identifying appropriate options for technological and societal responses.

Like the U.S. Global Research Program—the crosscutting national initiative to which the ORNL Center corresponds—the Center for Global Environmental Studies takes a new view of the kinds of research needed in this formidable but exciting field. The center's work is based on several assumptions that set it apart from the Laboratory's traditional approach to research and analyses. Those assumptions follow.

- The scope of the processes and problems we are exploring is far greater—both in scale and in time—than traditional research projects are equipped to deal with.

Problems such as ozone depletion, the greenhouse effect, and global change are no respecters of national borders; they affect the entire planetary commons. Our understandings and responses, therefore, must be equally broad. Similarly, processes such as climate change and dwindling biodiversity may become clearly evident only when viewed over decades or even centuries. We must therefore envision and develop programs that can serve as foundations on which to build for many years.

- Collaboration—both among traditionally competitive institutions and across disciplinary boundary lines—is absolutely essential for any meaningful understandings to emerge.

The globe's environment responds to the interactions of many different systems, factors, and processes: air circulation, ocean currents, land-use changes, economic incentives for development (or its converse), the migrations of smokestack industries, national energy practices and policies, and even political turmoil. Narrow, discipline-bound approaches can give us only detailed analyses of individual aspects of the biosphere—individual trees, so to speak—when what we need now is an overarching view of the global environmental forest.

- Policy--economically and politically practical policy—must be one of the prime drivers of global environmental research.

We must consider not only what is happening in (and to) the biosphere—not merely what should, ideally, be done about it—but also what can be done, given the economic, technological, and political constraints within which actions must be taken.

These, then, are the principles that guide the center's organization and work: a large-scale, long-term view; a commitment to collaboration, both among institutions and among disciplines; and a continual eye to realistic policy.

Areas of Focus

In keeping with the center's large-scale view, the central and unifying framework for our work is global systems analysis: developing increasingly sophisticated models that reflect the dynamic interactions of numerous subsystems—global vegetation; human cultures and behaviors; and earth systems such as atmospheric chemistry, ocean composition and circulation, and the links between air, land, and sea. Our long-term goal is to develop models that reflect the interplay of demographics, land-use patterns, economics, ecological relationships, and other factors that influence the globe's environment.

Complementing our central focus on global systems are four areas of more specific concentration.

1. Measurement science and instrumentation: better monitoring of the state of the environment and its changes. ORNL has a long history of excellence in instrumentation in high-energy physics, health physics, pollution monitoring, nuclear reactor technology, and nuclear and chemical waste. We are now directing this expertise toward instrumentation for atmospheric, terrestrial, and aquatic research. Areas of strength that can immediately benefit the center include laser-based instrumentation, which we expect to play an increasingly vital role in global-change research; mass spectrometry and isotopic analysis; remote sensing and fiber optics, another key technology for climate studies; and automation, miniaturization, and portability. Logical applications of this expertise include laser-based devices to measure trace gases, temperature, and pressure; low-cost, air-droppable packages for reading atmospheric or ocean conditions; and instruments for studying cloud formation and properties in support of the U.S. Atmospheric Radiation Measurement (ARM) Program.

2. Data systems: the key to making sense of the global environment, now and for decades to come. The amount of data collected in the course of global environmental research is already staggering and will grow explosively as newer, more sophisticated instruments and monitoring projects emerge. For example, in a few years National Aeronautics and Space Administration's Earth Observing System will begin transmitting enough data to fill all the books in the Library of Congress every three weeks. In addition to handling massive quantities of data, information systems must present the data in a user-friendly form, one that will also ensure the usability of information over decades, since the import of some data may not become clear for many years.

3. Large-scale environmental studies: projects that examine the environment from a longer perspective than traditional ecological research. Global-scale studies cannot be based on mere extrapolations of traditional detailed studies; many of the subtle ecological processes on which

traditional research thrives are less meaningful for these purposes than aggregate processes that are invisible at close range. The ORNL Center for Global Environmental Studies is developing tools and techniques for understanding how to scale up research to meet global needs.

4. Policy, energy, and human-systems analysis: the recognition that humankind is inextricably linked with the physical systems of the earth. In the past two centuries, our species has emerged as a primary—perhaps the primary—agent of global environmental change. Therefore, questions of human activity and policy, including the effects of technology, energy conversion, land use, population growth, and political and cultural patterns, must play a key role in global environmental studies. The Center for Global Environmental Studies is bringing together anthropologists, economists, political scientists, sociologists, planners, geographers, climatologists, and ecologists to examine the decision processes involved in global management of risks and resources. Building on extensive work already under way at ORNL and elsewhere, we are developing the theoretical underpinnings of a practical approach to the problems of decision-making involving many players and complex technical issues. Ultimately, this approach will produce a blend of theory and practice that erases the line which for so long has separated the "thinkers" from the "doers."

Summary

The range and depth of ORNL's scientific expertise uniquely qualify the Laboratory to take up the challenges of the Global Change Program. By establishing the Center for Global Environmental Studies, ORNL is drawing on its proven expertise and worldwide scientific connections, while also laying the foundation for expanded, focused research into the problems of global change.

The Center for Global Environmental Studies is dedicated to an earth system-centered, interdisciplinary approach to scientific research. It views human interaction with the environment, through population distribution, land use, technology, energy conversion, and other processes, as one of the driving forces of global environmental change. The center stands in a unique position to serve the needs of federal agencies and international efforts and to make a significant contribution to our understanding of the delicately balanced biosphere we call home.

Center Staff and Guests

M. P. Farrell

B. G. Eads[1]
W. R. Emanuel[2]
A. M. Hendricks[2]
P. Kanciruk[2]
S. Rayner[3]
M. G. Turner[4]

[1]*Instrumentation and Controls Division, ORNL.*
[2]*Earth Systems Section, ESD.*
[3]*Energy Division, ORNL.*
[4]*Environmental Analyses Section, ESD.*

ESD Award Highlights 4

ESD Scientific, Technical, and Administrative Achievement Awards

Scientific Achievement

The Environmental Sciences Division (ESD) presented Monica G. Turner the 1990 Scientific Achievement Award for her unique contributions to the problem of understanding and describing the relationships between disturbance, recovery, and landscape pattern, especially for her research on detecting and measuring the effects of ecological disturbance at large spatial scales.

Monica has engaged in a wide range of empirical and theoretical studies of disturbance effects and the processes of recovery, providing new insights into the formation of landscape patterns. The outstanding quality of her research and the exceptional level of her productivity, combined with her active leadership in national and international scientific societies, constitute key contributions to the development of landscape ecology as a new discipline.

Throughout her career, Monica has collaborated with a broad spectrum of scientists both within ESD and within the larger scientific community. Her colleagues have learned that her skill and enthusiasm for tackling new ideas and her understanding and patience in dealing with people make collaboration a most pleasant, rewarding, and productive experience. Her tenacious pursuit of excellence and her active and timely dissemination of research results through open-literature publications and collaborative exchange epitomize the standards of scientific achievement that the award represents.

Monica Turner

Technical Achievement

ESD presented Carla A. Gunderson the 1990 Distinguished Technical Achievement Award for her exemplary work as a technician on research projects in physiological ecology. In particular, she was recognized for her uncompromising commitment to accuracy in collecting and analyzing data as well as her thoroughness in publishing results. Carla has written articles on the effects that the plant hormone ethylene has on leaf gas-exchange processes, including photosynthesis. She currently works with Rich Norby on research into the responses of forest trees to increased levels of atmospheric CO_2.

Shirley Lawson

Carla Gunderson

Administrative Achievement

Shirley G. Lawson received ESD's 1990 Distinguished Administrative Achievement Award for her outstanding support to the Ecological Studies Section during the division's reorganization. Specifically, she was recognized for her dedication, cooperation, and extra effort in assuming the responsibilities of acting section secretary during a 9-month period of transition. Shirley also contributed far beyond the normal job requirements in completing research proposals and answering requests associated with the Oak Ridge National Environmental Research Park, which is managed by ESD staff.

Lists 5

Awards and Honors

The following ESD personnel received professional, corporate, or organizational awards during this reporting period.

ADAMS, S. M.
Fellow, American Institute of Fishery Research Biologists

ASHWOOD, T. L.
Significant Achievement Award for work with High School Honors Workshop, Martin Marietta Energy Systems, Inc.

BARNTHOUSE, L. W.
Author of the Year, Martin Marietta Energy Systems, Inc.; Technical Achievement Award, Martin Marietta Energy Systems, Inc.

BORDERS, D. M.
Registered Professional Engineer, Tennessee State Board of Architectural and Engineering Examiners

BURNS, T. P.
Robert C. Anderson Memorial Award, University of Georgia Research Foundation

BURTIS, M. D.
Award of Merit in Promotional Materials, Technical Publications Competition, East Tennessee Chapter of the Society for Technical Communication; Award of Merit for Whole Periodicals, East Tennessee Chapter of the Society for Technical Communication

CADA, G. F.
Appointment as a Fellow of the American Institute of Fishery Research Biologists

CHRISTENSEN, S. W.
Certificate of Appreciation, National Acid Precipitation Assessment Program

CUSHMAN, R. M.
Award of Merit for Whole Periodicals, East Tennessee Chapter of the Society for Technical Communication

DALE, V. H.
Technical Award, Martin Marietta Energy Systems, Inc.; Award of Excellence in Scholarly/Professional Articles, Technical Publications Competition, Society for Technical Communication; Award of Excellence for Scholarly/Professional Articles, Technical Publications Competition, East Tennessee Chapter of the Society for Technical Communication

DEANGELIS, D. L.
Technical Award, Martin Marietta Energy Systems, Inc.; Award of Excellence in Scholarly/Professional Articles, Technical Publications Competition, Society for Technical Communication; Award of Excellence for Scholarly/Professional Articles, Technical Publications Competition, East Tennessee Chapter of the Society for Technical Communication

EDWARDS, N. T.
Award of Excellence in Mechanical Illustrations, Black and White, Technical Art Competition, East Tennessee Chapter of the Society for Technical Communication; Award of Achievement, International Technical Art Competition, Society for Technical Communication

EMANUEL, W. R.
Technical Award, Martin Marietta Energy Systems, Inc.; Award of Excellence in Scholarly/Professional Articles, Technical Publications Competition, Society for Technical Communication; Award of Excellence for Scholarly/Professional Articles, Technical Publications Competition, East Tennessee Chapter of the Society for Technical Communication

GUNDERSON, C. A.
Distinguished Technical Achievement Award, Environmental Sciences Division, Oak Ridge National Laboratory

HATCHER, R. D., JR.
Nomination, Vice President and President-Elect, Geological Society of America; appointment to Board on Radioactive Waste Management, National Research Council

HOFFMAN, F. O., JR.
Appointment to the Advisory Panel Assessing Possible Health Risks at the Rocky Flats Plant, Colorado Department of Health

HUNSAKER, C. T.
Appointment as a consultant to the EPA Science Advisory Board

JOSLIN, J. D., JR.
Outstanding Paper presented in Division S-7 of the Annual Meeting of the Soil Science Society of America

KANCIRUK, P.
S16 Achievement Award, Martin Marietta Energy Systems, Inc.

KIMMEL, B. L.
Appointment to Scientific Review Panel, National Science Foundation Experimental Program to Stimulate Competitive Research

KING, A. W.
Technical Award, Martin Marietta Energy Systems, Inc.; Award of Excellence in Scholarly/Professional Articles, Technical Publications Competition, Society for Technical Communication; Award of Excellence for Scholarly/Professional Articles, Technical Publications Competition, East Tennessee Chapter of the Society for Technical Communication

LAWSON, S. G.
Distinguished Administrative Achievement Award, Environmental Sciences Division, Oak Ridge National Laboratory

LEMISZKI, P. J.
C. H. Gordon Award for Exceptional Professional Promise, Department of Geological Sciences, The University of Tennessee

LINDBERG, S. E.
Nomination for the DOE E. O. Lawrence Award

MCLAUGHLIN, S. B., JR.
Submittal for the Marcus Wallenberg Prize, The Marcus Wallenberg Foundation

MULHOLLAND, P. J.
Appointment as an Associate Editor of *Ecology* and *Ecological Monographs*

OLSON, R. J.
Member of the President's Council on Environmental Quality

O'NEILL, E. G.
Science Alliance Graduate Upgrade Award, The University of Tennessee

OWENS, J. G.
Five-Year Service Award for Site Operation, National Atmospheric Deposition Program

PARR, P. D.
Award of Excellence in Interpretive Illustrations, Black and White Line Art, International Arts Competition, Society for Technical Communication

PENG, T.-H.
Technical Award, Martin Marietta Energy Systems, Inc.; Award of Excellence in Scholarly/Professional Articles, Technical Publications Competition, Society for

Technical Communication; Award of Excellence for Scholarly/Professional Articles, Technical Publications Competition, East Tennessee Chapter of the Society for Technical Communication

POST, W. M., IV
Technical Award, Martin Marietta Energy Systems, Inc.; Award of Excellence in Scholarly/Professional Articles, Technical Publications Competition, Society for Technical Communication; Award of Excellence for Scholarly/Professional Articles, Technical Publications Competition, East Tennessee Chapter of the Society for Technical Communication

RAILSBACK, S.
Antarctica Service Medal, National Science Foundation and U.S. Navy

RANNEY, J. W.
Special Event Award, Martin Marietta Energy Systems, Inc.

REYES, O. M.
Wigner Fellowship, Oak Ridge National Laboratory

ROSE, K.
Special Achievement Award, Environmental Sciences Division, Oak Ridge National Laboratory

ROSEN, A.
Author of the Year, Martin Marietta Energy Systems, Inc.; Technical Achievement Award, Martin Marietta Energy Systems, Inc.

SHRINER, D. S.
Award for Outstanding Contribution to the National Acid Precipitation Assessment Program

SHUGART, L. R.
Appointed as a consultant to the U.S. EPA Science Advisory Board, Washington, D.C.; grant to organize advanced research workshop, NATO; editor of new journal *Ecotoxicology*

SPALDING, B. P.
Award of Excellence in Interpretive Illustration, Black and White Tone Art, East Tennessee Chapter of the Society for Technical Communication

STOW, S. H.
Appointment as Chairman of the Commission on the Hydrogeology of Hazardous Waste (1991-1992), International Association of Hydrogeologists

SUTER, G. W.
Author of the Year, Martin Marietta Energy Systems, Inc.; Technical Achievement Award, Martin Marietta Energy Systems, Inc.

TURNER, M. G.
Annual Scientific Achievement Award, Environmental Sciences Division, Oak Ridge National Laboratory; Award for Distinguished Scientific Achievement, Tennessee Chapter of the Association for Women in Science; appointment to Directorate for Temperate Ecosystems, U.S. Man and the Biosphere program; appointment as editorial advisor, *Climate Research*, Inter-Research Science Publishers

TURNER, R. S.
Award for Outstanding Contribution to the National Acid Precipitation Assessment Program Integrated Assessment; Commendation for Outstanding Lead Author of NAPAP SOS #10, National Acid Precipitation Assessment Program; Technical Contribution Award, EPA, Corvallis Environmental Research Laboratory; Significant Event Award, Oak Ridge National Laboratory

TURNER, R. R.
Professional Geologist License, State of Florida Board of Professional Regulation

VAN HOOK, R. I.
1991 Director's Award, Oak Ridge National Laboratory; Division of the Year Award, Oak Ridge National Laboratory

VAN WINKLE, W.
Appointment to Scientific Advisory Committee, Coastal Fisheries Ecosystems Program, Coastal Ocean Program, National Oceanic and Atmospheric Administration

VON DAMM, K. L.
Appointment to Alvin Review Committee, University-National Oceanographic Laboratory System (1991-1994)

WALTON, B. T.
Recertification as a Diplomate, 1991-1996, American Board of Toxicology

WATTS, J. A.
Distinguished Service Award, Tennessee Chapter of the Association for Women in Science; East Community Service Award for WATTec Activities, Volunteer Chapter of the Public Relations Society of America

WULLSCHLEGER, S. D.
Alexander Hollaender Postdoctoral Fellowship, DOE and Oak Ridge Associated Universities

Significant Accomplishments

During FY 1991 ESD reported numerous technical accomplishments, the most significant of which are listed here.

- ESD staff performed a second-phase screening-level assessment of radionuclide contamination in White Oak Creek Embayment. This assessment confirmed the need for immediate remedial action, as identified in the report ORNL-ER/9.

- ESD staff completed the training program in environmental laws and regulations begun early in FY 1990 for the Assistant Secretary for Environment, Safety and Health. As a result of the training program, the DOE Inspector General concluded, "DOE and contractor management have an improved awareness of their responsibilities and potential liabilities."

- Enhancing plant productivity through iron fertilization in the Antarctic has been suggested as a means of increasing oceanic CO_2 uptake, thereby lowering atmospheric concentrations. Model results indicate that a significant increase in CO_2 uptake through iron fertilization of Antarctic oceans is not possible because ocean mixing, not iron, is the limiting factor regulating ocean CO_2 uptake.

- ESD staff, using ^{15}N:^{14}N ratios, examined differences in the stable isotope composition of ammonium (NH_4-N) and nitrate (NO_3-N) in bulk precipitation and throughfall at Walker Branch Watershed. Results indicate the potential importance of atmospheric NH_4-N inputs to nitrogen cycling in the N-deficient forest.

- ESD led an effort to develop for DOE Headquarters the Basic R&D Plan in Support of Environmental Restoration, based on contributions from over 100 scientists at all national laboratories and many universities. The plan describes the fundamental scientific challenges that must be faced for the environmental restoration of DOE facilities.

- The ORNL Carbon Dioxide Information Analysis Center is compiling temperature and precipitation records for the U.S.S.R. as the initial stage in developing a global data base that will be used to verify the predictions of general circulation models.

- A symposium that was organized by COMPMECH staff and entitled "Individual-Based Approach to Fish Population Dynamics: Theory, Process Studies, and Modeling Approaches" was held as part of the annual meeting of the American Fisheries Society.

- Methods for analysis of mercury in rain have been developed by ESD staff for use in a U.S. Geological Survey (USGS) network for collection of trace metals in precipitation. These methods have been used to analyze several samples collected by USGS personnel.

- ESD staff completed measurements of the 298 permanent biomass inventory plots (10,000 individual tree observations) on Walker Branch Watershed. This is the seventh measurement of these plots since 1967.

- A major review of the dry deposition of reactive nitrogen compounds to

landscape surfaces (foliage, bark, forest floor surfaces) was published by ESD staff in *Atmospheric Environment* 25A:1615–34.

- At the request of the U.S. Environmental Protection Agency, ORNL is representing the United States as cochair of an international task force studying the application of the principles of environmental impact assessment to government policies, plans, and programs. The draft report, prepared by ORNL, was submitted to task force members on July 15, 1991. The report will be finalized at the March 1992 meeting of the task force in Geneva, Switzerland.

- ESD's Environmental Compliance Group continued to provide the DOE Office of Environmental Guidance with extensive support in tracking and analyzing new regulations, formulating draft guidance for DOE program and field offices, and conducting environmental laws and regulations training courses.

- An in situ vitrification demonstration at ORNL was successfully carried out by ESD staff in cooperation with Pacific Northwest Laboratories staff, with joint funding from the DOE Office of Technology Development and the DOE Office of Basic Energy Sciences. This was the first test using radioactive material.

- Energy Systems' Office of Groundwater Management was set up at ORNL to oversee groundwater issues at the five plants managed by the company. This office directs the activities of the five groundwater coordinators and the Oak Ridge Hydrology Support Program.

- The ORNL Carbon Dioxide Information Analysis Center reported that global total CO_2 emissions for 1989 reached the largest annual emissions ever (5.954×10^6 metric tons of carbon). U.S. emissions grew by 1.14%, down from the 4.78% growth seen in 1988; this marks the third consecutive year the nation's growth rate was higher than the global average growth rate. By contrast, emissions from Western Europe are still 12% below the 1979 maximum and are virtually unchanged since 1982.

International Activities

ESD staff have developed a sound base of international activities and work with a variety of foreign governments and research organizations. Following is a list of the FY 1991 activities.

- Selection of field sites in the former Soviet Union for evaluation of extent of mercury vapor in the atmosphere, under the auspices of the U.S.-U.S.S.R. Bilateral Agreement on Environmental Protection, which is coordinated through the EPA Office of International Activities (S. E. Lindberg)

- Air-surface exchange studies of mercury at the Swedish Environmental Restoration Institute, sponsored by EPRI (S. E. Lindberg)

- Chairmanship of International Commission on Hydrogeology of Hazardous Waste, meeting in Hannover, Germany. Representatives from Holland, Czechoslovakia, Germany, Poland, Canada, and Israel attended (S. H. Stow)

- Organization and direction of NATO Advanced Research Workshop on "Strategy for Biomarker Research and Application in the Assessment of Environmental Health" at The Netherlands Institute of Sea Research, sponsored by NATO, EPA, Proctor and Gamble, and Greenpeace International (L. Shugart, J. F. McCarthy, R. S. Holbrook, and G. W. Suter)

- Participation in North Sea cruise to assess pollution on environmental marine life in Dutch coastal waters, sponsored by The Netherlands Council of Oceanic Research (L. Shugart)

- Bioremediation demonstration for in situ cleanup of diesel fuel contaminate soil on Kwajalein Atoll, Marshall Islands, sponsored by the U.S. Army (R. L. Siegrist)

- In situ destruction of volatile organic compounds, sponsored by the DOE International Technology Exchange Program in collaboration with the University of Karlsruhe, Germany (R. L. Siegrist)

- Investigation and assessment of seashore buried waste deposits, Norway, sponsored by the Norwegian Centre for Soil and Environmental Research (R. L. Siegrist)

- Membership in the Planning Committee for Global Analysis, Interpretation and Modeling, for the International Geosphere-Biosphere Programme of the International Council of Scientific Unions (W. R. Emanuel)

- Studies on the responses of yellow poplar leaves to CO_2, light, and nitrogen in collaboration with a researcher from Estonia, sponsored by DOE OHER Carbon Dioxide Research Program (R. Norby)

- Project development visit to the Institute of Agrobiology at the University of Poznan, Poland, sponsored by the National Research Council. The purpose was to evaluate the potential for collaborative research on the transport of heavy metals across landscapes (R. L. Graham)

- Participation in joint research planning for long-term forest health monitoring in Poland, sponsored by the U.S. Forest Service, EPA, and Polish Academy of Sciences (H. Van Miegroet, S. E. Lindberg, and D. S. Shriner)

- Participation in research planning and design for joint U.S.-Estonian Academy of Sciences/Russian Academy of Sciences study on long-term forest health monitoring (L. L. Sigal and D. S. Shriner)

- Symposium on "Natural Resources Economics," hosted by ESD and sponsored by Partners in Education and the U. S. Agency for International Development, September 12–14. Eleven Brazilian scientists as well as ORNL staff attended (V. H. Dale, host)

- Development of a simulation model of colonization and land-use change as applied to a particular problem, deforestation in Rondônia, Brazil, that has major global environmental impacts, sponsored by the ORNL Director's Research and Development Fund (ESD and Energy Division staff, V. H. Dale, principal investigator)

- Work sponsored by the ORNL Director's Research and Development Fund and conducted by Brazilian scientist Marcos Pedlowski and ESD staff to obtain data on the land-use practices of colonists in Rondônia, Brazil, and their social and ecologic consequences. The data are used to test ideas being developed at ORNL about the interactions between socioeconomic and ecologic aspects of land-use change

- Studies initiated to combine economic and ecological principles in a set of models that determine the spatial allocation of agricultural activity. The theory is being developed for application to land-use practices under various national and international trade conditions (ESD and Energy Division staff)

- Participation in DOE cooperative research agreement with the Commission of the European Communities on the validation of radioecological food-chain models and in the International Biospheric Model Validation Study (BIOMOVS) (B. G. Blaylock)

- Participation in joint research planning and scientific exchange among the Institute of Energy Problems of Chemical Physics (INEPCP), the Institute of Oceanology of the Russian Academy of Sciences, DOE-ORO, and ORNL. Joint research is planned in the Bering and Chukchi seas to test for consequences of increased ultraviolet light on marine ecosystems (J. M. Grebmeier, L. W. Cooper, L. R. Shugart, and I. L. Larsen)

- Support to EPA as co-chair of an international task force to study the application of the principles of environmental impact assessment (EIA) to government plans, policies, and programs. Representatives of 15 European countries, the U.N. Economic Commission for Europe, and the Commission of Economic Communities participated in the task force (L. L. Sigal and J. W. Webb)

- Collaboration with the Institute of Atmospheric Physics, Beijing, China, (as part of the DOE and People's Republic of China Joint Research on the Greenhouse Effect) to compile *Two Long-Term Instrumental Climatic Data Bases of the People's Republic of China*, which contains monthly climate data. The records for some stations begin before 1900 (T. A. Boden)

- Collaboration with the Main Geophysical Observatory,

St. Petersburg, Russia, (under the auspices of the U.S.-U.S.S.R. Joint Committee on Cooperation in the Field of Environment Protection) to compile *Atmospheric CO_2 Concentrations Derived from Flask Samples Collected at U.S.S.R.-Operated Sampling Sites*, which presents daily atmospheric CO_2 concentrations at Teriberka Station, Ocean Station Charlie, Bering Island, and Kotelny Island (T. A. Boden)

- Cooperation with institutions in ten foreign countries (the former Soviet Union, Canada, Spain, France, Australia, Germany, Italy, Hungary, Switzerland, and the United Kingdom) to produce *Trends '91: A Compendium of Data on Global Change*, which presents information on emissions and atmospheric concentrations of important greenhouse gases as well as long-term climate data (T. A. Boden, R. J. Sepanski, and F. W. Stoss)

Research and Development Subcontracts and Interagency Agreements

O. J. Grooms

Presented here are the subcontractors with whom ESD had a subcontract or interagency agreement during this reporting period. The ESD researcher who served as technical contact is given in parentheses after the title of the project.

Advanced Sciences Group
Evaluation of chronic stress on the dynamics of fish populations in contaminated streams (S. M. Adams)

Assist in limnological and sedimentological studies (B. L. Kimmel)

Assist in characterization of natural organic matter in water and aquifer material from different geologic formations sampled in DOE Subsurface Microbiology Deep Probe Program (J. F. McCarthy)

Determine mobility of colloidal particles in groundwater and their effect on subsurface transport of other hazardous waste elements (J. F. McCarthy)

Provide biologist to assist with collection and processing of environmental samples (A. J. Stewart)

Amana Society, Inc.
Establishment and maintenance of silver maple monoculture viability trials (G. A. Tuskan)

Analysas Corporation
Technical support in geographic information and analysis of effects of acidic deposition on aquatic resources (C. T. Hunsaker)

Technical support in the Biomass Production Program (J. W. Ranney)

Arbor Day Institute
Conference support services for the National Fuelwood Conference held in Lincoln, Nebraska (G. A. Tuskan)

Arizona, University of
Analysis and modeling of hydrology and particle transport in support of a DOE project on field mobility of colloidal particles (J. F. McCarthy)

Auburn University
Research on selection of lignocellulosic species for energy crops (J. H. Cushman)

Examine variability for biomass production and plant composition in lespedeza sericea germplasm (J. H. Cushman)

Automated Sciences Group, Inc.
Provide services of a fishery biologist/limnologist to perform various field and laboratory duties related to biota, sediment, and water sampling studies on the Clinch River RCRA Facility Investigation (S. M. Adams)

Provide services of a quantitative fishery ecologist to be responsible for evaluating the importance of fish movement into and from contaminated areas and of fish trophic interactions on the bioaccumulation of contaminants in selected fish species (S. M. Adams)

Support to physiologist/endocrinologist in evaluating contaminant-related stress in aquatic systems (S. M. Adams)

Technical support of a physiological ecologist for analysis on effects of stress on aquatic organisms (S. M. Adams)

Technical support of a laboratory biochemist in assays and measurement of biological and sediment samples (S. M. Adams)

Geophysical mapping (T. O. Early)

Technical support on collection reduction and analysis of geophysical well-logging and cross- and down-hole studies related to the Hazardous Waste Remedial Actions Program (T. O. Early)

Ecological studies in environmental biomonitoring (M. G. Ryon)

Support in administration of large data bases used for research and assessment of regional environmental problems (D. S. Shriner)

Technical support to the Environmental Assessment Group in planning, organizing, and developing meetings, documents, and training materials (L. L. Sigal)

Technical support in the NPDES-mandated Biological Monitoring and Abatement programs at the Oak Ridge Y-12 Plant and ORNL (G. R. Southworth)

Battelle Pacific Northwest Laboratory

Support in the application of in situ vitrification at ORNL (G. K. Jacobs)

Review of data related to the ongoing fish kill at the Oak Ridge Y-12 Plant (J. M. Loar)

Workshop for preparation of long-term research plan in the area of environmental restoration requested by the Office of Energy Research (D. K. Solomon)

Brooks Rand, Ltd.

Chemical analysis of methylmercury water samples (R. R. Turner)

California, University of

Quantitative histopathological analysis of tissue of fish from East Fork Poplar Creek, White Oak Creek, and reference streams (S. M. Adams)

Provide the services of research assistant (Robert Frohn) on the basis of his specific training in the area of geographic information analysis and study of colonization in Rondonia, Brazil (V. Dale)

Development of a three-dimensional transport model of the carbon cycle in the ocean (M. P. Farrell)

Continuation of precise measurement of atmospheric carbon dioxide at Mauna Loa Observatory, Hawaii (M. P. Farrell)

Partial support to the National Center for Geographic Information and Analysis, University of California, to conduct meetings and research on

Remote Sensing and Geographic Information Systems (M. P. Farrell)

Partial support to the National Center for Geographic Information and Analysis, University of California, to organize and conduct the First International Conference/Workshop on Integrating Geographic Information Systems and Environmental Modeling (C. T. Hunsaker)

Support in laboratory studies on the permeability of fractured rocks (L. E. Toran)

Explore the feasibility of using growth enhancers developed at Los Alamos National Laboratory to increase biomass yields in woody and herbaceous energy crops (G. A. Tuskan)

Cascade Research, Inc.
Provide technical expertise and advice relating to integrated bioenergy systems (L. L. Wright)

The CEIP Fund, Inc.
Assist with the coordination of the Environmental Monitoring and Assessment Program's ecological indicators effort and contribute to landscape characterization tasks (C. T. Hunsaker)

Provide technical support in the quantitative analyses of surface water quality as it is affected by point and nonpoint discharges and by water use (M. J. Sale)

Work with public relations office at ORNL in preparing material for *ORNL Review* (S. H. Stow)

Center for Environmental Information, Inc.
Preparation of a data base compendium of global change centers in the United States (M. P. Farrell)

Center for Growth Studies
Partial support to the Center for Growth Studies, Houston advancedresearch Center, to conduct the Regions and Global Warming: Impacts and Response Strategies Workshop (M. P. Farrell)

CER Corporation
Provide well-drilling services (R. B. Clapp)

Provide written comments on a Notice of Proposed Rulemaking (F. E. Sharples)

Provide support for compliance assessments of Air Force bases (C. F. Sigmon)

Provide support for compliance assessments of FDA facilities (C. F. Sigmon)

Development of detailed plan for plugging and abandonment of wells and boreholes at WAG 6 (S. H. Stow)

Clemson University
Technical support on the study of natural organic colloids on the subsurface transport of contaminants (J. F. McCarthy)

Colorado State University
Involvement with the National Atmospheric Deposition Program that requires sample analysis by a central analytical laboratory for comparability of data on atmospheric deposition on a national scale (S. E. Lindberg)

Columbia University
Development of global coastal hazard data base (R. M. Cushman)

Cornell University
Collaborate on the preparation of one or two manuscripts on the results of

the wetland and riparian ecotone workshop and its relevance to ecological literature (C. T. Hunsaker)

Duke University
Support in evaluating exchanges of carbon between the atmosphere and terrestrial ecosystems as a result of land-use change (M. P. Farrell)

Energy Performance Systems
Analysis and reviews on how to match the objectives of the Short Rotation Woody Crops Program with the needs of potential utility users of wood (L. L. Wright)

Envirogen, Inc.
Provide treatability test data and bioreactor design assistance in support of demonstration of microbial degradation of organic contaminants in groundwater (S. E. Herbes)

ERCE
SARA/OSHA training for ESD staff (B. M. Ross)

E. R. Johnson Associates
Provide off-site office for technical assistance for the Office of Civilian Radioactive Waste Management (N. H. Cutshall)

Florida, University of
Support for graduate student to collect samples and perform mineralogical analysis of soils on Walker Branch Watershed (M. A. Huston)

Partial support for a workshop on Nearshore and Estuarine Cohesive Sediment Transport (J. W. Ranney)

Geo/Resource Consultants, Inc.
Provide technical assistance in developing and implementing training in environmental laws and regulations, perform regulatory analyses and develop compliance guidance, and perform environmental compliance assessments at federal facilities (F. E. Sharples)

Georgia Institute of Technology
Assist ORNL in concentrating natural organic matter (NOM) from groundwater for a DOE project on characterization and microbial utilization of NOM (J. F. McCarthy)

Georgia, University of
Support of Integrated Forest Study of atmospheric deposition (S. E. Lindberg)
Assist ORNL in concentrating natural organic matter (NOM) from groundwater for a DOE project on characterization and microbial utilization of NOM (J. F. McCarthy)

Optimizing energy yields in black locust through genetic selection (G. A. Tuskan)

H&R Technical Associates, Inc.
Provide data base development of hydrogeological data (C. S. Haase)

Hudson River Foundation
Measure changes in the forests of the Amazon basin (M. P. Farrell)

ICF Technology, Inc.
Provide technical support in reviewing environmental documents (L. L. Sigal)

Idaho, University of
Development of broadly adapted cultivars of winter rapeseed as a source of diesel fuel (J. H. Cushman)

Illinois, University of
The role of tropical forests in the global carbon cycle (M. P. Farrell)

Indiana University

Provide graduate students to support Environmental Analyses Section projects (S. G. Hildebrand)

Institute of Oceanographic Sciences

Develop three-dimensional models of the carbon cycle in the oceans (M. P. Farrell)

Iowa State University

Support in selection of forage species for energy crops in the Great Plains (J. H. Cushman)

Breeding clones for intensive culture of biomass for energy (part of DOE's Short Rotation Woody Crops Program) (G. A. Tuskan)

JAYCOR

Process benthic macroinvertebrate samples collected from McCoy Branch near the Oak Ridge Y-12 Plant and from several streams near the Paducah Gaseous Diffusion Plant (J. M. Loar)

Provide support in the category of environmental biology (Task title: ORNL Macrobenthos Analyses) (J. M. Loar)

Process benthic macroinvertebrate samples collected from East Fork Poplar Creek and Bear Creek near the Oak Ridge Y-12 Plant and from several reference streams on and off the Oak Ridge Reservation (J. M. Loar)

Process benthic macroinvertebrate samples collected from Mitchell Branch at the K-25 Site (J. M. Loar)

Process benthic macroinvertebrate samples collected from 16 sites on five streams near ORNL (J. M. Loar)

Technical support in the K-25 Site macrobenthos analyses (J. M. Loar)

Technical support in the ORNL macrobenthos analyses (J. M. Loar)

Technical assistance in the benthos support study (J. M. Loar)

Technical support in the Oak Ridge Y-12 Plant macrobenthos analyses (J. M. Loar)

Provide technical assistance on project addressing nutrient cycling in streams by maintenance of experimental facilities; sample collection; and biological, chemical, and radiological analyses (P. J. Mulholland)

Technical support in climate change, deforestation, afforestation, soils, and land availability (J. W. Ranney)

Assistance in assessing the feasibility of developing biomass-based alternative fuels (J. W. Ranney)

Provide assistance in ecological field and laboratory studies associated with the ORNL Biological Monitoring and Abatement Program (M. G. Ryon)

Provide support in the category of environmental biology (Task title: Fish Support Studies) (M. G. Ryon)

Provide support in the category of environmental biology (Task title: Environmental Compliance Assessment) (F. E. Sharples)

Provide support in the category of environmental biology (Task title: Regulatory Update and Analysis) (F. E. Sharples)

Support of environmental biologist for monthly reports of NEPA compliance assessments, environmental compliance assessments, and review of NEPA documents (L. L. Sigal)

Kansas State University
Determination of the best species and management techniques for short-rotation production of fuel wood in the Great Plains (L. L. Wright)

Kelso-Regen Associates
Engineering support in developing and constructing devices for dispensing andmonitoring CO_2 and pollutant gases and apparatuses for exposing plants to ultraviolet light in the field (J. W. Johnston)

Kentucky, University of
Conduct field study on biomass production by fescue and switchgrass alone and in mixed swards with legumes (J. H. Cushman)

Provide data needed (base-line cholinesterase activity) in order to establish protocols for biological monitoring during the destruction of chemical weapons (L. R. Shugart)

Plan and implement a biological monitoring research program at the Paducah Gaseous Diffusion Plant (B. T. Walton)

Knoxville College
Technical support for studies of biological communities and instream toxicity in East Fork Poplar Creek (H. L. Boston)

Support in studies of the biodegradation of polychlorinated biphenyls (H. L. Boston)

Marrich, Inc.
Provide for rapid and efficient processing of seismic refraction data in support of the ANS Project (T. O. Early)

Maryland, University of
Coordination of the Striped Bass and Bay Anchovy Key Species projects, which are a part of the EPRI-funded program on Compensatory Mechanisms in Fish Populations (W. Van Winkle)

Miami, University of
Provide graduate students to participate in multidisciplinary activities and become trained in the functions of an information analysis center for the international carbon dioxide research community (M. P. Farrell)

Michigan State University
Conference support services for International Black Locust Conference (L. L. Wright)

"Net Assimilation and Photosynthate Allocation of *Populus* Clones Grown Under Short Rotation Intensive Culture" as part of the DOE's Biofuels Feedstock Development Program (G. A. Tuskan)

Michigan Technological University
Conduct modeling and experimentation to evaluate and optimize in situ thermal treatment of volatile organic compounds in contaminated soils (R. L. Siegrist)

Mississippi State University
Technical support in early selection criteria and clonal propagation systems (G. A. Tuskan)

National Aeronautics and Space Administration
Computer support to run models of the atmosphere (M. P. Farrell)

Global historical climate network (M. P. Farrell)

National Oceanic and Atmospheric Administration
Temperature and precipitation in the United States (M. P. Farrell)

New Hampshire, University of
A study of the role of the oceans in the global carbon cycle through modeling exercises (M. P. Farrell)

North Dakota State University
Support on the selection of forage species for energy crops in the Great Plains (J. H. Cushman)

Oak Ridge Associated Universities
Laboratory analyses of water, sediment, and fish time for radionuclides (B. G. Blaylock)

Oak Ridge Research Institute
Technical support in the conduct of aquatic bioassays (A. J. Stewart)

Oklahoma State University
Evaluate *Populus* selection for fuel wood (G. A. Tuskan)

Oregon State University
Continued collection of oceanic carbonate data to verify ocean penetration of anthropogenic CO_2 (M. P. Farrell)

Pennsylvania State University
Development, verification, and validation of multiregion flow and transport models (P. M. Jardine)

Net energy and economic analysis for producing *Populus* hybrid under four management strategies (L. L. Wright)

Puerto Rico, University of
The role of tropical forests in the global carbon cycle (M. P. Farrell)

Purdue University
Evaluation of the agronomic and economic feasibility of different systems for producing herbaceous biomass on marginal lands (J. H. Cushman)

Roane State Community College
Student support for field work (N. T. Edwards)

Rochester, University of
Analysis of tritium and helium isotopes in groundwater (D. K. Solomon)

Science & Technology
Implementing Phase II of environmental training (F. E. Sharples)

Science Applications International Corporation
Support for evaluation of groundwater contamination and movement in relation to the ORNL WAG 2 remedial investigation (H. L. Boston)

Provide on-site junior-level data management support (M. A. Huston)

Assist in developing a consistent strategy for all groundwater programs at Energy Systems facilities, obtain copies of existing plans and procedures used in implementing groundwater programs at Energy Systems facilities, and prepare recommendations on plans and procedures that should be adopted at all facilities and new plans and procedures that should be developed (E. D. Smith)

Provide on-site data management support in soil characteristics, deposition chemistry, surface water chemistry, land use, runoff, and precipitation (R. S. Turner)

Provide off-site scientific programming support for the Foothills Parkway Environmental Report (R. S. Turner)
Provide on-site senior-level data management support to ESD (L. D. Voorhees)

Provide control of incoming analyses (status of sample analyses and detection of errors) as well as available access to existing data and associated statistical analyses (L. D. Voorhees)

Provide scientific programmer to assist ESD ecologists in data management and analysis (L. D. Voorhees)

Assist in ecological data management, data representation, and data analysis for ESD (L. D. Voorhees)

Selma University

Provide research personnel responsible for the isolation of toluene-degrading microorganisms and for preliminary screening of these organisms for the ability to degrade trichloroethylene (A. V. Palumbo)

Skidway Institute of Oceanography

Collect and analyze surface water andinterstitial water from the Clinch River and Watts Bar Reservoir for inorganic forms of arsenic (R. B. Cook)

Southern Illinois University

Genetic biomass and growth analysis of clonal silver maple in several locations (G. A. Tuskan)

Stanford University

Isolate cultures capable of degrading recalcitrant organic compounds and clone a set of biodegradation genes into a "starvation promoter" (A. V. Palumbo)

Structural Dynamics Research Corporation

Develop a finite element modeling package that would interface with groundwater flow and contaminant transport codes (O. M. Reyes)

Systematic Management Services, Inc.

Provide special expertise for ensuring the proper sequencing and integration of NE-33 Environmental Program Activities (G. K. Eddlemon)

Tennessee, The University of

Provide support for Dr. Lisa Shevenell to serve as a hydrogeologist in support of environmental restoration and ORHSP activities at ORNL (R. B. Clapp)

Provide for data analysis and continued guidance on monitoring station operation (R. B. Clapp)

Groundwater monitoring compliance of X-10 and to the Oak Ridge Hydrologic and Geologic Study project (R. B. Clapp)

Continued development of basin-wide spill forecasting model and training of X-10 emergency response staff (R. B. Clapp)

Perform X-ray fluorescence and diffraction analyses on sediment samples collected from the Clinch River and Watts Bar Reservoir (R. B. Cook)

Analytical preparation and determination of ^{18}O:^{16}O ratio on subsurface storm water using mass spectrophotometry (L. W. Cooper)

Technical support for management of herbaceous energy crop research in the Biofuels Feedstock Development Program (J. H. Cushman)

Technical support on long-term effects of soil erosion on crop production and on economics of energy crop production (J. H. Cushman)

Economic and technical analyses of issues related to herbaceous energy crop production (J. H. Cushman)

Support graduate student research on fracture characterization on the Conasauga Group and on the influence of fractures on the regional hydrologic system of the Oak Ridge Reservation (R. B. Dreier)

Provide high-resolution seismic survey for the purpose of imaging the shallow subsurface geologic features in the vicinity of the Paducah Gaseous Diffusion Plant (T. O. Early)

Provide environmental data systems design using CD-ROM platforms and design data analysis system using IBM/OS, VMS, and DOS platforms (M. P. Farrell)

Provide technical assistance with climatological data management activities by compiling climatological data, including quality control of data prior to data entry and recording data from instrumentation to scientific verification using analysis tools (M. P. Farrell)
Cover the services of Sonja B. Jones as a computer operator (M. P. Farrell)

Provide technical assistance by consolidating and replacing several University of Tennessee releases (M. P. Farrell)

Support in data base management in the CO_2 program (M. P. Farrell)

Life Sciences Distinguished Scientist, David White (C. W. Gehrs)

Provide UT support services to projects related to groundwater monitoring compliance at the Oak Ridge Y-12 Plant and to the Oak Ridge Reservation Hydrologic and Geologic Study (C. S. Haase)

Technical support on groundwater monitoring compliance at the Oak Ridge Y-12 Plant and the Oak Ridge Reservation (C. S. Haase)

Short-term and exploratory programmatic needs in areas where staff capability and/or funding uncertainty preclude ORNL staff commitments (S. E. Herbes)

Perform seismic imaging of the in situ vitrification melt (G. K. Jacobs)

Analysis of storm effluent samples via novel ion chromatograph techniques (P. M. Jardine)

Hydrologic characterization and subsurface transport (P. M. Jardine)

Investigation of soil characteristics in Walker Branch Watershed (S. Y. Lee)

Study on use of biological markers as indicators of environmental pollutants (J. F. McCarthy)

Support for DOE project on groundwater colloids. (J. F. McCarthy)

Provide data summaries and analyses in the form of manuscripts for submission to peer-reviewed journals (P. J. Mulholland)

Performance of light stable isotope ratio analysis on gaseous samples to determine spatial and temporal variability in biogeochemical cycling in watersheds (P. J. Mulholland)

Collection and analysis of ground-penetrating radar data at in situ vitrification (ISV) site. Information to be incorporated into report on the ISV test at SWSA 6 (J. E. Nyquist)

Provide monitoring and maintenance of biodegradation experiments (A. V. Palumbo)

Develop DNA and RNA probes for measurement of methanotrophic bacterial populations (A. V. Palumbo)

Support in the use of signature biomarker techniques for identification of individual organisms and characterization of microbial consortia known to degrade PCBs (A. V. Palumbo)

Provide expert assistance for surveying lichens and bryophytes along the proposed right-of-way for Section 8D of the Foothills Parkway (R. M. Reed)

Provide expert assistance for sampling fish and benthic communities in streams may be affected by construction and operation of Section 8D of the Foothills Parkway (R. M. Reed)

Analyze DNA biomarkers in animals obtained from polluted sites (S. R. Shugart)

Analytical preparation and determination of $^{13}C:^{12}C$ ratio hydrocarbon-contaminated soils using mass spectrophotometry (R. L. Siegrist)

Provide analysis and experimentation for evaluation of advanced oxidation of halocarbons in solvent-contaminated soil (R. L. Siegrist)

Provide support to analyze chlorine dynamics in upper East Fork Poplar Creek and in White Oak Creek (A. J. Stewart)

Periphyton analyses in biomonitoring (A. J. Stewart)

Support for Dr. Ronit Native as a hydrogeologist working on Oak Ridge Reservation studies during her sabbatical in the United States (S. H. Stow)

A cooperative venture between ESD and The University of Tennessee Graduate Program in Geological Sciences (S. H. Stow)

Life Sciences Distinguished Scientist, Robert Hatcher (S. H. Stow)

Investigations of the absorption of heavy metals and radioelements on minerals and rocks from aqueous solutions (G. K. Jacobs)

Modify existing national interregional agricultural model to include dedicated biomass energy crops (A. F. Turhollow)

Fund a University of Tennessee research associate (Dr. Kirk O. Winemiller) to work on the EPRI-funded Program "Compensatory Mechanisms in Fish Populations" (COMPMECH) (W. Van Winkle)

Workshop from the EPRI-funded program on Compensatory Mechanisms in Fish Populations (W. Van Winkle)

Support for EPRI-funded program on Compensatory Mechanisms in Fish Populations (W. Van Winkle)

Provide assistance in limnological, sedimentological, and water quality related data collection (K. L. Von Damm)

Data management support in the RCRA Facility Investigations for the Clinch River (L. D. Voorhees)

Tennessee Valley Authority

Southern Appalachian Man and the Biosphere Cooperative (J. W. Ranney)

Geophysical data acquisition and reduction services (S. H. Stow)

Tuskegee Institute
Strengthen programs in biomass and carbon dioxide research at Tuskegee Institute and ESD at ORNL (J. H. Cushman)

U.S. Department of Agriculture
Genetic variation among switchgrasses for agronomic traits, forage quality, and biomass fuel production (J. H. Cushman)

Increasing the biomass production of alder plantations in the Pacific Northwest (G. A. Tuskan)

Short-rotation woody crop trials for energy production (G. A. Tuskan)

U.S. Environmental Protection Agency
Collaborative research on bioremediation of contaminated sites (R. R. Turner)

Virginia Polytechnic Institute and State University
Conduct research on the selection of lignocellulosic species for energy crops (J. H. Cushman)

Provide samples needed to establish base-line cholinesterase activity in order to establish protocols for biological monitoring during the destruction of chemical weapons (L. R. Shugart)

Washington, University of
Chemical analysis of soil solutions and soil extracts for ammonium and nitrate (H. Van Miegroet)

Evaluation and genetic improvement of black cottonwood for short-rotation coppice culture (G. A. Tuskan)

Yale University
Conduct stable isotope investigation of Oak Ridge Reservation hydrology systems (C. S. Haase)

Technology Transfer

I. L. Larsen

During FY 1991 inquiries from industry stimulated the initiation of a copyright for a software program developed by N. H. Cutshall and I. L. Larsen for use in low-energy photon analysis.

In technology transfer to universities, ESD continues to lend its expertise to low-level gamma-ray spectrometry developments. Dr. Gerald Matisoff of Case Western Reserve University visited ESD regarding the establishment of capabilities in this area.

Two patent disclosure forms were filed by the Microbial Interactions Group during the fiscal year. Rights to both were waived by DOE. The first patent form originated from work under a project on EDTA degradation funded by the DOE Office of Health and Environmental Research. It describes a process that includes the replacement of cobalt in a cobalt-EDTA complex with iron and the degradation of the iron-EDTA by bacteria. The second patent form originated from a Directors Fund project. It describes an automated process control method for bioreactors based on the use of genetically engineered bacteria as biosensors. The bacteria are designed to emit light under defined conditions; the light level is monitored and used in a feedback loop to maintain high bacterial activity.

Specific biosensors were developed to indicate toluene degradation (being used in a Director's Fund project) and metabolism of organic mercury (transferred to EPA). A constitutive light-emitting strain was developed for studies of biofilm formation (being used by The University of Tennessee).

Education Activities

Introduction

S. E. Herbes

Since its inception ESD has developed and maintained strong relationships with a broad range of educational institutions. In addition to encouraging staff to develop collaborative research programs with university researchers, for more than two decades ESD has provided opportunities for student and faculty guests to participate in ongoing ESD research activities for periods varying from several weeks to several years. The enthusiasm, expertise, and fresh insights of these guests provide a continuing source of research creativity for the benefit of research sponsors. In return, participation in ongoing ESD research provides the education guests with opportunities to apply their textbook knowledge, expand their areas of expertise, and help solve environmental problems of national significance.

Guests, ranging from high school students to university faculty, are appointed through a wide variety of programs administered by the ORNL Office of Science Education and by Oak Ridge Associated Universities, as well as through subcontracts with individual universities. The diversity of the programs provides flexibility in identifying appointments for candidates with widely varying educational levels, purposes, and lengths of stay. ESD education programs are coordinated through the Education Committee, whose role is to advise division management on questions of education policy and to ensure that these programs continue to provide exceptional opportunities for student involvement while meeting ESD's programmatic objectives.

During the past several years, national concern has focused on the steadily decreasing number of college students who choose careers in science and engineering. DOE's response to these trends has been to underscore the importance of both strengthening and supporting existing precollege science education curricula and to actively promote involvement of under-represented minorities in career-track science and engineering education programs. In keeping with DOE's renewed emphasis in these areas, ESD education programs during the past several years have expanded research opportunities for high school students and teachers, as well as for minority students and faculty.

In FY 1991 these initiatives have been reflected in the continuing expansion of the American Chemical Society High School Study ("SEED") Program to provide summer-long research opportunities for high school students; the successful completion in July 1991 of the fourth annual DOE High School Honors Workshop in the Environmental Sciences; continuing commitment to provide opportunities for high school teachers to become involved in research; the increased activities of the division's Minority Education Liaison and of other ESD staff in developing, expanding, and ensuring high-quality research experiences for minorities in ESD; and the continued expansion of activities of the Ecological and Physical Sciences Study Center, an ORNL Science Education Center operated in cooperation with the Oak Ridge Natural Environmental Research Park.

Education Programs

DOE High School Honors Workshop in the Environmental Sciences

J. A. Watts

DOE sponsors science education workshops for exceptional high school students at seven national laboratories each summer. The workshop at ORNL focuses on the environmental sciences. Fifty-nine students from 48 states, the District of Columbia, Puerto Rico, and 8 foreign countries participated in the 2-week ORNL program in FY 1991. Of the participants, 58% were female; in addition, 17% of the American students represented ethnic minorities.

Each student was assigned to 1 of 17 research projects. These projects (led by 40 scientists from ESD and the ORNL Health and Safety Research Division) gave the students opportunities to conduct hands-on research in such areas as geochemistry, environmental toxicology, conservation biology, molecular biology, botany, wildlife ecology, and soil physics. The projects also provided them instruction in the use of large computerized models, data bases, and geographical information systems. Members of each research group prepared a written report and gave an oral presentation to their peers.

In addition, students were placed in one of three groups, each working on a major environmental theme: global climate change, chemical agent incineration, or contamination of water resources. The theme groups (led by six staff members from ESD and the ORNL Energy Division) studied all sides of the issue, and their work culminated in a series of public hearings during which students role-played opposing factions.

Throughout the program, students also participated in seminars and special programs at the Oak Ridge National Environmental Research Park and at the Great Smoky Mountains National Park. At the end of the workshop, all the students and research leaders were asked to evaluate the program. Students unanimously agreed that their perceptions of science had been positively changed or positively reinforced. Research leaders typically felt that the program had challenged and refreshed their own perceptions of science.

Ecological and Physical Sciences Study Center

T. L. Lashley and P. D. Parr

The Ecological and Physical Sciences Study Center is a program of the ORNL Science Education Center in cooperation with the Oak Ridge National Environmental Research Park. Now in its eighth year, the center has grown rapidly as a precollege science education program. From 125 students in 1984, the study center has grown to serve over 19,000 students and teachers during the 1990–91 school year. Study center staff now include a director and eight instructors, all of whom work on a part-time basis under subcontract.

The primary purpose of the study center is to enhance environmental and science education for precollege students (kindergarten through high school). Half-day field or laboratory activity units at the Oak Ridge National Environmental Research Park (mainly at the Freels Bend cabin area and the Graphite Reactor site) emphasize a hands-on approach to learning

about ecological relationships and physical science concepts. Currently, 40 activity units are offered. Objectives also include furnishing informational and instructional materials for teachers to use in developing their own study units, providing special presentations and programs for teachers and the public, and adapting units so that disabled students can participate.

Secondary School Science Education Programs

G. J. Haynes and S. E. Herbes

This year seven high school students participated in ESD research projects through the American Chemical Society's SEED program. The goal of SEED is to encourage outstanding juniors and seniors to consider careers in science and mathematics by providing an 8- to 10-week summer research experience. Although the students spend most of their time with their research advisors, they also participate in seminars, write papers, and receive career guidance from the ORNL University and Educational Programs (UEP) Office and ESD staff. The hands-on research experience that the students gain can often motivate them to pursue careers in science or mathematics.

During the past several years, ORNL has initiated numerous programs to strengthen science education on the secondary school level by providing opportunities for teachers and students to participate directly in ORNL research projects. During summer 1991, six secondary school teachers from Oklahoma, Tennessee, Texas, Washington, Wisconsin, and Spain worked for 8 weeks in ESD through the Science Teachers Research Involvement for Vital Education and the Teacher Research Associates programs. Several ESD staff also contributed to area secondary science education by participating as speakers in high schools through the UEP Visiting Scientist Program.

Minority Educational Institution Initiatives

H. L. Boston and M. S. Hendricks

ESD efforts associated with minorities have primarily addressed three areas: (1) increasing the participation of minority students in ESD education programs; (2) encouraging minority faculty to collaborate with ESD researchers and to participate in faculty research programs in ESD; and (3) providing opportunities for minority students at the undergraduate and graduate levels to work with ESD researchers, with the goal of eventually recruiting some of these students as Martin Marietta Energy Systems, Inc., employees. The two focal areas for Minority Educational Institution (MEI) activities have been Historically Black Colleges and Universities (HBCUs) and Hispanic educational institutions.

As the newly appointed ESD Minority Education Liaison, M. S. Hendricks worked to actively facilitate communications between ESD and the ORNL Minority Educational Institution office, as well as to take a leading position in ESD's direct interaction with minority institutions, their faculty, and students. The liaison acted as a contact point for minority applications for education programs and worked with the ESD education coordinator to ensure that student and faculty applications were circulated among ESD staff. The recommendations of the ESD ad hoc committee for MEIs were implemented through an orientation meeting that addressed the needs and concerns of incoming minority students. M. S. Hendricks kept in contact with students placed in ESD and conducted informal exit interviews to ensure continual

improvement in the experiences of future students.

In FY 1991, ESD staff strengthened their ties with faculty at several MEIs through continuing participation in the Urban League's Black Executive Exchange Program. A member of the ad hoc committee participated in a two-day National Environmental Career Conference organized by the CEIP fund, a nonprofit environmental internship organization. The conference provided an opportunity to meet with hundreds of highly qualified minority students who have an interest in environmental careers. A number of students were identified either as potential participants in ESD educational programs or as potential employees. Other students gained guidance and encouragement to continue their education.

Staff also took advantage of opportunities at large national meetings to strengthen ties with MEI faculty. These ties are a useful means for contacting and recruiting students for education programs and employment opportunities. Because students often are unaware of the many opportunities available and hesitant to venture into unfamiliar areas (such as programs at national laboratories), first-hand knowledge of a faculty member is important to potential applicants. These faculty ties also provide a means of disseminating information about research opportunities at ORNL and encouraging collaborative research between ESD staff and faculty at MEIs.

During FY 1991, ESD staff actively moved to promote the full participation of minorities in science outside the division through participation in special committees of large national scientific organizations (e.g., the Ecological Society of America's Committee for Women and Minorities in Science). These outside activities allow division staff to carry some of ESD's successful approaches to a wider audience. Joining these nationwide efforts not only provides additional opportunities for ESD to increase participation in its minority educational programs but also contributes to ESD's broader efforts to improve minority participation in science.

A blanket subcontract with Knoxville College, a local HBCU, was continued to allow students to work part-time with researchers in ESD. Three students participated under this arrangement in FY 1991. Although students' responsibilities are to provide technical support rather than to develop independent research projects, staff advisors are expected to involve the students in ongoing research activities as much as possible. This program is designed to encourage subsequent participation in various ORNL education programs as well as to provide a unique opportunity for students to expand their career options through exposure to the world of environmental research.

Undergraduate Education Program

G. J. Haynes

Several ORNL and ORAU programs for undergraduate student participation in ESD research and assessment projects provide a continuing opportunity for interaction between students and staff. In FY 1991 a total of 42 undergraduates, representing 24 different institutions, participated in divisional research activities.

Highly qualified undergraduates are selected from colleges and universities throughout the United States (see table) on the basis of academic performance, references, future research interests, and availability of appropriate positions in ESD. Students are assigned to ESD advisors, who guide them through a

summer- or semester-long experiment or project associated with one of the ESD programs. The research experience is supplemented through seminars, workshops, oral and poster presentations, course work, and preparation of a research paper. Participants also become familiar with sophisticated, state-of-the-art scientific research equipment. Students gain experience that can lead to success in graduate studies and to an expanded understanding of career opportunities in environmental research.

Graduate and Postgraduate Education Programs

S. E. Herbes

ESD provides the opportunity for graduate and postdoctoral research consistent with the mission of ORNL. During FY 1991, a total of 38 students participated in graduate research in ESD (see table). While maintaining the traditionally strong participation of The University of Tennessee Graduate Program in Ecology, ESD hosted graduate students from 14 other universities. In addition, 16 postdoctoral interns and 2 Hollaender Fellows pursued research studies as part of division programs.

Graduate research opportunities vary in length, from internships of several months' duration to multiyear Ph.D. dissertation projects. Student research is guided by selected ESD staff members, one of whom serves on the student's university academic guidance committee. Tuition, fees, and stipends for some of the graduate students are provided through DOE educational assistance programs administered through ORAU and UEP. Many students are supported through ESD programmatic funds, and several are self-supported.

In addition to students in residence, ESD programs support graduate research at many of the universities with which subcontractual arrangements are maintained (see the section of this report entitled "Research and Development Subcontracts and Interagency Agreements").

Faculty Program

S. E. Herbes

ESD provides opportunities for professional educators to participate in collaborative research with division staff. During this reporting period, 11 university faculty participated in summer or sabbatical research at ESD through the ORAU Faculty Research Participation and sabbatical programs. In addition, many faculty members visited ESD for workshops, seminars, or subcontract consultations.

Universities and secondary schools represented by ESD guests during the period October 1, 1990, through September 30, 1991

Institution	Students			Postdoctoral appointees	Faculty		Program[a]
	High school	Undergraduate	Graduate		High school	College/university	
Arizona State University			1				LIP
Austin-East High School (Tennessee)					1		STRIVE
Boston University			1				LIP
Carleton College		1					PIP
Carnegie Mellon Institute			2				Practicum
Chalmers University of Technology (Sweden)			1				Practicum
Clinton High School (Tennessee)	1						SEED
Colorado State University			1				Practicum
Cornell University		2					SRI, Sub
Dartmouth College			1				Practicum
Denison University						1	FSP
Duke University				1			PRTP
Earlham College						1	GLCA/ACM
East Tennessee State University		2					SRI
Fulton High School (Tennessee)	2						SEED
Harvard College		1					SRI
Hebrew University (Israel)						1	Sub
Heritage High School (Tennessee)	1						SEED
Indiana University		1	1	1			Sub, PIP, PRTP
Irving Middle School (Oklahoma)					1		TRAP
Joseph Jantsch High School (Washington)					1		TRAP
Karns High School (Tennessee)	1						SEED
Kenyon College		1					SRP
Knoxville College		1					Sub
Louisiana State University				1			PRTP
Mansfield High School (Texas)					1		TRAP
Massachusetts Institute of Technology			1				LOP
Michigan Technological University						1	FRP
Miami University (Ohio)			1	1			Sub, PRTP
Middle Tennessee State University		1					SRI
Mount Vernon College		1					SRP
Murray State University			1				GSRP
Notre Dame University		1					PIP
Ohio University		1					SRP
Oregon State University				1			PRTP
Pennsylvania State University		1	1				ORSERS, Sub

Universities and secondary schools represented by ESD guests during the period October 1, 1990, through September 30, 1991 (continued)

Institution	Students			Postdoctoral appointees	Faculty		Program[a]
	High school	Under-graduate	Graduate		High school	College/ university	
Purdue University			1				GSRP
Roane State Community College		12					Sub
St. Olaf College						1	GLCA/ACM
Stanford University				1			Hollaender
State University of New York—Albany				1			PRTP
Southwest Missouri State University		1					SRP
Syracuse University		2					ORSERS, SRI
Torrejor High School (Spain)					1		TRAP
University Fed. Rio de Janeiro (Brazil)				1			PRTP
University of Arizona		1					Practicum
University of Arkansas				1			Hollaender
University of California—Davis				1			PRTP
University of Chicago						1	FRP
University of Florida			1				Practicum
University of Georgia		1		3			PIP, Hollaender, Practicum
University of Illinois			1				LIP
University of Iowa		1					SRP
University of Michigan			1			1	Sub, FRP
University of Mississippi						1	FRP
University of New Hampshire		1					PIP
University of North Carolina			1				LIP
University of Puerto Rico		1					ORSERS
University of Puerto Rico High School	2						SEED
University of Rochester				1			PRTP
University of South Carolina		1					SRI
University of Tennessee—Chattanooga		1					PIP
University of Tennessee		1	17[b]	9		1	PRTP, GSRP, Sub, PIP, LIP
University of Washington				1			PRTP
University of Wisconsin—Stevens Point		1					ORSERS
University of Wyoming			1				Practicum
Universidad del Turabo (Puerto Rico)						1	FRP
Vanderbilt University			2				Sub, Practicum
Virginia Polytechnic Institute		2		1			SRI, PRTP
Virginia State University						1	FRP

Universities and secondary schools represented by ESD guests during the period October 1, 1990, through September 30, 1991 (continued)

Institution	Students			Postdoctoral appointees	Faculty		Program[a]
	High school	Undergraduate	Graduate		High school	College/university	
Washington State University		1					ORSERS
Wisconsin Dells High School (Wisconsin)					1		TRAP
Yale University		1					SRI
Total	7	42	37	25	6	11	

[a]FRP = Faculty Research Program; FSP = Faculty Sabbatical Program; GLCA/ACM = Great Lakes Colleges Association/Associated Colleges of the Midwest; GSRP = Graduate Student Research Participation Program; Hollaender = Alexander Hollaender Postdoctoral Fellowship Program; LGP = Laboratory Graduate Program; LIP = Legal Internship Program; ORSERS = Undergraduate Oak Ridge Science and Engineering Research Semester Program; PIP = Professional Internship Program; PRTP = Postgraduate Research Training Program; SEED = American Chemical Society High School Study Program; SRI = Summer Research Internship; SRP = Undergraduate Summer Research Program; STRIVE = Science Teachers Research Involvement for Vital Education; Sub = subcontract to ESD from university; TRAP = Teacher Research Associate Program.

[b]Program/department affiliations: ecology, 4; environmental practice, 1; environmental toxicology, 4; law, 1; microbiology, 1; nuclear engineering, 1; plant and soil science, 2; fisheries/wildlife, 2; zoology, 1.

Affirmative Action

V. R. Tolbert and A. U. Sheard

ESD strongly supports the Martin Marietta Energy Systems, Inc., Equal Employment Opportunity program and the ORNL Affirmative Action program. The division has made conscientious efforts to ensure job equality for all employees regardless of race, color, religion, sex, or national origin. In addition, ESD has taken steps to expand employment opportunities for minorities, women, and the disabled. During FY 1991, ESD continued to support affirmative action principles in four main areas: recruiting and hiring, promotions, career development, and education programs. ESD has continued to build upon the groundwork laid in the past and to expand efforts to identify and recruit minority staff for positions throughout the division. ESD has encouraged personal development opportunities for minorities, women, and the disabled. The following summarizes ESD's progress in affirmative action during this reporting period.

- ESD has a sincere commitment to develop closer relationships with minority educational institutions (MEIs). These relationships allow identification and development of potential minority employees and offer opportunities for subcontract interactions and the further development of MEI capabilities.
  - The Division Director visited Virginia State University to discuss possibilities for future collaboration between the university and ESD. A minority female, head of the Geology Department, worked with Earth Sciences Division staff this summer and is working with ESD to establish a Science Semester program for the university.
  - An ad hoc Adopt-a-School education committee was formed to assist in exposing minority children to the environmental sciences and to develop their interests in science. As a result of this effort, at least nine SEED Program applications were submitted by minority students to the University Relations office. Six minority SEED students worked in ESD during the summer.
  - ESD continues to be active in the Center for Environmental Intern Programs minority job fair and was a contributing sponsor of the fair in San Diego. A minority staff member was a recruiter at the job fair. The division has contacted a number of individuals identified from the job fair for potential jobs within ESD.
- ESD continues to have a strong commitment to increasing opportunities for disabled individuals.
  - A deaf employee was offered another job within the division where her job skills could be better utilized. Telecommunication Device for the Deaf (TDD) phones were moved to her work area and to the areas of staff with whom she would need to communicate. A vibrating pager was purchased for her use, and safety warning lights were installed where needed to accommodate her move.

- Hearing-impaired employees hosted a group of high school students who are taking sign language as a second language for a tour of their working environment.

- Female professional staff members continue to be actively involved as officers and members of the local chapter of the Association for Women in Science (AWIS). ESD female staff were the recipients of the Outstanding Scientific Achievement and the Outstanding AWIS Service awards for 1991. The division recognized the award recipients with a luncheon with the Director of the Laboratory.

  - An ESD female staff member served as the technical program chairman for the AWIS National Conference in June in Washington, D.C.; another female staff member also participated.

- The division has pursued affirmative action efforts through hiring and staffing during the year.

  - ESD has recruited professional females and minorities during the year. A minority female was hired as a Wigner Fellow. A minority female has been offered a position in the Earth Sciences Section.

  - ESD hired a minority female as a subcontractor.

  - ESD actively recruited a number of minority secretarial candidates for potential job openings in the division and the Laboratory and hired a minority secretary.

  - An ESD minority female participating in the Black Executive Exchange Program identified two minority females whose resumes ESD forwarded to staffing for employment opportunities at ORNL.

- ESD has promoted affirmative action objectives by extending to its employees further opportunities for professional development and skills training.

  - Female professional staff members attended a variety of national and international conferences and workshops and were involved in training opportunities as either leaders or participants.

  - A minority secretary graduated with an associate business science degree in computer sciences; she has been promoted to section secretary. Another minority female graduated with a master's degree in business administration. Division management actively pursued employment opportunities outside the division for the minority female earning the master's degree to provide her an opportunity for career advancement.

  - An administrative secretary in the division took a 10-month assignment with the DOE Office of Environmental Restoration and Waste Management, Technical Support Division, in Germantown, Maryland, for expanded job experience.

  - A female staff member was chair of the Technical Program for WATTec for 1991. She is also secretary of the WATTec Board of Directors.

  - ESD managers attended a cultural diversity workshop.

- ESD has taken steps to include more women and minorities in the various

training and educational programs that are open to visiting students, faculty, and scientists. These efforts will help ESD develop additional potential employees from these groups.

- ESD hosted the 2-week DOE National High School Honors Workshop in Environmental Sciences, which enabled outstanding high school students from each of the 50 states and from several foreign countries to learn more about science and to participate in hands-on research efforts while visiting ESD. A female was chair of this program, and 11 minority students participated in the program.

- Six minority SEED, Professional Internship Program, or Student Participation in Research students worked in ESD during the summer. The division has maintained contact with these students and is encouraging them to return next summer. Three students from Knoxville College have also been working at ORNL as a result of ESD staff involvement with the college. Efforts are under way to establish a formalized program between ESD and Knoxville College and to establish an internship program.

- Division management has established a relationship with a company that will identify interns, particularly minority interns, who are eligible to participate in division programs.

- A minority female completed her Ph.D. under the direction of ESD staff.

Seminar Program

T. A. Boden

J. D. Marsh
A. V. Palumbo
M. J. Sale
M. G. Turner

During the past year the ESD Seminar Committee and Chairman coordinated a diverse program of guest speakers (listed here) to inform ESD staff and other interested members of the local scientific community about topics of general interest in the environmental sciences. The Seminar Committee relies largely on suggestions from ESD staff members concerning the selection of outstanding speakers.

W. C. Oechel, Department of Biology, San Diego State University, La Jolla, California. "Effects of Global Change on Carbon Storage in Arctic Ecosystems."

D. O. Hall, King's College, University of London, London, England. "Biomass Fuel and/or Carbon Sequestering?"

J. H. Gibbons, Office of Technology Assessment, U. S. Congress, Washington, D.C. "OTA as an Experiment in Governance."

S. R. Carpenter, Center for Limnology, University of Wisconsin, Madison. "Whole Lake Experiments: Population, Community, and Ecosystem Responses."

R. D. Holt, Museum of Natural History, University of Kansas, Lawrence. "Conservation Implications of Top Predator Removal: A Theoretical Perspective."

K. Gottschalk, U.S. Forest Service, University of West Virginia, Morgantown. "Gypsy Moth: An Ecological Perspective and Some Current Research Initiatives in Eastern Forests."

T. E. Lovejoy, Smithsonian Institution, Washington, D.C. "The Minimum Critical Size of the Ecosystems Project."

S. P. Hubbell, Department of Ecology and Evolutionary Biology, Princeton University, Princeton, New Jersey. "The Current Status of the National Institute of the Environment."

Visitors Hosted

G. J. Haynes

During FY 1991 a total of 1576 persons visited the ESD facilities as part of tour groups. This number includes the groups listed in the table below as well as an additional 126 persons, many of whom were high school students and university undergraduates on Saturday educational tours hosted by Public Relations. The diversity of visitors reflects interest in the many areas of environmental research conducted in the division.

Tour groups hosted from October 1, 1990, through September 30, 1991

Institution[a]	Date	Number in tour	ESD host(s)
Capt. J. R. Masion and guests	10/31/90	5	A. J. Stewart
ORNL and UT students	11/01/90	5	G. J. Haynes
UT student researchers	11/05/90	5	G. J. Haynes
U.S.S.R. All-Union Research Institute	11/06/90	5	G. J. Haynes, R. J. Norby, J. W. Ranney
Bryan College deans	11/09/90	5	C. J. Ford, C. R. Wenzel, N. T. Edwards
American Chemical Society students	11/12/90	10	C. R. Wenzel
Collegedale Academy students	11/15/90	48	N. T. Edwards, E. G. O'Neill
Greater Knoxville Research Network	11/16/90	13	A. J. Stewart
Christian Academy chemistry and physics class	11/20/90	50	C. R. Wenzel
Science Technology Executive Seminar Center	11/28/90	30	P. J. Hanson
Values Committee quarterly meeting	12/07/90	25	H. Boston
Energy Systems, J. J. DeNapoli	12/10/90	1	G. J. Haynes
Portsmouth visitors	12/13/90	3	G. J. Haynes
Oak Ridge Science and Engineering Research	1/07/91	30	R. J. Norby
ORAU Science Minimester	1/15/91	20	M. S. Adams
ORAU Science Minimester	1/17/91	20	M. S. Adams
DOE interns	2/04/91	15	H. Boston
Pellissippi State Community College deans	2/11/91	14	H. Boston, K. T. Wilson
DOE new employee orientation	2/13/91	40	C. R. Wenzel

Tour groups hosted from October 1, 1990, through September 30, 1991 (continued)

Institution[a]	Date	Number in tour	ESD host(s)
DOE new employees	2/12/91	40	R. J. Norby
National Speech Competition	2/21/91	12	M. S. Adams
Junior Science Symposium	3/01/90	25	C. J. Ford, C. R. Wenzel
Elder Hostel group	3/06/91	30	C. R. Wenzel
Heritage School	3/07/91	11	C. R. Wenzel
Leadership Oak Ridge	3/12/91	44	H. Boston, C. R. Wenzel
Leadership Oak Ridge	3/12/91	44	H. Boston, W. A. McNabb
French Trade Commission	3/18/91	22	G. J. Haynes
Farragut Science Honor Society	3/20/91	25	M. S. Adams
Ferrum College	3/21/91	10	A. J. Stewart
Dr. David Harry and associates	3/25/91	13	P. J. Hanson, J. W. Ranney, G. A. Tuskan
University of North Carolina physics students	3/26/91	8	J. D. Joslin
Fletcher Academy	3/28/91	10	A. J. Stewart
Association for Women in Science	4/12/91	26	G. J. Haynes
ORNL new employees tour	4/22/91	25	C. R. Wenzel
ORNL new employees tour	4/25/91	25	C. R. Wenzel
Puerto Rican visitors	5/07/91	6	R. I. Van Hook
Darlington School	5/21/91	50	N. T. Edwards, W.A. McNabb, R. J. Norby
Darlington School	5/21/91	50	N. T. Edwards, C. R. Wenzel
Middle Tennessee State University	5/23/91	17	H. Boston, C. R. Wenzel
Environmental problems class	5/23/91	17	H. Boston, C. R. Wenzel
ORAU Science Minimester	5/28/91	12	G. J. Haynes, C. R. Wenzel
ORAU Science Minimester	5/29/91	25	H. Boston, C. R. Wenzel
Ruby Prins and students	6/05/91	16	P. J. Mulholland, A. J. Stewart
Dick Swaja and students	6/10/91	6	G. J. Haynes
Lue Volk and guests	6/12/91	18	G. J. Haynes
NSF/Francis Marion College	6/27/91	30	P. J. Hanson
NSF/Enhancement Workshop	6/26/91	47	C. R. Wenzel

Tour groups hosted from October 1, 1990, through September 10, 1991 (continued)

Institution[a]	Date	Number in tour	ESD host(s)
French-American Environmental Foundation	7/09/91	4	G. J. Haynes
UT Science Alliance	7/11/91	28	G. J. Haynes
DOE High School Honors Program students	7/15/91	60	G. J. Haynes, A. Steinman, G. Tuskan
DOE-Headquarters, Andy Wallo	7/15/91	4	A. J. Stewart
UT Math Department	7/17/91	14	G. J. Haynes
Environmental Restoration Advisory Group	7/17/91	20	H. Boston
Western Kentucky University	7/18/91	20	C. A. Gunderson, T. Tschaplinski
ORNL staff	7/22/91	10	S. D. Wullschleger
ORAU student research participants	7/24/91	20	G. J. Haynes
Accounting interns	7/25/91	15	G. J. Haynes
DOE engineering interns	7/29/91	20	G. J. Haynes
Energy Systems co-op students	7/31/91	35	J. D. Joslin
Appalachian Honors Workshop	7/31/91	42	J. H. Cushman, G. J. Haynes, W. A. McNabb, A. J. Stewart
Energy Systems co-op students	8/06/91	35	S. M. Adams
STRIVE and TRAP programs	8/07/91	55	G. J. Haynes, R. Evans
Executive Seminar Center	8/08/91	30	R. J. Norby
DOE and DOD visitors	8/30/91	2	R. Evans
Tokyo Power and Tokyo University	9/13/91	4	H. Boston, R. I. Van Hook
Dr. Bruce Serlin	9/16/91	1	N. T. Edwards, G. J. Haynes, P. J. Mulholland, A. T. Palumbo
DOE new employees	9/19/19	40	R. J. Norby
Total		1467	

[a]DOD = U.S. Department of Defense; DOE = U.S. Department of Energy; Energy Systems = Martin Marietta Energy Systems, Inc.; NSF = National Science Foundation; ORAU = Oak Ridge Associated Universities; ORNL = Oak Ridge National Laboratory; STRIVE = Science Teachers Research Involvement for Vital Education; TRAP = Teacher Research Associate Program; UT = The University of Tennessee.

Conferences Organized or Chaired

During the past year, ESD staff members actively participated in numerous conferences. Listed below are conferences organized or chaired by members of the division.

17th Annual Aquatic Toxicity Workshop—Bioindicators, Government of Canada, Vancouver, British Columbia, Canada, November 1990. Chairman and organizer: Adams, S. M.

Third Topical Meeting on Emergency Preparedness and Response, American Nuclear Society, Chicago, Illinois, April 1991. Chairman and organizer: Baes, C. F., III

Workshop on Ecological Risk Assessment, National Research Council, Airlie, Virginia, February-March 1991. Chairman and organizer: Barnthouse, L. W.

Biofuels Energy Conference, Biofuels Feedstock Development Program and IEA Bioenergy Task V, Davis, California, September 1991. Chairman: Cushman, J. H.

Workshop on Natural Resource Economics, U.S. Agency for International Development and Partners in Education for ten visiting Brazilian scientists, Oak Ridge, Tennessee, September 1991. Chairman: Dale, V. H.

U.S. Japanese Collaborative Research Workshop, National Science Foundation—Japan Society for Promotion of Science, Oak Ridge, Tennessee, September 1991. Organizer: DeAngelis, D. L.

Short-Course on Populations and Ecosystems, Swedish Agricultural University, Uppsala, Sweden, April 1991. Organizer: DeAngelis, D. L.

Dense Non-Aqueous Phase Liquid Workshop, DOE, Atlanta, Georgia, July 1991. Chairman and organizer: Early, T. O.

Symposium for Annual Meetings of the Ecological Society of America, San Antonio, Texas, August 1991. Chairman and organizer: Gardner, R. H.

Remote Sensing and DOE Research Parks, DOE, Oak Ridge, Tennessee, June 1991. Chairman and co-organizer: Graham, R. L.

23rd Annual Air Pollution Workshop, California Department of Food and Agriculture, EPRI, Southern California Edison, Lake Arrowhead, California, April 1991. Chairman: Hanson, P. J.

Symposium on Terranes in the Appalachian/Caledonia Orogen, Geological Society of America, Baltimore, Maryland, April 1991. Chairman and organizer: Hatcher, R. D., Jr.

Women in Science, ORNL and ORAU, Oak Ridge, Tennessee, April 1991. Organizer: Haynes, G. J.

BIOMOVS—Biospheric Model Validation Study, Swedish National Institute for Radiation Protection, Stockholm, Sweden, October 1990. Chairman: Hoffman, F. O.

International Symposium on the Biological Aspects of the Chernobyl Accident, U.S.S.R. Academy of Sciences, Zeleny

Mys, Ukraine, U.S.S.R., September 1990. Chairman: Hoffman, F. O.

Validation of Assessment Model Predictions/Multiple Pathways Analysis, International Atomic Energy, Vienna, Austria, December 1990. Chairman and organizer: Hoffman, F. O.

Fourth Tennessee Water Resources Symposium, ORNL and Environmental Restoration Program, Knoxville, Tennessee, September 1991. Organizer: Huff, D. D.

Symposium: Regional Ecological Risk Assessment, International Association of Landscape Ecology World Congress, International Association of Landscape Ecology, Ottawa, Canada, July 1991. Chairman and organizer: Hunsaker, C. T.

First International Conference/Workshop on Integrating, National Center for Geographic Information and Analysis, Boulder, Colorado, September 1991. Chairman and organizer: Hunsaker, C. T.

63rd Annual Water Pollution Control Federation Conference, GIS and Environmental Modeling, Washington, D.C., October 1990. Chairman and organizer: Hunsaker, C. T.

International Symposium on Ecological Indicators, U.S. EPA, Fort Lauderdale, Florida, October 1990. Chairman and organizer: Hunsaker, C. T.

Second Annual Walker Branch Watershed Research Symposium, DOE OHER, Oak Ridge National Laboratory, March 1991. Chairman and organizer: Huston, M. A.

ESA Contributed Papers on Remote Sensing, Ecological Society of America, San Antonio, Texas, August 1991. Chairman and organizer: Huston, M. A.

Ecological Physiology of Conifers, IUFRO, Abakan, U.S.S.R., August 1991. Chairman: Luxmoore, R. J.

Concepts in Manipulations of Groundwater Colloids for Environmental Restoration, DOE, Manteo, North Carolina, October 1990. Chairman and organizer: McCarthy, J. F.

Transect Workshop II, DOE OHER, Las Cruces, New Mexico, March 1991. Chairman and organizer: O'Neill, R. V.

NATO Advanced Study Institute on Global Carbon Cycle, NATO, Il Ciocco, Italy, September 1991. Chairman: Peng, T.-H.

Annual Conference of the American Society of Civil Engineers, ASCE Water Resources Planning and Management Division, New Orleans, Louisiana, May 1991. Chairman: Railsback, S. F.

Fourth Tennessee Water Resources Symposium, Tennessee Section, American Water Resources Association, Knoxville, Tennessee, September 1991. Chairman: Sale, M. J.

NATO Advanced Research Workshop on Biomarkers, NATO, USEPA, Procter and Gamble, and Green Peace, Texel, The Netherlands, May 1991. Organizer: Shugart, L. R.

Third Meeting of the International Task Force on the Application of the Principles of Environmental Impact Assessment to Policies, Plans, and Programs, EPA, Washington, D.C., April 1991. Chairman and organizer: Sigal, L. L.

President's Council on Environmental Quality (CEQ)/EPA Workshop on CERCLA and NEPA at Federal Sites, CEQ/EPA, Washington, D.C., July 1991. Facilitators: Sigal, L. L.; Webb, J. W.; Schramm, W. E.; and Smith, E. D.

NEPA Integration: Effective, Efficient Environmental Compliance in the 1990s, President's Council on Environmental Quality, Alexandria, Virginia, March 1991. Steering committee: Sigal, L. L.

Fourth Meeting of the International Task Force on the Application of the Principles of Environmental Impact Assessment to Policies, Plans, and Programs, EPA, Geneva, Switzerland, August 1991. Co-chairs: Sigal, L. L., and Webb, J. W.

WATTec, Knoxville, Tennessee, February 1991. Chairman: Sigmon, C. F.

Commission on Hydrogeology of Hazardous Waste, International Association of Hydrogeologists, Hannover, Germany, May 1991. Chairman: Stow, S. H.

International Symposium on High-Level Waste Disposal, DOE American Nuclear Society, Las Vegas, Nevada, April 1991. Organizer: Stow, S. H.

Chesapeake Bay Ecological Risk Assessment Workshop, EPA and Chesapeake Research Consortium, Solomons, Maryland, May 1991. Chairman: Suter, G. W.

Conference for College Women, Oak Ridge National Laboratory, Knoxville, Tennessee, May 1991. Session chairman and organizer: Tolbert, V. R.

Marker-Aided Selection Workshop, Biofuels Feedstock Development Program and Weyerhaeuser, Gatlinburg, Tennessee, June 1991. Chairman and organizer: Tuskan, G. A.

21st Southern Forest Tree Improvement Conference, Southern Forest Tree Improvement Committee, Knoxville, Tennessee, June 1991. Organizer: Tuskan, G. A.

Technologies for a Greenhouse-Constrained Society, DOE, Oak Ridge, Tennessee, June 1991. Planning committee: Van Hook, R. I.

Symposium on Individual-Based Approach to Fish Population Dynamics: Theory, Process Studies, and Modeling Approaches, American Fisheries Society, San Antonio, Texas, September 1991. Chairman and organizer: Van Winkle, W. W.

Meeting the Challenges of the 21st Century, Association for Women in Science, Washington, D.C., June 1991. Chairman and organizer: Watts, J. A.

Biomass Energy Strategies Workshop, EPA and DOE, Oak Ridge, Tennessee, November 1990. Chairman and organizer: Wright, L. L.

Publications

ESD staff and guest assignees clear the following with the ORNL Laboratory Records Department for publication during Fy 1991.

Adams, M. B., and G. E. Taylor, Jr. 1990. Effects of ozone on forests in the northeastern United States. pp. 65–92. In Proceedings of the Ozone Risk Communication Conference, University of Massachusetts, Amherst, April 21–22, 1987. Lewis Publishers, Chelsea, Michigan.

Adams, M. B., N. T. Edwards, G. E. Taylor, Jr., and B. L. Skaggs. 1990. Whole-plant ^{14}C-photosynthate allocation in *Pinus taeda* L.: Seasonal patterns at ambient and elevated ozone levels. Can. J. For. Res. 20:152–57.

Adams, M. B., J. M. Kelly, G. E. Taylor, Jr., and N. T. Edwards. 1990. Growth of five families of *Pinus taeda* L. during three years of ozone exposure. New Phytol. 116:689–94.

Adams, S. M. (ed.). 1990. Biological Indicators of Stress in Fish. American Fisheries Society, Bethesda, Maryland.

Adams, S. M. 1990. Biological indicators of toxicity stress. p. 1061. In Book of Abstracts, 17th Annual Workshop on Aquatic Toxicity, Vancouver, British Columbia, November 5–8, 1990.

Adams, S. M. 1991. Use and application of bioindicators for addressing issues of concern to the forestry products industry. Abstracts and Presentations. For National Council of the Paper Industry on Air and Soil Improvement 1991 Southern Regional Meeting, Charleston, South Carolina.

Adams, S. M., and M. S. Greeley, Jr. 1991. Assessment and evaluation of the ecological health of fish populations in Hartwell Reservoir: Exposed to PCBs. Interagency Agreement DOE 1610-D011-1/TVA TV-R0575V. Tennessee Valley Authority, Oak Ridge, Tennessee.

Adams, S. M., M. S. Greeley, and L. R. Shugart. 1990. Direct and indirect mechanisms of chronic contaminant stress on fish populations. p. 297. In Book of Abstracts, 17th Annual Workshop on Aquatic Toxicity, Vancouver, British Columbia, November 5–8, 1990.

Adams, S. M., M. S. Greeley, and L. R. Shugart. 1991. Responses of fish to pollutant stress: Evaluating the relative importance of direct and indirect mechanism. Abstract. For Proceedings of the Sixth International Symposium on Responses of Marine Organisms to Pollutants, Woods Hole Oceanographic Institute, Woods Hole, Massachusetts, April 24–26, 1991.

Allen, T. F. H., and R. V. O'Neill. 1991. Improving predictability in networks: The role of system specification through hierarchy theory. pp. 101–114. In T. P. Burns and M. Higashi (eds.), Theoretical Studies of Ecosystems. Cambridge University Press, Cambridge, England.

Amano, H., and C. T. Garten, Jr. 1991. Uptake of tritium by plants from atmosphere and soil. Environ. Int. 17:23–29.

Andersen, C. P., and S. B. McLaughlin. 1991. Seasonal changes in water relations of *Picea rubens* at two high elevation sites. Tree Physiol. 8:11–22.

Andersen, C. P., S. B. McLaughlin, and W. K. Roy. 1991. A comparison of seasonal patterns of photosynthate production and use in branches of red

spruce saplings at two elevations. Can. J. For. Res. 21(4):455–61.

Andersen, C. P., S. B. McLaughlin, and W. K. Roy. 1991. Foliar injury symptoms and pigment concentrations in red spruce saplings in the southern Appalachians. Can. J. For. Res. 21(7):1119–23.

Anderson, T. A., and B. T. Walton. 1990. Enhanced mineralization of ^{14}C-trichloroethylene in the rhizosphere of a legume from a contaminated field site. p. 45. In Book of Abstracts, 11th Annual Meeting of the Society of Environmental Toxicology and Chemistry, Arlington, Virginia.

Anderson, T. A., J. J. Beauchamp, and B. T. Walton. 1991. Degradation of a mixture of volatile and semivolatile organic chemicals in soil. J. Environ. Qual. 20:420–24.

Ashwood, T. L., D. S. Wickliff, and C. M. Morrissey. 1990. Active sites environmental monitoring program: Program plan. ORNL/M-1197.

Ashwood, T. L., D. S. Wickliff, C. M. Morrissey, and H. L. Adair. 1990. Active sites monitoring at Oak Ridge National Laboratory. pp. 397–99. In Proceedings of SPECTRUM '90 Nuclear and Hazardous Waste Management International Topic Meeting, Knoxville, Tennessee, September 30–October 4, 1990. American Nuclear Society, La Grange Park, Illinois.

Ashwood, T. L., D. S. Wickliff, and C. M. Morrissey. 1991. Active sites environmental monitoring program: Mid-FY 1991 summary report. ORNL/M-1442.

Baes, C. F. III, and C. L. Hardy. 1991. Hazardous terminology. CERCLA Information Brief EH-231-003/0191. DOE Office of Environmental Guidance, Oak Ridge National Laboratory.

Baes, C. F. III, and C. L. Hardy. 1991. RCRA/CERCLA Update. Vol. 90 (4). DOE Office of Environmental Guidance, Oak Ridge National Laboratory.

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Adams, S. M., and D. L. DeAngelis. 1991. "Intermediate Food-Chain Regulations by Prey: A Working Hypothesis." Annual Meeting of the American Fisheries Society, San Antonio, Texas, September.

Adams, S. M., and M. S. Greeley. 1990. "Direct and Indirect Mechanisms of Chronic Stress on Fish Populations." 17th Annual Aquatic Toxicology Workshop, Vancouver, British Columbia, Canada, November.

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Anderson, T. A., and B. T. Walton. 1990. "Enhanced Mineralization of ^{14}C-Trichloroethylene in the Rhizosphere of a Legume from a Contaminated Field Site." 11th Annual Meeting, Society of Environmental Toxicology and Chemistry, Arlington, Virginia, November.

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Ashwood, T. L., D. Wickliff, C. M. Morrissey, and H. L. Adair. 1990. "Active Sites Monitoring at Oak Ridge National Laboratory." Spectrum '90, Knoxville, Tennessee, October.

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Baes, C. F., III. 1991. "The Safe Drinking Water Act." DOE Training (2-day), Gaithersburg, Maryland, April; St. Louis, June; Denver, July.

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Boston, H. L., H. Van Miegroet, I. L. Larsen, A. E. Walzer, and J. E. Carlton. 1990. "The Fate of Radionuclides in Sewage Sludge Applied to Land." Fourth International Conference on Environmental Contamination, Barcelona, Spain, October.

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Brenkert, A. L., R. B. Cook, K. A. Rose, C. C. Brandt, and C. R. Olsen. 1991. "Determination of Sediment Accumulation and Mixing Rates Using ^{137}Cs and ^{210}Pb in Watts Bar Reservoir." Fourth Tennessee Water Resources Symposium, Knoxville, Tennessee, September.

Burlage, R. S. 1991. "Genetically Engineered Bioluminescent Bacterial Reporters as Biosensors in Environmental Samples." Annual Meeting of the Society for Industrial Microbiology, Philadelphia, August.

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Burns, T. P. 1991. "Ascendancy, Fittedness and a Hierarchical Model of Ecosystem Development." International Society for Ecological Modelling Annual Meeting, San Antonio, Texas, August.

Cada, G. F. 1991. "Effects of Hydroelectric Turbine Passage on Fish Early Life Stages." Waterpower '91, Denver, July.

Chang, L. H., S. F. Railsback, and R. T. Brown. 1990. "Modeling Study of Climate Change Effects on Adult Striped Bass Habitat in Douglas Reservoir." Conference on Southern Appalachian Man and the Biosphere, Gatlinburg, Tennessee, November.

Chang, L. H., and S. W. Christensen. 1991. "Use of a Fish Bioenergetics Model to Evaluate Effects of Dissolved Oxygen Mitigation at Norris Dam." Fourth Annual Tennessee Water Resources Symposium, Knoxville, Tennessee, September.

Chason, J. W., and M. A. Huston. 1991. "Spatial and Temporal Variation in Forest Canopy Leaf Area." Association of Southeastern Biologists, Annual Conference, Boone, North Carolina, April.

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Cook, R. B., B. L. Kimmel, and F. O. Hoffman. 1991. "Environmental Contamination: Scientific Data vs Public Perception." WATTec '91, 18th Annual Technical Conference, Knoxville, Tennessee, February.

Cowan, J. H., Jr., K. A. Rose, and E. D. Houde. 1991. "Size-Specific Vulnerability of Fish Larvae to Theoretical Predators: An Individual-Based Numerical Experiment." Annual Meeting of the American Fisheries Society, San Antonio, Texas, September.

Crumby, W. D., S. M. Adams, M. S. Greeley, Jr., and M. G. Ryon. 1991. "Relationships Between Reproductive and Population Responses of Redbreast Sunfish to Pulp Mill Effluents." Annual Meeting of the American Fisheries Society, San Antonio, Texas, September.

Cunningham, M. 1990. "An Investigation of Local Population Size and Propagation of *Aureolaria patula* (Chapm.) Pennell, a Rare Hemiparasite." Natural Areas Conference, Concord, California, October.

Cushman, J. H. 1991. "Future Directions in DOE's Biofuels Research." Biofuels Energy Conference, Davis, California, September.

Cushman, J. H. 1991. "New Directions in Biofuels Feedstock Development Research." Southeastern Regional Biomass Energy Program Planning Committee, Muscle Shoals, Alabama, August.

Cushman, J. H., and S. B. McLaughlin. 1991. "Cellulosic Energy Crops: Developing Forages for Fuel." Southern Pasture and Forage Crop Improvement Conference, Starkville, Mississippi, May.

Cushman, R. M. 1991. "Using Climate Model Output to Assess the Impacts of Climate Change on Water Resources." Water Resources: Planning and Management and Urban Water Resources, New Orleans, May.

Dale, V. H., F. Southworth, R. V. O'Neill, and R. Frohn. 1991. "Simulating Spatial Patterns and Socio-Economic and Ecologic

Effects of Land Use Change in Rondônia, Brazil." Annual Meeting of the Ecological Society of America, Symposium on Theoretical Approaches for Predicting Spatial Effects in Ecological Systems, San Antonio, Texas, August.

Dale, V. H., F. Southworth, R. V. O'Neill, and R. Frohn. 1991. "Linking Socio-Economic Causes and Ecologi: Effects of Deforestation in Rondônia, Brazil." World Congress of International Association for Landscape Ecology, Colloquium on Forest Management Policy and Forest Landscapes, Ottawa, July.

Daniels, R. C. 1991. "Sea Level Rise: Two Case Studies for 2100." Annual Convention of the Association of American Geographers, Miami, April.

Davis, T. L., A. Liu, J. R. Tabor, and R. D. Hatcher, Jr. 1990. "Possible Late Paleozoic (?) Ductile Front Exposed in the Columbus Promontory, North Carolina: Implications for Emplacement of the Blue Ridge-Piedmont Thrust Sheet, Southern Appalachians and the Kinem." Annual Meeting of the Geology Society of America, Dallas, November.

DeAngelis, D. L. 1990. "Smallmouth Bass in Variable Boreal Lake Environments." Annual Meeting of the American Society of Zoology, San Antonio, December.

DeAngelis, D. L. 1991. "Lectures on Population-Ecosystem Ecology." Lecture, Department of Ecology and Environmental Research, University of Uppsala, Uppsala, Sweden, April 1991.

DeAngelis, D. L., T. Friesen, B. J. Shuter, and M. S. Ridgway. 1991. "Modeling Early Life History Stages of Smallmouth Bass in an Ontario Lake." Annual Meeting of the American Fisheries Society, San Antonio, Texas, September.

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D'Surney, S. J., S. Adams, T. W. White, M. Greeley, R. Halbrook, G. W. Suter II, J. McCarthy, and L. Shugart. 1991. "Assessing the Health Status of Antarctic Marine Ecosystems: Consequences of Environmental Pollution." First International Symposium on Ocean Pollution, Mayagüez, Puerto Rico, April.

Eddlemon, G. K. 1990. "Decision Making and NEPA Follow-up." DOE Mid-level Management Training Course on Environmental Laws and Regulations, Richland, Washington, October.

Eddlemon, G. K. 1990. "Preparing NEPA Documentation." DOE Mid-level Management Training Course on Environmental Laws and Regulations, Richland, Washington, October.

Eddlemon, G. K. 1991. "An Approach to Assessing Effects of Radioactive Effluents on Freshwater Invertebrates." 1991 Annual Meeting of North American Benthological Society, Santa Fe, New Mexico, May.

Edwards, G. S., J. M. Kelly, and N. T. Edwards. 1991. "Ozone, Acidic Precipitation, and Soil Mg Effects on Growth and Nutrition of Loblolly Pine Seedlings over Three Growing Seasons." Air and Waste Management Association, Vancouver, British Columbia, June.

Edwards, N. T., P. J. Hanson, T. J. Tschaplinski, L. R. Shugart, and S. J. D'Surney. 1991. "Responses of *Populus*, *Quercus*, *Pinus* and *Glycine max* to Enhanced UV-B Radiation under Field Conditions." Annual American Institute of

Biological Sciences Meeting, San Antonio, Texas, August.

Farrell, M. P., and P. Kanciruk. 1991. "Global Data Bases: Problems and Issues." International Association of Meteorology and Atmospheric Physics Workshop on Climatic Effects of Atmospheric Trace Constituents, Vienna, August.

Flamm, R. O., M. G. Turner, and R. G. Lee. 1991. "Land-Use Patterns: Implications for Long-Term Sustainable Development and Environmental Vitality, Two Conceptual Models." World Congress of Landscape Ecology, Ottawa, July.

Fontaine, T. A. 1990. "Raingage Network Characteristics and Runoff Model Error, Symposium on Urban Hydrology and Drainage Issues." American Water Resources Association Annual Conference, Denver, November.

Fontaine, T. A. 1991. "Modeling Extreme Rainfall Runoff Events." American Water Resources Association Annual Conference, New Orleans, September.

Fontaine, T. A. 1991. "Transport of Contaminated Sediment During Floods in White Oak Creek near Oak Ridge, Tennessee." Fourth Tennessee Water Resources Symposium, Knoxville, Tennessee, September.

Fontaine, T. A., and H. L. Boston. 1991. "Sediment Movement and Contaminant Transport on a Small Watershed." American Geophysical Union Spring Meeting, Baltimore, May.

Foreman, J. L. 1991. "Water-Rock Interaction in the Nolichucky Shale (Upper Cambrian), East Tennessee: Fluid Inclusion and Stable Isotopic Data from Vein Calcites." Sigma X Graduate Student Paper Contest, The University of Tennessee, Knoxville, February.

Foreman, J. L., K. R. Walker, L. J. Weber, S. G. Driese, and R. B. Dreier. 1991. "Slope and Basinal Carbonate Deposition in the Nolichucky Shale (Upper Cambrian), East Tennessee: Effect of Carbonate Suppression by Siliciclastic Deposition on Basin-Margin Morphology." Core Workshop on Mixed Carbonate-Siliciclastic Sequences, Dallas, April.

Francis, C. W., and B. P. Spalding. 1991. "In Situ Grouting of Low-Level Burial Trenches with a Cement-based Grout." Environmental Remediation '91, Pasco, Washington, September.

Franklin, M. J., D. C. White, and H. S. Issacs. 1990. "Effect of Bacterial Biofilms on Carbon Steel Pit Propagation In Phosphate Containing Medium." International Congress on Microbially Influenced Corrosion, Knoxville, October.

Franklin, M. J., J. B. Guckert, D. C. White, and H. S. Issacs. 1991. "Spatial and Temporal Relationships Between Localized Microbial Metabolic Activity and Electrochemical Activity of Steel." Meeting of National Association of Corrosion Engineers, Cincinnati, March.

Friend, A. L., P. T. Tomlinson, E. G. O'Neill, N. T. Edwards, and R. E. Dickson. 1990. "Biochemical Composition of Loblolly Pine Treated with Ozone, Acidic Precipitation, and Magnesium." Annual Meeting of the American Society of Agronomy, San Antonio, Texas, October.

Gardner, R. H., and F. O. Hoffman. 1990. "Past, Present and Future Developments in Uncertainty Analysis." Symposium/Workshop on Validity of Environmental Transfer Models, Stockholm, October.

Garland, S. B., II, G. R. Peyton, and L. E. Rice. 1990. "Evaluation of

Advanced Oxidation Process for Treatment of Groundwater." 63rd Annual Conference, Water Pollution Control Federation, Washington, D.C., October.

Garten, C. T., Jr., P. J. Hanson, P. J. Mulholland, and H. Van Miegroet. 1990. "Nitrogen-15 Abundance in a Forest Watershed Reflects Spatial Variation in N Cycling." Southern Appalachian Man and the Biosphere Conference, Gatlinburg, Tennessee, November.

Gehrs, C. W., J. M. Loar, A. J. Stewart, J. F. McCarthy, L. R. Shugart, and S. M. Adams. 1990. "Biological Monitoring Related to Demonstration of Waste Remediation." Symposium on Environmental Biotechnology: From the Flask to the Field, Knoxville, Tennessee, October.

Gornitz, V., T. W. White, and R. M. Cushman. 1991. "Vulnerability of the U.S. to Future Sea Level Rise." Coastal Zone '91, Long Beach, California, July.

Graham, R. L. 1991. "A Spatially Explicit Analysis of the Potential for Woody Biomass Energy Crops in the United States." International Associate for Landscape Ecology Conference, Ottawa, August.

Graham, R. L. 1991. "Biomass Energy Program at Oak Ridge National Laboratory." EPA Research Laboratory, Corvallis, Oregon, February.

Graham, R. L. 1991. "Classifying Forest Productivity at Different Scales." Symposium—Ecological Land Classification, Charlotte, North Carolina, January.

Graham, R. L. 1991. "Evaluating Forest Land Use Change in Central Africa by Using Satellite Imagery." Second Annual Walker Branch Watershed Research Symposium, Oak Ridge, Tennessee, March.

Graham, R. L. 1991. "Linking Forestry to Energy and Agriculture to Reduce Greenhouse Gas Emissions." Conference on Forests and Global Change, Arlington, Virginia, June.

Graham, R. L. 1991. "Short-Rotation Woody Crops for U.S. Energy Production: The Potential for Reducing National Carbon Dioxide Emissions." Southern Regional Meeting of National Council on Air and Stream Improvement, Charleston, North Carolina, June.

Greeley, M. S., Jr., S. M. Adams, R. Epler, P. Pack, S. Sharp, and E. Tan. "Mixed Function Oxidase Activities as Biomarkers for Pollutant Exposure: Effects of Reproductive Status and Gender." 11th Annual Meeting, Society of Environmental Toxicology and Chemistry, Arlington, Virginia, November.

Greeley, M. S., Jr., A. M. Perez, C. G. Hull, and M. G. Ryon. 1991. "Use of a Fish Embryo-Larval Test to Evaluate the Developmental Toxicity of Water From a Stream Receiving Mixed Industrial Effluents." Sixth International Symposium on Responses of Marine Organisms to Pollutants, Woods Hole, Massachusetts, April.

Gunderson, C. A., and R. J. Norby. 1991. "Photosynthetic Responses of Yellow-Poplar and White Oak to Long-Term Atmospheric CO_2 Enrichment in the Field." American Society of Plant Physiologists—Annual Meeting, Albuquerque, New Mexico, July.

Gwo, J. P., G.-T. Yeh, G. V. Wilson, and P. M. Jardine. "Modeling Subsurface Flow with a Multi-Region Approach." National Spring Meeting of the American Geophysical Union, Baltimore, May.

Gwo, J. P., G.-T. Yeh, P. M. Jardine, and G. V. Wilson. 1991. "A Multi-Region Approach to Modeling Subsurface Transport." National Spring Meeting of the American Geophysical Union, Baltimore, May.

Haase, C. S., W. M. McMaster, S. H. Stow, and R. D. Hatcher. 1991. "An Integrated Hydrologic and Geologic Study to Support Monitoring Compliance and Environmental Restoration Activities at Oak Ridge." Waste Management '91, Tucson, Arizona, March.

Haase, C. S., S. H. Stow, and K. L. Von Damm. 1991. "The Disposal of Liquid Low-Level Radioactive Wastes by Underground Injection at the U.S. DOE's ORNL." Spring Meeting of the American Geophysical Union, Special Session on Hydrological and Hydrochemical Aspects of Deep Underground Injection of Hazardous Wastes, Baltimore, May.

Halbrook, R. S., L. R. Shugart, S. M. Adams, and J. M. Loar. 1991. "Review of Several Studies Associated with a Biological Monitoring and Abatement Program." 18th Annual Toxicity Workshop on Ecological Perspectives on Aquatic Toxicology, Ottawa, September-October.

Halbrook, R. S., J. M. Loar, S. M. Adams, M. C. Black, H. L. Boston, A. J. Gatz, M. S. Greeley, Jr., W. R. Hill, R. L. Hinzman, J. F. McCarthy, M. G. Ryon, E. M. Schilling, J. G. Smith, G. R. Southworth, and A. J. Stewart. 1991. "Tennessee's East Fork Poplar Creek: A Biological Monitoring and Abatement Program." 18th Annual Aquatic Toxicity Workshop, Ottawa, Canada, September.

Hanson, P. J., D. S. Ramer, N. T. Edwards, and T. J. Tschaplinski. 1990. "Contrasting Impacts of UV-B Radiation on Crop and Tree Species: Leaf Physiology." Annual Meeting of the American Society of Agronomy, San Antonio, Texas, October.

Hanson, P. J., M. A. Huston, D. E. Todd, D. F. Grigal, R. A. Goldstein, W. F. Harris, G. S. Henderson, and D. W. Johnson. 1991. "Changing Tree Growth in an Oak-Hickory Forest: The Wet 1970s Versus the Dry 1980s." International Symposium: Physiology and Determination of Crop Yield, Gainesville, Florida, June.

Harrington, B. 1991. "Hydrological Data Analysis with a Geographical Information System." Fourth Tennessee Water Resources Symposium, Knoxville, Tennessee, September.

Hatcher, R. D., Jr., J. A. Austin, Jr., P. R. Stoffa, J. K. Costain, J. Coruh, A. C. Johnston, D. S. Sawyer, and D. T. Secor. 1990. "Southern Appalachian Crustal Section (SACS)." Annual Meeting of the Geological Society of America, Dallas, November.

Haynes, G. J. 1991. "Undergraduate Research Opportunities at the Oak Ridge National Laboratory." North American Benthological Society Annual Meeting, Santa Fe, New Mexico, May.

Hemenway, A., Y. Weber, R. M. Reed, and J. T. Stone, Jr. 1991. "Environmental Analysis of Clean Coal Technologies." Coal in the Environment '91, London, April.

Hill, W. R., and M. G. Ryon. 1991. "Light-Limited Grazer Growth in a Tennessee Stream." North American Benthological Society Annual Meeting, Santa Fe, New Mexico, May.

Hill, W. R., H. L. Boston, and A. D. Steinman. 1991. "Grazing Snails Depress Chlorophyll-Specific Production in Periphyton." North American

Benthological Society Annual Meeting, Santa Fe, New Mexico, May.

Hinzman, R. L., T. D. Richardson, and A. J. Stewart. 1991. "Effects of Suspended Solids on the Feeding Rate of a Lotic Snail." Annual Meeting of the North American Benthological Society, Santa Fe, New Mexico, May.

Hoffman, F. O. 1990. "Conclusions of BIOMOVS Phase I: BIOMOVS on the Validity of Environmental Transfer Models." National Institute of Radiation Protection, Stockholm, October.

Hoffman, F. O. 1991. "The Use of Chernobyl Fallout Data to Test Model Predictions of the Transfer of ^{131}I and ^{137}Cs from the Atmosphere Through Agricultural Food Chains." Third Topical Meeting on Emergency Preparedness and Response, American Nuclear Society, Chicago, April.

Hoffman, F. O., B. G. Blaylock, and J. R. Trabalka. 1991. "Historical Overview of Releases to the Environment of Radioactive Materials and Other Contaminants from the Oak Ridge Facilities." State of Tennessee, Department of Health, Nashville, September.

Holdren, G. R., Jr., T. C. Strickland, P. L. Ringold, B. Rosenbaum, and R. S. Turner. 1990. "Sensitivity of the Critical-Load-Setting Process to Model Selection and Regionalization Schemes." Task Force on Mapping, Working Group on Abatement Strategies, UN-ECE, Geneva, November.

Horwedel, J. E., S. F. Railsback, and H. I. Jager. 1991. "Automated Sensitivity Analysis for FORTRAN Models." Water Resource Planning and Management and Urban Water Resources, 18th Annual Conference and Symposium, New Orleans, May.

Huff, D. D. 1989. "Status of Site Characterization at Oak Ridge." DOE Environmental Biotechnology Group, Berkeley, California, December.

Huff, D. D., and C. S. Haase. 1990. "Groundwater Monitoring Challenges on the Oak Ridge Reservation." DOE/EPA Workshop on Methods for Siting Groundwater Monitoring Wells, Las Vegas, December.

Hunsaker, C. T. 1990. "Assessing Risk of Ecological Disturbance." Ecology and Planning: The Landscape Dimension, Sacramento, California, October.

Hunsaker, C. T. 1990. "Ecological Indicators for the Environmental Monitoring and Assessment Program." Association of Ecological Research Centers, Washington, D.C., November.

Hunsaker, C. T. 1990. "Ecosystem Assessment Methods for Cumulative Effects at the Regional Scale." Ecology and Planning: The Landscape Dimension, Sacramento, California, October.

Hunsaker, C. T., R. V. O'Neill, D. A. Levine, S. P. Timmins, and B. L. Jackson. 1991. "Proof of Concept Research on Landscape Characterization." Ecological Society of America Meeting, San Antonio, Texas, July.

Hunsaker, C. T., and R. V. O'Neill. 1991. "Landscape Characterization for Regional Ecological Risk Assessment." International Association of Landscape Ecology World Congress, Ottawa, July.

Hunsaker, C. T., D. A. Levine, S. P. Timmins, B. L. Jackson, and R. V. O'Neill. 1990. "Landscape Characterization for Assessing Regional Water Quality." International Symposium on Ecological Indicators, Fort Lauderdale, Florida, October.

Hunsaker, C. T., D. E. Carpenter, and M. C. Fabrizio. 1991. "Indicators and Integration: Weaving the Fabric of Regional Assessment." 76th Annual Meeting of the Ecological Society of America, San Antonio, Texas, August.

Hunsaker, C. T., R. A. Nisbet, D. Lam, J. A. Browder, M. G. Turner, W. L. Baker, and D. B. Botkin. 1991. "Spatial Models of Ecological Systems and Processes: The Role of GIS." First International Conference/Workshop on Integrating Geographic Information Systems and Environmental Modeling, Boulder, Colorado, September.

Huston, M. A. 1991. "Second Annual Walker Branch Watershed Research Symposium." ESD, ORNL, Oak Ridge, Tennessee, March.

Jackson, B. L. 1991. "SAS Macros for Converting Between ARC/INFO Import/Export Files and SAS Data Sets." SAS Users Group International 16th Annual Conference, New Orleans, February.

Jacobs, G. K. 1990. "In Situ Vitrification for Remediation of Contaminated Soils." Geological Sciences Colloquia. The University of Tennessee, Knoxville, Tennessee, October.

Jager, H. I., and W. S. Overton. 1991. "Explanatory Models for Ecological Response Surfaces." First International Conference/Workshop on Integrating Geographic Information Systems and Environmental Modeling, Boulder, Colorado, September.

Jardine, P. M., F. M. Dunnivant, and J. F. McCarthy. 1990. "Modeling the Transport of Dissolved Organic Carbon in Aquifer Columns." American Society of Agronomy National Meeting, San Antonio, Texas, October.

Jardine, P. M., G. V. Wilson, J. F. McCarthy, R. J. Luxmoore, P. A. Taylor, and L. W. Zelazry. 1990. "Hydrogeochemical Processes Controlling the Transport of Dissolved Organic Carbon Through a Forested Hillslope." American Society of Agronomy National Meeting, San Antonio, Texas, October.

Kay, D. P., and T. J. Tschaplinski. 1991. "Induction of Plant Secondary Metabolites Confers Protection Against Short-Term Exposure to Enhanced Levels of UV-B Radiation." 1991 EUREKA Conference, Pasadena, California, March.

Kelly, J. M., G. S. Edwards, and N. T. Edwards. 1990. "Growth and Nutrition of Loblolly Pine Seedlings as Affected by Ozone, Rainfall Acidity, and Soil Mg Status." Annual Meeting of the Soil Science Society of America, San Antonio, Texas, October.

Kim, K. H., and S. Y. Lee. 1990. "Immobilization of Radiostrontium in Contaminated Soils by Phosphate Treatment." American Society of Agronomy National Meeting, San Antonio, Texas, October.

Kim, K. H. and S. Y. Lee. 1990. "Immobilization of Radioactive Strontium in Contaminated Soils by Phosphate Treatment." Fall Meeting of the Material Research Society, Symposium on Scientific Basis for Nuclear Waste Management, Boston, November.

Kimmel, B. L. 1991. "Off-Site ER Program Activities—An Overview." ORNL/UT/TVA Water Resources Consortium, Knoxville, Tennessee, September.

Kimmel, B. L. 1991. "Reservoirs as Ecosystems—A Conceptual View." International Seminar on Limnology, Guadalajara, Mexico, February.

Kimmel, B. L., and D. W. Swindle. 1990. "Remedial Investigation of Clinch River and Watts Bar Reservoir Contamination." American Nuclear Society, Washington, D.C., November.

King, A. W. 1991. "Quantifying Regional Changes in Terrestrial Carbon Storage by Extrapolation from Local Ecosystem Models." Workshop on Carbon Cycling in Boreal Forest and Subarctic Ecosystems, Corvallis, Oregon, September.

King, A. W., W. R. Emanuel, and W. M. Post. 1991. "Terrestrial Ecosystems as Part of the Global Carbon Cycle: Source or Sink." Annual Meeting of the Ecological Society of America, San Antonio, August.

Kszos, L. A., A. J. Stewart, and P. A. Taylor. 1990. "An Evaluation of Nickel Toxicity in a Contaminated Stream and in Laboratory Tests." Society of Environmental Toxicology and Chemistry, 11th Annual Meeting, Arlington, Virginia, November.

Kszos, L. A., M. G. Ryon, J. G. Smith, J. M. Loar, and A. J. Stewart. 1990. "Biomonitoring to Evaluate Water Quality: A Synthesis of Toxicity Test Data and Surveys of Invertebrate and Fish Communities." Water Pollution Control Federation, 63rd Annual Meeting, Washington, D.C., October.

Letcher, B. H., J. A. Rice, and K. A. Rose. 1991. " A Simulation Model Examination of the Relative Importance of Starvation vs Predation Mortality of Larval Fish." 76th Annual Meeting of the Ecological Society of America, San Antonio, Texas, August.

Levine, D. A., and C. T. Hunsaker. 1991. "Using GIS to Apply Field-Scale Models to Watershed-Level Processes: Nutrient and Sediment Movement." First International Conference/Workshop on Integrating Geographic Information Systems and Environmental Modeling, Boulder, Colorado, September.

Levine, M. B. 1990. "The Clean Water Act." DOE Workshop (4-Day), Richland, Washington, October; Chicago, October; Savannah River, South Carolina, November.

Levine, M. B. 1990. "Risk Assessment and Risk Management." DOE Workshop (4-Day), Chicago, October; Richland, Washington, October; Savannah River, South Carolina, November.

Levine, M. B. 1990. "The Clean Water Act." Overview Course, Oak Ridge, Tennessee, November; Piketon, Ohio, November; Paducah, Kentucky, December.

Levine, M. B. 1990. "The Clean Air Act." Overview Course, Piketon, Ohio, November.

Levine, M. B. 1990. "The Safe Drinking Water Act." Overview Course, Piketon, Ohio, November; Paducah, Kentucky, December.

Levine, M. B. 1990. "Overview of Environmental Laws and Regulations for Environmental Protection Officers." Presentation, Environment, Safety, and Health Workshop for Environmental Protection Officers, ANL, Argonne, Illinois, November.

Levine, M. B. 1990. "The DOE NEPA Compliance Strategy." Overview Course, Piketon, Ohio, November; Paducah, Kentucky, December.

Liang, L., J. F. McCarthy, and T. M. Williams. 1991. "Iron Dynamics During Injection of Dissolved Organic Carbon into a Sandy Aquifer." National

Meeting of the American Chemistry Society, Symposium on Shallow Aquifer Chemistry, Atlanta, April.

Liang, L., and J. F. McCarthy. 1991. "Colloidal Transport of Metal Contaminants." Metal Speciation and Comtamination of Soil, Jekyll Island, Georgia, May.

Lien, S. C. T., A. S. Kubo, and N. H. Cutshall. "DOE Office of Technology Development Serves Environmental Restoration and Waste Management Needs." Annual Meeting of the American Associati .n for Advancement of Science, Washington, D.C., February.

Lindberg, S. E. 1991. "The Flux of Sulfate in Forest Canopy Throughfall: An Indicator of Atmospheric Deposition or a Coincidental Relationship." International Conference on Atmosphere/Surface Exchange Processes, Richland, Washington, June.

Lingle, W. N., T. D. Sherrod, J. M. Loar, W. W. Tolbert, and B. L. Kimmel. 1991. "Off-Reservation Activities of the DOE Oak Ridge Environmental Restoration Program." Governor's Office Briefing, Nashville, Tennessee, May.

Loar, J. M. 1991. "Biological Monitoring Programs on the DOE Oak Ridge Reservation." State of Tennessee Governor's Office, Nashville, Tennessee, May.

Loar, J. M. 1991. "Ecological Effects of Nonpoint-Source Pollution." U.S. Senate Subcommittee on Environmental Protection, Washington, D.C., July.

Loar, J. M. 1991. "Ecological Risk of Aquatic Habitat Degradation." American Chemical Society, New York, August.

Luxmoore, R. J. 1991. "Evaluation of Temporal Changes in Soil Barrier Water Content." 17th Annual EPA Hazardous Waste Research Symposium, Cincinnati, April.

Luxmoore, R. J., A. W. King, and M. L. Tharp. 1991. "Approaches to Scaling Up Physiological Processes of Conifers." International Union of Forest Research Organizations International Symposium, Abakan, U.S.S.R., August.

Luxmoore, R. J., M. Cunningham, L. K. Mann, and M. G. Tjoelker. 1990. "Urea Fertilization Effects on Growth and Nutrition of American Sycamore." Soil Science Society of America Annual Meeting, San Antonio, Texas, October.

Marland, G. 1991. "Carbon Dioxide Emissions from Fossil-Fuel-Based Electricity Systems." Environmental Challenges for Asian-Pacific Energy Systems, Kuala Lumpur, Malaysia, January.

Marland, G. 1991. "Global Climate Change: Some Implications, Opportunities, and Challenges for U.S. Forestry." 21st Southern Forest Tree Improvement Conference, Knoxville, Tennessee, July.

McCarthy, J. F. 1991. "Field Manipulations of Colloids in a Sandy Aquifer." Commissariat de l'Energie Atomique, Paris, May.

McCarthy, J. F. 1990. "Subsurface Transport of Contaminants: Role of Mobile Colloidal Particles." Annual Meeting of the Soil Science Society of America, San Antonio, Texas, October.

McCarthy, J. F. 1991. "Role of Colloids in Subsurface Transport of Contaminants." Michigan State University, East Lansing, Michigan, January.

McCarthy, J. F., S. M. Adams, M. S. Greeley, Jr., R. S. Halbrook, and L. R. Shugart. 1991. "Biomarker-Based Biomonitoring for Evaluating Health and Ecological Effects of Environmental Contamination." 15th Annual U.S. Army Environmental Research and Development Symposium, Williamsburg, Virginia, June.

McCarthy, J. F., R. S. Halbrook, and L. R. Shugart. 1991. "Conceptual Strategy for Design, Implementation, and Validation of a Biomarker-Based Biomonitoring Capability." NATO Advanced Research Workshop, Texel, The Netherlands, May.

McCarthy, J. F., L. Liang, P. M. Jardine, and T. M. Williams. 1990. "Field Manipulations of Colloids in a Sandy Aquifer." DOE Meeting on Concepts in Manipulating Colloids, Manteo, North Carolina, October.

McClellan, E. A., and R. D. Hatcher, Jr. 1991. "Deformation and Accretionary Succession in Part of the Southern Trondheim Nappe, Einunnfjellet-Savalen Area and Northern Jotun Nappe Tesse-Lom Area, Southern Norway." International Geological Correlation Programme, Tromso, Norway, August.

Mulholland, P. J. 1991. "Hydrogeochemistry of Walker Branch, a Small Forested Watershed in the Ridge and Valley Province of Eastern Tennessee." Water Resources Initiative Seminar Series, Tennessee Valley Authority, Norris, Tennessee, July.

Mulholland, P. J. 1991. "Hydrology and Chemistry of a First-Order Stream in Karst Terrain: Effects of Soil Zone and Bedrock Zone Flow." Fourth Tennessee Water Resources Symposium, Knoxville, Tennessee, September.

Mulholland, P. J., and A. D. Rosemond. 1991. "Response of Periphyton to a Longitudinal Nutrient Gradient in a Forest Stream." Annual Meeting of the North American Benthological Society, Sante Fe, New Mexico, May.

Mulholland, P. J., and A. D. Steinman. 1991. "Mechanisms of Nutrient Cycling in Nutrient-Limited Streams." Annual Meeting of the Ecological Society of America, San Antonio, Texas, August.

Niemela, S. L., S. M. Adams, M. S. Greeley, Jr., D. Dycus, and R. McPherson. 1991. "PCB Accumulation and Reproduction in Largemouth Bass." Annual Meeting of the American Fisheries Society, San Antonio, Texas, September.

Nivens, D. E. 1990. "Non-Destructive Monitoring of Microbial Biofilms at Solid-Liquid Interfaces Using On-Line Devices." International Congress on Microbially Influenced Corrosion, Knoxville, Tennessee, October.

Norby, R. J. 1991. "Carbon Storage by Forests in a CO_2 Enriched Atmosphere: Physiological and Microbial Feedbacks." Gordon Research Conference, Applied and Environmental Microbiology, New London, New Hampshire, July.

Nyquist, J. E., G. K. Moore, S. C. Young, and R. B. Clapp. 1991. "Use of Electromagnetic Borehole Flowmeter to Delineate Groundwater Producing Fractures." Fourth Annual Tennessee Water Resources Symposium, Knoxville, Tennessee, September.

O'Neill, E. G., and R. J. Norby. 1991. "First-Year Decomposition Dynamics of Yellow-Poplar Leaves Produced Under CO_2 Enrichment." Annual Meeting Ecological Society of America, San Antonio, Texas, August.

O'Neill, R. V., C. T. Hunsaker, and D. A. Levine. 1990. "Monitoring

Challenges and Innovative Ideas." Ecological Indicators, Ft. Lauderdale, Florida, October.

O'Neill, R. V. 1990. "Presentation on Land Characterization." Meeting of Association of Ecosystem Research Centers, Washington, D.C., November.

Olsen, C. R. 1991. "Cosmogenic Beryllium-7: New Tracer Applications for Quantifying Environmental Processes." Annual Meeting of Geological Society of America, Symposium on Geology and the Environment: Studies of Natural and Man-made Radionuclides, Baltimore, May.

Olsen, C. R. 1990. "Radionuclide Tracers for Estuarine Processes." Presentation, NOAA Headquarters, Washington, D.C., November.

Palumbo, A. V., P. A. Boerman, G. W. Strandberg, T. L. Donaldson, H. L. Jennings, T. J. Phelps, A. J. Lucero, D. C. White, and S. E. Herbes. 1991. "A Co-Metabolic Approach to Groundwater Remediation." Environmental Remediation '91: Cleaning Up the Environment for the 21st Century, Pasco, Washington, September.

Palumbo, A. V., W. Eng, P. A. Boerman, G. W. Strandberg, T. L. Donaldson, and S. E. Herbes. 1991. "The Effects of Diverse Organic Contaminants on Trichloroethylene Degradation by Methanotrophic Bacteria and Methane-Utilizing Consortia." In Situ and On-Site Bioreclamation, An International Symposium, San Diego, March.

Parker, A., A. V. Palumbo, J. F. McCarthy, and P. M. Jardine. 1991. "Growth of Bacteria from Deep Subsurface Environments in Response to Water and Nutrient Additions." 91st Annual Meeting, American Society of Microbiology, Dallas, May.

Peng, T.-H. 1991. "Distribution of Radiocarbon in the Antarctic Ocean: Implications Regarding Effects of Ozone Depletion on Global Carbon Cycle." 14th International Radiocarbon Conference, Tucson, Arizona, May.

Peng, T.-H., and W. S. Broecker. 1991. "Dynamical Limitations on the Antarctic Iron Fertilization Strategy." 1990 Fall Meeting of American Geophysical Union, San Francisco, December.

Railsback, S. E. 1991. "Dispersion and Fate of Wastewater Released from Submerged and Surface Discharges at McMurdo Station, Antarctica." First International Ocean Pollution Symposium, Mayagüez, Puerto Rico, May.

Railsback, S. E. 1991. "U.S. Department of Energy Reservoir Research Activities at Oak Ridge National Laboratory." Interagency Research Meeting, Reservoir Water Quality, Denver, February.

Railsback, S. F., and M. J. Sale. 1991. "Review of Mitigation Effectiveness for Fisheries and Water Quality." Water Power '91, Denver, July.

Railsback, S. F., G. F. Cada, L. J. Chang, and M. J. Sale. 1991. "Review of Mitigation Methods for Fish Passage, Instream Flows, and Water Quality." Water Power '91, Denver, July.

Reed, R. M. 1990. "Decision Making and NEPA Follow-Up." DOE Mid-Level Management Training Course on Environmental Laws and Regulations, Willowbrook, Illinois, October.

Reed, R. M. 1990. "NEPA Compliance Planning." DOE Mid-Level Management Training Course on Environmental Laws and Regulations, Richland, Washington, October.

Reed, R. M. 1990. "Preparing NEPA Documentation." DOE Mid-Level Management Training Course on Environmental Laws and Regulations, Willowbrook, Illinois, October.

Reed, R. M. 1990. "Special Topics in the NEPA Process I. Integrating Other Environmental Laws into NEPA Reviews." DOE Mid-Level Management Training Course on Environmental Laws and Regulations, Richland, Washington, October.

Reed, R. M., Y. Weber, J. T. Stone, and A. Hemenway. 1991. "Clean Coal Technology Demonstration Program: Part II, Environmental Impacts." First World Coal Institute Conference on Coal in the Environment, London, April.

Reed, R. M., M. S. Salk, and J. W. Webb. 1991. "Evaluation of Impacts on Wetlands: Do NEPA Analyses Integrate Wetland Protection Requirements?" 1991 Conference of National Association of Professionals, Baltimore, April-May.

Reed, R. M., Sigal, L. L., and J. W. Webb. 1991. "Using Programmatic EIAs: When, Where, and How?" 11th Annual Meeting of International Association for Impact Assessment, Urbana, Illinois, June.

Reyes, O., and H. H. Einstein. 1991. "Failure Mechanisms of Fractured Rock—A Fracture Coalescence Model." Seventh International Congress of the International Society of Rock Mechanics, Aachen, Germany, September.

Richardson, T. D., and A. D. Rosemond. "Food Selection in a Lotic Generalist: Effects of Nutrients Additions on Snail Foraging Behavior." Annual Meeting of the North American Benthological Society, Santa Fe, New Mexico, May.

Rose, K. A. 1991. "Individual-Based Modeling of Fish Population Dynamics." Eighth Annual Southeastern Mathematical/Statistical Ecology Conference, Fontana Dam, North Carolina, March.

Rose, K. A., and J. Cowan. 1991. "Individual-Based Modeling of YOY Striped Bass Population Dynamics." Annual Meeting of the American Fisheries Society, San Antonio, Texas, September.

Rosemond, A. D. 1991. "An Autumnal Shift from Herbivory to Detritivory in a Woodland Stream and the Consequent Effects on Algae." 76th Annual Meeting of the Ecological Society of America, San Antonio, Texas, August.

Rosemond, A. D. 1991. "Seasonal Changes in Factors Controlling Algal Biomass and Productivity in a Deciduous Forest System." Annual Meeting of the North American Benthological Society, Santa Fe, New Mexico, May.

Sale, M. J., and R. G. Otto. 1991. "Improved Methods for Determining Instream Flow Requirements for Fish Populations." Water Power '91, Denver, July.

Salk, M. S. 1990. "NEPA Compliance Planning." DOE Environmental Laws and Regulations Course, Augusta, Georgia, November.

Salk, M. S. 1990. "Special Topics in the NEPA Process: Integrating Other Environmental Review Requirements into NEPA Reviews." DOE Environmental Laws and Regulations Course, Albuquerque, New Mexico, August; Oak Ridge, Tennessee, August; Augusta, Georgia, November.

Salk, M. S., and L. N. McCold. 1991. "NEPA and the Endangered Species Act: Complementary Approaches or Regulatory Excess." 1991 National Association of Environmental Professionals Annual Conference, Baltimore, April-May.

Shugart, L. R. 1990. "DNA Alterations as Potential Biomarker in Evaluating Exposure and Environmental Effects of Toxic Chemicals." 11th Annual Meeting, Society of Environmental Toxicology and Chemical, Arlington, Virginia, November.

Shugart, L. R. 1991. "Strategies for Assessing the Health of the Pilar Ecosystems." First International Symposium on Ocean Pollution, Mayagüez, Puerto Rico, May.

Shugart, L. R., J. F. McCarthy, J. J. Beauchamp, D. H. Rosenblatt, M. Small, J. E. Caton, and W. H. Griest. 1991. "TNT Metabolites in Animal Tissues from U.S. Army Ammunition Sites." 15th Annual U.S. Army Environmental R&D Symposium, Williamsburg, Virginia, June.

Siegrist, R. L. 1990. "Data Quality Management for Difficult Contaminants." Data Sufficiency and Decision Making for Site Remediation, short course, University of Wisconsin, Madison, November.

Siegrist, R. L. 1990. "Development and Implementation of Soil Quality and Cleanup Criteria for Contaminated Sites." Third International KfK/TNO Conference on Contaminated Soils, Karlsruhe, Federal Republic of Germany, December.

Siegrist, R. L. 1990. "International Review of Approaches for Establishing Cleanup Goals for Hazardous Waste Contaminated Land." Multi-Stakeholder Contaminated Sites Consultation Workshop, Canadian Council of Ministers of the Environment, Toronto, November.

Siegrist, R. L. 1990. "Methods Development for Sampling Contaminated Soils and Sediments for Volatile Organic Compound Measurements." (Poster presentation.) Third International KfK/TNO Conference on Contaminated Soils, Karlsruhe, Federal Republic of Germany, December.

Siegrist, R. L. 1990. "Soil Sampling Techniques for Contaminated Site Remediation." Understanding Site Remediation, short course for the Tennessee Valley Authority National Fertilizer and Environmental Research Center by the University of Wisconsin, Muscle Shoals, Alabama, October.

Siegrist, R. L. 1991. "Balance in Environmental Measurements: Issues and Challenges Associated with Sampling." 33rd Rocky Mountain Conference on Analytical Chemistry, Denver, July.

Siegrist, R. L. 1991. "Bioremediation of Polluted Soils: An Overview." Buried Waste Deposits and Polluted Soils, Norwegian Centre for Soil and Environmental Research, Aas, Norway, September.

Siegrist, R. L. 1991. "Data Quality Management for Difficult Contaminants. Data Sufficiency and Decision Making for Site Remediation, Short course, University of Wisconsin, Madison, November.

Siegrist, R. L. 1991. "Environmental Sampling at Contaminated Sites: Issues and Challenges." Pittsburgh Conference on Analytical Chemistry, Chicago, March.

Siegrist, R. L. 1991. "Volatile Organic Compounds in Soils as Affected by Sampling Practices and Some Implications for Soil Remediation." National Symposium on Soil Venting, Environmental Protection Agency, Houston, April.

Siegrist, R. L. 1991. "Data Quality Management for Difficult Contaminants: Volatile Organic Compounds." Workshop on Data Sufficiency and Decision Making for Site Remediation, San Diego, June.

Sigal, L. L. 1990. "Decision Making and NEPA Follow-Up." DOE Mid-Level Management Training Course on Environmental Laws and Regulations, Augusta, Georgia, November.

Sigal, L. 1991. "Tiger Team Assessments: NEPA Compliance Lessons Learned." DOE Training Course: Environmental Laws and Regulations, Oak Ridge, Tennessee, August.

Sigal, L., and A. N. Miller. 1991. "International Environmental Impact Assessment." 16th Annual Conference of the National Association of Environmental Professionals, Baltimore, April.

Sigmon, C. F. 1990. "Comprehensive Environmental Response, Compensation, and Liability Act." DOE Training, Portsmouth, Ohio, November; Paducah, Kentucky, December.

Sigmon, C. F. 1990. "Resource Conservation and Recovery Act." DOE Training, Oak Ridge, Tennessee, October; Portsmouth, Ohio, November; Paducah, Kentucky, December.

Sigmon, C. F. 1990. "Toxic Substances Control Act." DOE Training, Oak Ridge, Tennessee, October; Portsmouth, Ohio, November; Paducah, Kentucky, December.

Sigmon, C. F. 1991. "Environmental Compliance Auditing Workshop: Evaluating Compliance with Selected Portions of RCRA." Training Workshop, Las Vegas, April.

Smith, E. D. 1991. "Integrating NEPA and CERCLA." Oak Ridge Hydroforum, Oak Ridge, Tennessee, February.

Smith, J. G., J. A. Williams, and A. W. McWhorter. 1991. "Evaluation of Sphaeriid Clam (*Sphaerium fabale*) Natality as an Indicator of Water Quality." 39th Annual Meeting of the North American Benthological Society, Santa Fe, New Mexico, May.

Solomon, D. K., E. A. Sudicky, J. A. Cherry, and R. T. Poreda. 1990. "Effects of Dispersion on $^{3}H/^{3}He$ Ages in Shallow Aquifers." American Geophysical Union Fall Meeting, San Francisco, December.

Solomon, D. K., R. T. Poreda, E. A. Sudicky, and J. A. Cheng. 1990. "Groundwater Dating with ^{3}H and ^{3}He Isotopes: Effects of Dispersion and Utility for Defining Groundwater Flow and Solute Transport Parameters." Concepts in Manipulating Groundwater Colloids, Manteo, North Carolina, October.

Steinman, A. D., and H. L. Boston. 1991. "Photosynthetic Characteristics of Lotic Bryophytes." North American Benthological Society, Santa Fe, New Mexico, May.

Stewart, A. J., and J. M. Loar. 1990. "Spatial and Temporal Variability of Biomonitoring Data." Biological Monitoring of Freshwater Ecosystems, West Lafayette, Indiana, November-December.

Stewart, A. J., W. R. Hill, and K. D. Ham. 1991. "Chlorine Dynamics and Toxicity in an Industrially Impacted Stream." Annual Meeting of the North American Benthological Society, Santa Fe, New Mexico, May.

Stone, J. T., A. Hemenway, R. M. Reed, and Y. Weber. 1991. "Clean Coal Technology Demonstration Program: Part I, Technologies and Emissions." First World Coal Institute Conference on Coal in the Environment, London, April.

Stoss, F. W. 1991. "CDIAC: Responding to Changing Information Needs." 84th Annual Meeting, Air and Waste Management Association, Vancouver, British Columbia, June.

Stoss, F. W. 1991. "Carbon Dioxide Information Analysis Center: Providing Information About Global Change." Annual Meeting of the American Association for the Advancement of Science, Washington, D.C., February.

Stow, S. H. 1991. "Environmental Restoration Activities on the Oak Ridge Reservation." Presentation to Local Civic Group, Harriman, Tennessee, April.

Stow, S. H. 1991. "The SARE Program of the Geological Society of America." American Association of State Geologists, Saratoga Springs, New York, May.

Suter, G. W., II. 1990. "Estimation of Risks of Contaminants to Populations of Aquatic Organisms." EPA Workshop on Recommendations for Revising the National Water Quality Criteria Guidelines, Arlington, Virginia, December.

Suter, G. W., II. 1990. "Extrapolation Error and Use of Uncertainty Factors." Organization for Economic Cooperation and Development Workshop on the Extrapolation of Aquatic Toxicity Data to the Real Environment, Arlington, Virginia, December.

Suter, G. W., II. 1990. "Rapid Chronic Tests as Surrogates for Life Cycle Tests." EPA Workshop on Recommendations for Revising the National Water Quality Criteria Guidelines, Arlington, Virginia, December.

Suter, G. W., II, and L. W. Barnthouse. 1990. "Application of Risk Assessment Paradigms to the Chesapeake Bay." Chesapeake Research Conference on New Perspectives in the Chesapeake System, Baltimore, December.

Suter, G. W., II, S. W. Christensen, and Y. I. Jager. 1991. "Fitting Exposure-Response Models to Tests of Acidification Effects on Fish." Annual Meeting, Society of Environmental Toxicology and Chemistry, Arlington, Virginia, November.

Timmins, S. P., B. J. Jackson, and C. T. Hunsaker. 1991. "Landscape Modelling for a Nationwide Raster Dataset: The Need for Algorithm Efficiency and Data Compression." National Center for Geographic Information Analysis, Boulder, Colorado, September.

Tolbert, V. R., H. J. Eckman, and J. G. Smith. 1991. "Effects of Differences in Temperature and Water Quality on the Distribution of *Hydropsyche depravata* in East Fork Poplar Creek." North American Benthological Society Annual Meeting, Santa Fe, New Mexico, May.

Toran, L. E., D. K. Solomon, W. M. McMaster, and C. M. Morrissey. 1991. "Matrix Diffusion as a Mechanism to Explain Recent Tritium and Old ^{14}C in Groundwater from Fractured Sedimentary Rocks." American Geophysical Union Spring Meeting, Baltimore, May.

Toran, L. E., D. K. Solomon, W. M. McMaster, and C. M. Morrissey. 1991. "Uncertainties in ^{14}C Dating in Fractured Sedimentary Rocks on the Oak Ridge Reservation." Fourth

Tennessee Water Resources Symposium, Knoxville, Tennessee, September.

Trabalka, J. R., and S. I. Auerbach. 1990. "One Western Perspective of the 1957 Soviet Nuclear Accident." International Union of Radioecologists, Seminar on Comparative Assessment of the Environmental Impact of Radionuclides Released During Three Major Nuclear Accidents, Kyshtym, Windscale, and Chernobyl, Luxembourg, Belgium, October.

Tschaplinski, T. J. 1991. "Drought Resistance of *Populus deltoides* Bartr. cv. Siouxland." Southern Biomass Conference, Baton Rouge, Louisiana, January.

Tschaplinski, T. J., D. B. Stewart, P. J. Hanson, and R. J. Norby. 1991. "Osmotic Adjustment in Five Tree Species Under Elevated CO_2 and Water Stress." American Society of Plant Physiologists, Albuquerque, New Mexico, July.

Turner, M. G., W. H. Romme, and R. H. Gardner. 1991. "Landscape Disturbance Models and the Long-Term Dynamics of Natural Areas." 76th Annual Meeting of the Ecological Society of America, San Antonio, Texas, August.

Turner, R. R., and K. L. Willett. 1991. "Chemical Form of Mercury in Contaminated Soil Affects Performance on Leaching Test." Annual Meeting of American Chemical Society, Atlanta, April.

Turner, R. S. 1990. "Susceptibility of Asian Ecosystems to Soil-Mediated Acid Rain Damage." Second Workshop on Acid Rain in Asia, Bangkok, Thailand, November.

Van Hook, R. I. 1991. "Biofuel Feedstock and the Environment." Environmental and Energy Study Institute Congressional Work Session on Alternate Fuels, Washington, D.C., May.

Van Hook, R. I. 1991. "Future Environmental Chemistry Needs: A National Laboratory Perspective." Planning Workshop on Environmental Chemistry and Chemical Engineering, Washington, D.C., May.

Van Hook, R. I. 1991. "The Role of Biofuel in Reducing CO_2 Emissions to the Atmosphere." U.S. Alternative Fuels Council, Denver, February.

Van Miegroet, H., D. W. Johnson, and D. E. Todd. 1990. "Soil Solution Chemistry in Spruce-Fir Forests at Different Elevations in the Great Smoky Mountains National Park in the United States." International Conference on Acidic Deposition—Its Nature and Impacts, Glasgow, United Kingdom, September.

Van Miegroet, H., D. W. Johnson, and D. E. Todd. 1990. "Spruce Nutrition in the Great Smoky Mountains—Testing the Ca-Mg Deficiency Thypothesis." Soil Science Society of America Annual Meeting, San Antonio, Texas, October.

Van Miegroet, H., D. W. Johnson, D. E. Todd, and J. D. Goodlaxson. 1990. "Nitrogen Dynamics in High-Elevation Spruce Sites in the Great Smoky Mountains National Park." First Southern Appalachian Man and the Biosphere Conference, Gatlinburg, Tennessee, November.

Van Miegroet, H., H. L. Boston, and D. W. Johnson. 1991. "The Role of Land Application of Municipal Sludge in Short-Rotation Woody Biomass Production." 1991 Southern Biomass Conference, Baton Rouge, Louisiana, January.

Von Damm, K. L. 1991. "Seafloor Hydrothermal Activity at 9-10°N EPR: First Results from a New System." Department of Geology, Georgia State University, Atlanta, May.

Von Damm, K. L. 1991. "Seafloor Hydrothermal Activity at 9–10°N EPR: First Results from a New System." Department of Geology, The University of Tennessee, Knoxville, Tennessee, August.

Von Damm, K. L., J. M. Grebmeier, I. L. Larsen, and C. R. Olsen. 1990. "Identification of Sediment Sources and Short-Term Sediment Remobilization in the Savannah River Estuary Using ^{7}Be, ^{B7}Cs, and ^{210}Pb." American Geophysical Union, San Francisco, December.

Voorhees, L. D. 1991. "Development and Implementation of the Oak Ridge Field Office Environmental Information System (OREIS)." Energy Systems Environmental, Safety and Health Managers Meeting, Oak Ridge, Tennessee, July.

Voorhees, L. D. 1991. "Development and Implementation of the Oak Ridge Field Office Environmental Information System (OREIS)." DOE/EPA/TDEC/Energy Systems Senior Managers Meeting, Chattanooga, Tennessee, July.

Voorhees, L. D. 1991. "Status of the Oak Ridge Field Office Environmental Information System (OREIS)." Environmental Restoration Regulatory Interface Meeting, Knoxville, Tennessee, September.

Voorhees, L. D., and R. A. McCord. 1991. "Development of a Consolidated Data Base System for Environmental Data at Oak Ridge DOE Facilities." DOE Conference, Environmental Remediation '91, Pasco, Washington, September.

Webb, J. Warren. 1990. "Preparing NEPA Documentation." DOE/OR Environmental Restoration NEPA Training, Oak Ridge, Tennessee, December.

Whicker, F. W., H. Grogan, U. Berstrom, and F. O. Hoffman. 1990. "BIOMOVS Scenario B-8: The Relative Importance of Ingestion for Multiple Pathway Dose Assessments." BIOMOVS on the Validity of Environmental Transfer Models, National Institute of Radiation Protection, Stockholm, October.

White, D. C., D. E. Nivens, N. W. Mittelman, J. Q. Chambers, J. M. H. King, and G. S. Sayler. 1991. "Non-Destructive On-Line Monitoring of MIC." Corrosion '91, National Association Corrosion Engineering Symposium, Cincinnati, March.

White, T. W. 1991. "The Global Coastal Hazards Data Base Created From Multiple Polygon Coverages in ARC/INFO." Environmental Systems Research Institute 11th Annual User Conference, Palm Springs, California, May.

Wicker, L. F., and J. E. Richmond. 1990. "The Effects of Perrier Water and Trace Metal Amendment on the Fecundity of *Ceriodaphnia dubia*." 11th Annual Meeting, Society of Environmental Toxicology and Chemistry, Global Environmental Issues: Challenge for the 90s, Arlington, Virginia, November.

Wicker, L. F., and J. E. Richmond. 1990. "The Effects of Perrier Water and Trace Metal Amendment on the Fecundity of *Ceriodaphnia dubia*." Society of Environmental Toxicology and Chemistry, 11th Annual Meeting, Global Environmental Issues: Challenge for the 90s, Arlington, Virginia, November.

Winemiller, K. O., and W. Van Winkle. 1991. "Life History Strategies Among North American Fishes: Theoretical Implications of a Multivariate Comparative Analysis." American Society of

Ichthyologists and Herpetologists, New York, June.

Winemiller, K. O., and W. Van Winkle. 1991. "Life History Theory as a Comparative Framework for the Individual-Based Approach to Fish Population Dynamics." American Fisheries Society, San Antonio, Texas, September.

Wright, L. L. 1990. "Role of New Wood Energy Crops in Mitigation of Fossil CO_2 Emissions." Conference on Biomass for Utility Applications, Tampa, Florida, October.

Wright, L. L. 1991. "Biomass Energy Crop Development." XVII Pacific Sciences Congress, Honolulu, May.

Wright, L. L. 1991. "Development of Biomass Energy Crops." 1991 American Association for the Advancement of Science Annual Meeting, Washington, D.C., February.

Wright, L. L. 1991. "Overview of Short-Rotation Forests in the United States." Second Brazilian Meeting on Forestry Economics and Planning: Agroforestry Systems, Curitiba, Brazil, September-October.

Wright, L. L. 1991. "Woody and Herbaceous Energy Crops." XVII Pacific Science Congress, Honolulu, May.

Wright, L. L., and E. Hansen. 1991. "Short-Rotation Woody Crops: EPRI Questions Answered." Waste-to-Energy/Biomass Working Group Meeting, Nashville, Tennessee, April.

Wu, Y., M. G. Turner, W. H. Romme, and L. L. Wallace. 1991. "A Landscape Simulation Model of Winter Foraging by Large Ungulates." Ecological Society of America Annual Meeting, San Antonio, Texas, August.

Wullschleger, S. D., D. M. Oosterhuis, and B. R. Bondada. 1990. "Reassimilation of Respired Carbon Dioxide by Developing Cotton Bolls." Annual Meeting of the American Society of Agronomy, Madison, Wisconsin, November.

Other Professional Activities

ADAMS, S. M.

Chairman: 17th Annual Aquatic Toxicity Workshop—Bioindicators, sponsored by Government of Canada, Vancouver, British Columbia, November 1990.

Member: Awards Committee (Students), American Fisheries Society; ESD representative to ORNL Animal Care Committee.

Participant: 17th Annual Aquatic Toxicity Workshop, sponsored by the Government of Canada, Vancouver, British Columbia, November 1990; Sixth International Symposium on the Effects of Pollutants on the Marine Environment, sponsored by Woods Hole Oceanographic Institute, Woods Hole, Massachusetts, April 1991; NCASI National Meeting Council of Paper Industry for Air and Stream Improvement, sponsored by NCASI, Charleston, South Carolina, June 1991; National Meeting of American Fisheries Society, sponsored by American Fisheries Society, San Antonio, Texas, September 1991.

Faculty: Adjunct Faculty, Ecology/ Environmental Toxicology, The University of Tennessee.

Editor: Associate Editor for book, Ecological Society of America.

Advisor: Ken Ham and Christine G. Hulls, Ph.D. candidates, The University of Tennessee; Stan Sharp, M.S. candidate, The University of Tennessee.

Ad Hoc Reviewer: Transactions of the American Fisheries Society; Copeia; proposals for NSF and EPRI.

ALLISON, L. J.

Chairman: Third Meeting of the Task Force on the Application of the Principles of Environmental Impact Assessment to Government Policy, Plans, and Programs, sponsored by EPA/ORNL, Washington, D.C., April 1991; CEQ/EPA Workshop on CERCLA and NEPA at Federal Sites, sponsored by CEQ/EPA, Washington, D.C., July 1991.

ASHWOOD, T. L.

Advisor: Julie B. Klein, B.S. candidate, West Liberty State College; T. L. Phung, B.S. candidate, Yale University; Lisa S. Schilling, B.S. candidate, Virginia Polytechnic Institute and State University.

Ad Hoc Reviewer: Water, Air, and Soil Pollution.

Other: Vice-chairman, Environmental Review Board, Roane County.

BAES, C. F. III

Chairman: Third Topical Meeting on Emergency Preparedness and Response, sponsored by American Nuclear Society, Chicago, April 1991.

Participant: 4-Day DOE Training Course on Environmental Laws, Chicago, October 1990; 4-Day DOE Training Course on Environmental Laws, Augusta, Georgia, October 1990; 4-Day DOE Training Course on Environmental Laws, Germantown, Maryland, December 1990; 4-Day DOE Training Course on Environmental Laws, Idaho Falls, Idaho, December 1990; 3-Day Overview of Environmental Laws, sponsored by DOE-ER, Gaithersburg, Maryland, April 1991; 2-Day Workshop on Environmental Laws and Regulations, sponsored by DOE, St. Louis, June 1991.

BARNTHOUSE, L. W.

Chairman: Workshop on Ecological Risk Assessment, sponsored by National Research Council, Airlie, Virginia, February-March 1991.

Member: National Research Council: Board on Environmental Studies and

Toxicology, Committee on Risk Assessment Methodology.

Participant: Society for Environmental Toxicology and Chemistry, Arlington, Virginia, November 1990; EPA Ecological Risk Assessment Strategy Workshop, Miami, April 1991; EPA Ecological Risk Assessment Framework Review, Rockville, Maryland, June 1991; Ecological Society of America Annual Meeting, San Antonio, Texas, August 1991.

Editor: Editorial Board Member, *Environmental Toxicology and Chemistry.*

BEAUCHAMP, J. J.

Participant: Review of BMAP and Canada Goose Neck Collar Studies, ESD, ORNL, March 1991; BMAP Landscape Analysis Core Workgroup Meeting, ESD, ORNL, May 1991; Program Review of Vegetation Field Study at SRS/MCB, ESD, ORNL, July 1991; Surface Water Sampling Program, ESD, ORNL, July 1991.

Ad Hoc Reviewer: Canadian Journal of Fisheries and Aquatic Sciences; *Communication in Statistics Theory and Methods.*

BLAYLOCK, B. G.

Member: International Union of Radioecologists; National Council of Radiation Protection and Measurement.

Faculty: Adjunct Professor Graduate Program in Radioecology, The University of Tennessee.

Advisor: Richard Graham, and Deborah Mohrbacher, Ph.D. candidates, The University of Tennessee; Alicia Water, M.S. candidate, The University of Tennessee.

Ad Hoc Reviewer: NCRP *Reporter.*

BOGLE, M. A.

Member: Association for Women in Science.

Other: Event Supervisor, Regional and State Science Olympiad, Museum of Science and Energy, Oak Ridge, Tennessee; Volunteer Scientist, Science-by-Mail Program.

BORDERS, D. M.

Member: Associate Member, American Society of Civil Engineers.

Participant: Fourth Tennessee Water Resources Symposium, sponsored by the Tennessee Section of the American Water Resources Association, Knoxville, Tennessee, September 1991.

BRANDT, C. C.

Participant: 1991 Winter Conference, sponsored by the American Statistical Association, New Orleans, January 1991; Fourth Tennessee Water Resources Symposium, sponsored by the Tennessee Section of the American Water Resources Association, Knoxville, Tennessee, September 1991.

BRENKERT, A. L.

Participant: Sedimentation Engineering Using HEC 6, sponsored by Arizona State University, Tucson, April–May 1991.

BURNS, T. P.

Member: International Society for Ecological Modeling, 1992 Program-Hawaii Meetings.

Participant: Synthesis of Species Population Dynamics and Ecosystem Processes, sponsored by U.S./Japan Cooperative Research Program, ORNL, September 1991.

CADA, G. F.

Participant: EPRI Downstream Migrant Study Workshop, sponsored by Electric Power Research Institute, York Haven, Pennsylvania, October 1990; Sandia National Laboratory Tiger Team Audit, DOE, Albuquerque, New Mexico, April 1991.

Ad Hoc Reviewer: Canadian Journal of Fisheries and Aquatic Science; Transactions

of the American Fisheries Society; North American Journal of Fisheries Management; The Environmental Professional.

CHASON, J. W.

Participant: Association of Southeastern Biologists Annual Meeting, sponsored by Association of Southeastern Biologists, Boone, North Carolina, April 1991.

CHRISTENSEN, S. W.

Participant: West Coast Review Team Meeting, EPRI Downstream Migrant Study, sponsored by EPRI, Elwha Hydroelectric Project, Port Angeles, Washington, November 1990; Site Visit, Skagit River Basin Existing and Proposed Hydroelectric Projects, Federal Energy Regulatory Commission, Concrete, Washington, May 1991.

CLAPP, R. B.

Ad Hoc Reviewer: Water Resources Research.

Other: Consultant, North Carolina Nature Conservancy.

COOK, R. B.

Participant: NEPA Workshop, sponsored by ER Division, Oak Ridge, Tennessee, December 1990; WATTec, Knoxville, Tennessee, February 1991.

Ad Hoc Reviewer: Canadian Journal of Fisheries and Aquatic Sciences; *Biogeochemistry*; *Water, Air, and Soil Pollution*; proposal for the Natural Sciences and Engineering Research Council of Canada; book chapter for Scientific Committee on Problems of the Environment.

CUSHMAN, J. H.

Chairman: Biofuels Energy Conference, sponsored by Biofuels Feedstock Development Program and IEA Bioenergy Task V, Davis, California, September 1991.

Member: Planning Committee, Southern Regional Biomass Energy Program; Ad Hoc Planning Committee, Southern Biomass Conference; Sigma Xi.

Participant: 1991 Southern Biomass Conference, sponsored by Louisiana Department of Agriculture and Forestry and Louisiana State University, Baton Rouge, January 1991; FY 1993 CE Program Planning Workshop Transportation Sector, sponsored by Solar Energy Research Institute, Golden, Colorado, February 1991; Biomass From Energy and Wastes XV, sponsored by Institute of Gas Technology, Washington, D.C., March 1991; Southern Pasture and Forage Crop Improvement Conference, sponsored by Mississippi State University, Starkville, May 1991; Biomass Feedstock/Conversion Scale-Up Working Group, sponsored by DOE, Washington, D.C., June 1991; Biofuels Energy Conference, sponsored by Biofuels Feedstock Development Program and Institute of Gas Technology Bioenergy Task V, Davis, California, September 1991.

Editor: Editorial Board, *Bioresource Technology.*

Ad Hoc Reviewer: Proposal, Southern Regional Biomass Energy Program; publication, Union of Concerned Scientists.

CUSHMAN, R. M.

Participant: Water Resources: Planning and Management and Urban Water Resources, sponsored by American Society of Civil Engineers, New Orleans, May 1991.

Advisor: Kevin R. Birdwell, M.S. candidate, Murray State University; Richard C. Daniels, M.A. candidate, Miami University.

Ad Hoc Reviewer: The Environmental Professional; *Environmental Management*; proposal to DOE.

CUTSHALL, N. H.

Participant: National Conference of Radiation Control Program Directors, sponsored by NCRCPD, Wichita, Kansas, May 1991; Annual Meeting of Health

Physics Society, Washington, D.C., July 1991; National Leadership Conference, sponsored by Future Business Leaders of America, Anaheim, California, July 1991; Chemical Congress of North America, sponsored by American Chemical Society, New York, August 1991.

Editor: Editorial Board, DOE's Five-Year Plan for 1993–1997.

Ad Hoc Reviewer: Proposal for Sea Grant, NOAA.

On Assignment: DOE, Washington, D.C.

DALE, V. H.

Chairman: Workshop on Natural Resource Economics, sponsored by U.S. Agency for International Development and Partners in Education.

Participant: Workshop on Modeling Global Climate Change, sponsored by the U.S. Forest Service, Tucson, Arizona, November 1990; National Research Council Meeting on Sustainable Agriculture, Washington, D.C., February 1991; Second Annual Walker Branch Watershed Symposium, sponsored by DOE OHER, ORNL, Oak Ridge, Tennessee, March 1991; Technologies forGreenhouse-Constrained Society, Oak Ridge, Tennessee, June 1991; Symposium on Forest Management Policy and Forest Landscapes, sponsored by International Association of Landscape Ecology, Ottawa, Canada, July 1991; Symposium on Theoretical Approaches for Predicting Spatial Effects in Ecological Systems, sponsored by Ecological Society of America, San Antonio, Texas, August 1991.

Advisor: Robert Frohn, Ph.D candidate, University of California—Santa Barbara.

Ad Hoc Reviewer: Canadian Journal of Forest Research; *Landscape Ecology*; proposals for NSF, NASA, and Maryland Department of Natural Resources.

Other: Chairman, Citizens for Quality Growth, City of Oak Ridge.

DEANGELIS, D. L.

Chairman: U.S. Japanese Collaborative Research Workshop, sponsored by NSF—Japan Society for Promotion of Science, Oak Ridge, Tennessee, September 1991; Short Course on Populations and Ecosystems, Swedish Agricultural University, Uppsala, Sweden, April 1991.

Participant: South Atlantic Bight Recruitment Experiment Meeting, sponsored by NSF—Sea Grants, Raleigh, North Carolina, February 1991.

Faculty: Adjunct Professor, Graduate Program in Ecology, The University of Tennessee.

Advisor: Yiannis Matsinos, Ph.D. candidate, The University of Tennessee.

Editor: Associate Editor, *Mathematical Biosciences*.

DEARSTONE, K. C.

Participant: 11th Annual ESRI User Conference, sponsored by ESRI, Palm Springs, California, May 1991; NCGIA First National Conference/Workshop on Integrating GIS and Environmental Modeling, sponsored by NCGIA, Boulder, Colorado, September 1991; Fourth Tennessee Water Resources Symposium, sponsored by the Tennessee Section of the American Water Resources Association, Knoxville, Tennessee, September 1991.

Ad Hoc Reviewer: Proposal for DOE.

DOLL, W. E.

Participant: Eastern Section Seismological Society of America, sponsored by Colby College, Virginia Polytechnic Institute and State University, Blacksburg, Virginia, October 1990.

Faculty: Assistant Professor, Geology, Colby College.

Advisor: Harry Evans, B.A. candidate, Colby College.

DREIER, R. B.

Participant: Practical Tracing of Groundwater, Karst Terranes, sponsored

by Geological Society of America, Dallas, October 1990; Groundwater Flow Through Fractured Media, sponsored by University of Wisconsin, Madison, December 1990; Borehole Geophysics in Environmental and Engineering Investigations, sponsored by COLOG, Knoxville, Tennessee, March 1991; DOE Workshop on DNAPL, sponsored by DOE, Atlanta, July 1991; Geochemical Modeling of Groundwater, sponsored by National Water Well Association, Chicago, August 1991; Basic Ground Water Modeling on a PC: Transient Flow in 2-D and 3-D, sponsored by National Water Well Association, Seattle, September 1991.

Faculty: Adjunct Assistant Professor, Geology, The University of Tennessee.

Advisor: P. J. Lemiszki, Ph.D. candidate, The University of Tennessee.

EARLY, T. O.

Chairman: DNAPL Workshop, sponsored by DOE, Atlanta, July 1991.

Editor: Nuclear Safety.

EDDLEMON, G. K.

Member: Sigma Xi.

Participant: Pre-Tiger Team Assessment of the Oak Ridge K-25 Site, Martin Marietta Energy Systems, Inc., Oak Ridge, Tennessee, August 1990–November 1991; DOE Training Course on Environmental Laws and Regulations, Richland, Washington, October 1990; Environmental Compliance Assessment of the Food and Drug Administration (Federal Building 8), Washington, D.C., November 1990; Tiger Team Assessment of Princeton Plasma Physics Laboratory, Princeton, New Jersey, February 1991; Environmental Compliance Audit of Naval Inactive Ship Maintenance Facility, U.S. Navy, Philadelphia, March 1991; Tiger Team Assessment of Sandia National Laboratory, Albuquerque, New Mexico, April 1991; Environmental Compliance Audit of Naval Inactive Ship Maintenance Facility, U.S. Navy, Portsmouth, Virginia, May 1991; Annual Meeting of North American Benthological Society, Santa Fe, New Mexico, May 1991; Environmental Compliance Audit of Naval Inactive Ship Maintenance Facility, U.S. Navy, Pearl Harbor, Hawaii, June–July 1991; Environmental/Waste Management Issues at Paducah and Portsmouth Gaseous Diffusion Plants, sponsored by DOE Office of Uranium Enrichment, Lexington, Kentucky, July 1991; Tiger Team Assessment of Los Alamos National Laboratory, Los Alamos, New Mexico, September–October 1991.

Advisor: Patricia O'Connell, J.D. candidate, University of Illinois Law School.

EDWARDS, N. T.

Participant: UV-B Measurements Workshop, sponsored by USDA, CSRS, and AFEAS, Denver, January 1991.

Ad Hoc Reviewer: Health Physics.

EMANUEL, W. R.

Member: Working Group on Integrated Global Change Modeling, Committee on Global Change, National Research Council.

Participant: Workshop on the Scientific Basis of Global Warming Potential Indices, sponsored by NASA, NOAA, EPA, and DOE, Boulder, Colorado, November 1990; Workshop on the Engineering Response to Global Environmental Change, sponsored by Engineering Foundation, Palm Coast, Florida, May 1991; Review Panel—Global Change Distinguished Postdoctoral Fellows, sponsored by ORAU, Atlanta, June 1991; Global Power Research Workshop, sponsored by EPRI, Carmel, California, July 1991; NASA Review Panel on Terrestrial Ecological Studies, Washington, D.C., July 1991; Aspen Global Change Institute Summer Session, Aspen, Colorado, August 1991; NATO Advanced Study Institute on the Global Carbon Cycle, Il Ciocco, Italy, September 1991.

FARRELL, M. P.

Participant: CDIAC Program Review, sponsored by DOE OHER, ORNL, December 1990, September 1991; Carbon Cycle Conference, sponsored by DOE OHER, ORNL and Washington, D.C., August 1991.

Advisor: Kim Chapman, B.S. candidate, East Tennessee State University.

Other: Participant, Friends of ORNL.

FAULKNER, M. A.

Participant: Environmental Systems Research User Conference, sponsored by ESRI, Palm Springs, California, May 1991; National Conference on Integrated Water Information Management, sponsored by EPA, USGS, Multi-State Fish and Wildlife Information Systems Project, Atlantic City, New Jersey, August 1991.

FLAMM, R.

Participant: Southern Appalachian Man and the Biosphere Planning Meeting, sponsored by SAMAB, Asheville, North Carolina, April 1991; World Congress of Landscape Ecology, International Association for Landscape Ecology, Canadian Society for Landscape and Ecology, US-IALE, Ottawa, July 1991.

Ad Hoc Reviewer: Environmental Entomology.

FONTAINE, T. A.

Member: American Water Resources Association; American Geophysical Union.

Participant: Annual Meeting of the American Water Resources Association, Denver, November 1990; Modeling the Behavior of Radionuclides on a Soil-Aquatic System Including Rivers and Reservoirs, sponsored by Pacific Northwest Laboratory, Richland, Washington, March 1991; American Geophysical Union, sponsored by American Geophysical Union, Baltimore, May 1991; Annual Meeting of the American Water Resources Association, sponsored by the American Water Resources Association, New Orleans, September 1991; Fourth Tennessee Water Resources Symposium, Knoxville, Tennessee, September 1991.

Ad Hoc Reviewer: Journal of the Hydraulics Division—American Society of Civil Engineers; Water Resources Bulletin.

FORD, C. J.

Participant: Remedial Approaches for Sites with Contaminated Sediments, sponsored by EPA, Atlanta, Philadelphia, and Kansas City, Missouri, June and August 1991.

FRANCIS, C. W.

Ad Hoc Reviewer: Health Physics; proposals for the state of Wisconsin.

FRANK, M. L.

Participant: Pathway Analysis and Risk Assessment for Environmental Compliance and Dose Reconstruction, sponsored by Radiological Assessments Corporation, Kiawah Island, South Carolina, February 1991.

GARDNER, R. H.

Chairman: Symposium for the Annual Meeting of the Ecological Society of America, San Antonio, Texas, August 1991.

Participant: DOE Symposium on Theoretical Ecology: Progress and Prospects, Washington, D.C., April–May 1991; Cary Conference IV: Humans as Components of Ecosystems, Institute of Ecosystem Studies, Millbrook, New York, May 1991; IGBP Meeting on Global Change and Terrestrial Ecosystems, Trondheim, Norway, June 1991; Annual Meeting of the Ecological Society of America, San Antonio, Texas, August 1991.

Faculty: Adjunct Professor, Department of Ecology, The University of Tennessee.

Advisor: Sandra Lavorel, Thesis Committee Member, Center for Environmental Research, Montpellier, France.

Ad Hoc Reviewer: Ecology; Landscape Ecology; Proceedings of the Fourth Annual Symposium on the Natural History of Lower Tennessee and Cumberland River Valleys, proposals for NSF.

Other: Chairman, ORNL's Seed Money Committee; ORNL's Showcase Seminar Series.

GARTEN, C. T., JR.

Participant: Southern Appalachian Man and the Biosphere Conference, sponsored by TVA, Gatlinburg, Tennessee, and TVA, November 1990; Second Annual Walker Branch Watershed Research Symposium, sponsored by DOE OHER, Oak Ridge, Tennessee, and TVA, March 1991. *Advisor:* R. S. Thomason, B.S. candidate, Tennessee Technological University; Christopher A. Thoms, B.S. candidate, University of Wisconsin; Laura Broughton, B.S. candidate, Dartmouth College; David M. Byers, B.S. candidate, Claremont McKenna College; Karin Wolfe, B.S. candidate, Centre College.

Ad Hoc Reviewer: Journal of Environmental Quality; Environmental Pollution; Tree Physiology; Health Physics; proposal for EPA.

GRAHAM, R. L.

Chairman: Co-organizer, Biomass Energy Strategies Workshop, sponsored by DOE, Oak Ridge, Tennessee, November 1991; Remote Sensing and DOE Research Parks, sponsored by DOE, Oak Ridge, Tennessee, June 1991.

Member: Technical Steering Committee for U.S. Forest Service Center for Forest Environmental Studies, U.S. Forest Service.

Participant: Interagency Workshop on Deforestation, sponsored by NASA/EPA, Washington, D.C., May 1991; Central Africa Research Meeting, sponsored by U.S. Agency for International Development, Washington, D.C., August 1991.

Advisor: Hope Barrett, M.S. candidate, The University of Tennessee.

Ad Hoc Reviewer: Canadian Journal of Forestry; Western Journal of Applied Forestry; proposals for NASA and USDA; EPA program.

GREBMEIER, J. M.

Participant: U.S. JGOFS Southern Ocean Process Study Workshop, sponsored by Joint Oceanographic Institute, Inc., Lamont-Doherty Geological Observatory, Paisades, New York, October 1990; Workshop on the 1993 Northeast Water expedition, sponsored by NSF, Bremerhaven, Germany, February 1991; U.S./U.S.S.R. Workshop on the Bering/Chukchi Seas, sponsored by the U.S. Fish and Wildlife Service, San Francisco, March 1991; GLOBEC Southern Ocean Zooplankton and Climate Change Workshop, sponsored by Joint Oceanographic Institute, Inc., and Scripps Institution of Oceanography, La Jolla, California, May 1991; ASLO Spring Meeting, American Society of Limnology and Oceanography, Halifax, Nova Scotia, June 1991; Polar Biology and Medicine Panel Review—Antarctica, sponsored by NSF, Washington, D.C., August 1991.

Faculty: Research Assistant Professor, Graduate Program in Ecology, The University of Tennessee.

Ad Hoc Reviewer: Limnology and Oceanography; Nature; Marine Ecology Programs Series; proposals for NSF.

GREELEY, M. S., JR.

Participant: 17th Annual Aquatic Toxicity Workshop, sponsored by National Steering Committee (Canada), Vancouver, British Columbia, November 1990; Sixth International Symposium on the Effects of Pollutants on the Marine Environment, sponsored by Woods Hole Oceanographic Institute, Woods Hole, Massachusetts, April 1991.

Advisor: Christine Gettys Hull, Ph.D. candidate, The University of Tennessee; Stan Sharp, M.S. candidate, The University of Tennessee; John Platt, B.S. candidate, The University of Tennessee.

Ad Hoc Reviewer: Intermural Grant Proposal, New York City University.

GRIZZARD, T.

Advisor: David Morgan, B.S. candidate, Roane State and The University of Tennessee; Robert Stewart, B.S. candidate, Roane State and The University of Tennessee.

GUNDERSON, C. A.

Member: American Society of Plant Physiologists.

Participant: Second Annual Walker Branch Watershed Research Symposium, sponsored by DOE OHER, Oak Ridge, Tennessee, March 1991; Early Selection of Forest Tree Species Combining Morphophysiological Trails and Molecular Markers, sponsored by ORNL and Weyerhaeuser, Gatlinburg, Tennessee, June 1991; Annual Meeting of the American Society of Plant Physiologists, sponsored by the American Society of Plant Physiologists, Albuquerque, New Mexico, July 1991; Biofuels Energy Conference, sponsored by Biofuels Feedstock Development Program, Davis, California, September 1991.

Ad Hoc Reviewer: Plant Physiology and Biochemistry.

HANSON, P. J.

Chairman: 23rd Annual Air Pollution Workshop, sponsored by California Department of Food and Agriculture, EPRI, and Southern California Edison, Lake Arrowhead, California, April 1991.

Member: American Association for the Advancement of Science; American Society of Plant Physiologists; American Society of Agronomy.

Participant: Walker Branch Watershed Program Review, sponsored by DOE, Oak Ridge, Tennessee, January 1991; Second Annual Walker Branch Watershed Research Symposium, sponsored by DOE OHER, Oak Ridge, Tennessee, March 1991; 23rd Annual Air Pollution Workshop, sponsored by Statewide Air Pollution Research Center, University of California—Riverside, Lake Arrowhead, California, April 1991; International Symposium: Physiology and Determination of Crop Yield, American Societies of Agronomy, Crop Science, and Soil Science, Gainesville, Florida, June 1991.

Advisor: DOE High School Honors Students from Alaska, Utah, Wisconsin, and Puerto Rico; Stephanie Bohlman, postgraduate, New College, Sarasota, Florida.

Ad Hoc Reviewer: Atmospheric Environment; Forest Science; Tree Physiology; Physiologia Planetarium; proposals for NSF, USDA, USDA Forest Service.

HARDY, C. L.

Participant: Introduction to Biological Monitoring, sponsored by the Nature Conservancy, Nashville, Tennessee, May 1991; Introduction to Environmental Laws and Regulations, sponsored by DOE Office of Energy Research, Germantown, Maryland, April–May 1991.

HARGROVE, W. W.

Participant: Plants and Their Environments, sponsored by First Biennial Scientific Conference on the Greater Yellowstone Ecosystems, Mammoth Hot Springs Hotel, Yellowstone National Park, Wyoming, September 1991.

HARRINGTON, B.

Participant: Introduction to Groundwater Geochemistry, sponsored by National Water Well Association, Long Beach, California, January 1991; Advanced AML-ARC/INFO Course, sponsored by

Environmental Systems Research Institute, Atlanta, February 1991; SAS Basics I and II, sponsored by SAS Institute, Cary, North Carolina, March 1991; ESRI User Conference, sponsored by Environmental Systems Research Institute, Palm Springs, California, May 1991; Introduction to Relational Data Bases and Using ROBI with ARC/INFO, sponsored by Environmental Systems Research Institute, Redlands, California, May 1991; Basic Statistics Using SAS/STAT Software, sponsored by SAS Institute, Chicago, June 1991; SAS Programming, sponsored by SAS Institute, Cary, North Carolina, July 1991.

HATCHER, R. D., JR.

Chairman: Symposium on Terranes in the Appalachian/Caledonia Orogen, NE-SE Section of the Geological Society of America, sponsored by Geological Society of America, Baltimore, April 1991.

Member: Board of Directors, DOSECC, Inc.; EDGE Planning Committee, Houston Area Research Center; Earth Sciences Advisory Committee, Westinghouse-Savannah River Site; Board on Radioactive Waste Management, National Academy of Sciences; Structural Geology/Tectonics Division Career Award Nominating Committee, Geological Society of America; Committee on Committees, Geological Society of America; Council (Board of Directors) and Executive Committee, Geological Society of America; ORNL Corporate Fellows Subcommittee on Geosciences, ORNL.

Participant: Invited participant, symposium sponsored by European Union of Geosciences, Strasbourg, France, March 1991; Appalachian Structure and Tectonics, sponsored by Geological Society of America, NE-SE Section, Baltimore, March 1991; Terrane Accretion and Related Processes in the Appalachians and Related Crustal Blocks II, sponsored by Geological Society of America, NE-SE Section, Baltimore, March 1991; Nickelsen Symposium: Deformation Mechanisms in Fold-Thrust Belts III, sponsored by Geological Society of America, NE-SE Section, Baltimore, March 1991; Structural Interaction Between Blue Ridge and Appalachian Cover Rocks I, sponsored by Geological Society of America, NE-SE Section, Baltimore, March 1991; HyTec Panel on Coupled Processes Field Trip and Review of Yucca Mountain Project, sponsored by National Academy of Sciences/DOE, Yucca Mountain, Nevada, January–March 1991; Field Trip in Swiss and Italian Alps, sponsored by University of Basel and Geologische Vereinigung, Switzerland and Italy, April 1991; External review of Geological Sciences Department, sponsored by Rutgers University, New Brunswick, New Jersey, May 1991; Strategic Planning Retreat, Environmental Management Systems, sponsored by Clemson University, Department of Group Systems Engineering, Clayton, Georgia, May 1991; Terranes in the Arctic Caledonides, sponsored by International Geological Correlation Programme, Oslo, August 1991.

Faculty: UT/ORNL Distinguished Scientist, Science Alliance, Department of Geological Sciences, The University of Tennessee.

Editor: Special Volume Editor (IGC Symposium), *Tectonophysics.*

Advisor: John O. Costello, Ph.D. candidate, University of South Carolina; Timothy L. Davis, Janet L. Hopson, Peter J. Lemiszki, Angang Liu, and Elizabeth A. McClellan, Ph.D. candidates, The University of Tennessee; H. Ann Burns, Michael J. Quinn, Gregory M. Yanagihara, and S. Allen Young, M.S. candidates, The University of Tennessee.

Ad Hoc Reviewer: Journal of Geophysical Research; Southeastern Geology; two articles in *The Evolution of the Alpine Basement*, J. von Raumer and F. Neubauer, ed.; *Geology*; paper for

ASCE Geotechnical Engineering Division; NSF Program; NSF proposals; Petroleum Research Fund proposal; Natural Sciences and Engineering Research Council of Canada proposal; presentation for National Academy of Science Board on Radioactive Waste Management Symposium.

HAYNES, G. J.

Chairman: Women in Science, sponsored by ORNL and ORAU, Oak Ridge, Tennessee, April 1991.

Member: Martin Marietta Energy Systems, Inc., Values Committee.

Advisor: Cedric T. Revenard, undergraduate, France University, Paris.

HERBES, S. E.

Participant: In Situ and On-Site Bioreclamation, sponsored by Battelle International, San Diego, March 1991; Mid-Year Review, sponsored by DOE Office of Technology Development, Gaithersburg, Maryland, June 1991; Environmental Biotechnology, sponsored by The University of Tennessee—Knoxville Management Research and Education Institute, Knoxville, Tennessee, October 1991.

Faculty: Adjunct Professor, Graduate Program in Ecology, The University of Tennessee.

Ad Hoc Reviewer: Proposal for Natural Sea Grant College Program.

HILDEBRAND, S. G.

Member: Public Relations Committee, American Fisheries Society.

Participant: Ecological Risk Assessment, sponsored by National Research Council, National Academy of Science, Warrenton, Virginia, February 1991; Theoretical Ecology Program Review, sponsored by DOE, Gaithersburg, Maryland, April 1991; 42nd Annual Meeting of American Institute of Biological Sciences, San Antonio, Texas, August 1991; Technologies for a Greenhouse-Constrained Society, sponsored by DOE, Oak Ridge, Tennessee, June 1991.

Faculty: Adjunct Professor, Graduate Program in Ecology, The University of Tennessee.

HILL, W. R.

Member: American Society of Limnology and Oceanography; Physiological Society of America; North American Benthological Society.

Advisor: Audrey Barker, B.A. candidate, Carleton College; Rachel Mooney, B.A. candidate, Syracuse University.

Ad Hoc Reviewer: Ecology; Journal of the North American Benthological Society.

Other: Volunteer instructor, graduate course in stream ecology, The University of Tennessee.

HOFFMAN, F. O.

Chairman: International Symposium on the Biological Aspects of Chernobyl Accident, sponsored by U.S.S.R. Academy of Sciences, Zeleny Mys, Ukraine, U.S.S.R., September 1990; BIOMOVS—Biospheric Model Validation Study, sponsored by Swedish National Institute for Radiation Protection, Stockholm, October 1990; Validation of Assessment Model Predictions/Multiple Pathways Analysis, sponsored by International Atomic Energy Agency, Vienna, December 1990.

Member: U.S./U.S.S.R. Joint Coordinating Committee on Civilian Nuclear Reactor Safety, Task 7. ID, Agricultural Food Chains and Uncertainty Analysis; International Atomic Energy Agency, IAEA/VAMP, Multiple Pathways Model Validation; National Council on Radiation Protection and Measurement, Task Group 16 of Scientific Committee 64; National Council on Radiation Protection and Measurement, Task Group 1 of Scientific Committee 84; Health Advisory Panel for Rocky Flats Dose Reconstruction, Department of Health, State of

Colorado; Scientific Advisory Panel for the Hanford Thyroid Morbidity Study, Centers for Disease Control, Atlanta; Health Advisory Panel for Dose Reconstruction at Oak Ridge, Department of Health, State of Tennessee.

Participant: First International Conference on the Biological Aspects of the Chernobyl Accident, sponsored by U.S.S.R. Academy of Sciences, Zeleny Mys, Ukraine, U.S.S.R., September 1990; BIOMOVS—On the Validity of Environmental Transfer Models, sponsored by Swedish National Institute for Radiation Protection, Stockholm, October 1990; Consultant's Meeting on Revision to Safety Series No. 57, sponsored by International Atomic Energy Agency, Vienna, December 1990; Health Advisory Panel, sponsored by Department of Health, State of Colorado, Denver and Alameda, Colorado, October 1990, January 1991, March 1991, May 1991, and September 1991; WATTec, sponsored by DOE and Martin Marietta Energy Systems, Inc., Knoxville, Tennessee, February 1991; Environmental Dose Reconstruction and Risk Assessment, sponsored by Radiological Assessment Corp., Kiawah Island, South Carolina, February 1991; Evaluation of NCRP Screening Assessment Models, sponsored by National Council on Radiation Protection and Measurements, Washington, D.C., and Kiawah Island, South Carolina, October 1990 and March 1991; Hanford Thyroid Morbidity Study, sponsored by Centers for Disease Control, Atlanta, and Seattle, March 1991 and July 1991; Hanford Environmental Dose Reconstruction Project, sponsored by Battelle Pacific Northwest Laboratory and Hanford Environmental Dose Reconstruction Technical Steering Panel, Pasco, Washington, July 1991; Third Topical Meeting on Emergency Preparedness and Response, sponsored by American Nuclear Society, Chicago, April 1991; Evaluation of Contamination in Sediment, sponsored by EPA, Atlanta, June 1991; Risk Assessment Kick-off Workshop, sponsored by Oak Ridge Operations, Environmental Restoration Program, Knoxville, Tennessee, June 1991; Health Advisory Panel, sponsored by Department of Health, State of Tennessee, Nashville, September 1991.

Faculty: Invited lecturer in nuclear engineering, The University of Tennessee.

Advisor: Richard V. Graham and Deborah Mohrbacher, Ph.D. candidates, The University of Tennessee; Janna Hammonds, M.S. candidate, The University of Tennessee.

Ad Hoc Reviewer: Health Physics; Risk Analysis.

HOLLADAY, S. K.

Member: American Society for Testing and Materials, D-34; American Water Works Association; American Business Womens Association; American Society of Quality Control.

HUDSON, W. S.

Participant: Clean Water Act Compliance Course, sponsored by Government Institutes, Arlington, Virginia, September 1991; Storm Water Discharge Regulations Course, sponsored by Government Institutes, Arlington, Virginia, September 1991.

HUFF, D. D.

Chairman: Fourth Tennessee Water Resources Symposium, sponsored by ORNL and Environmental Restoration Program, Knoxville, Tennessee, September 1991.

Member: Tennessee Section, American Institute of Hydrology.

Faculty: Adjunct Professor, Geology Department, The University of Tennessee.

Ad Hoc Reviewer: Manuscripts for *Waste Management* (Pergammon); RFI documents for ORNL ER Program.

HUNSAKER, C. T.

Chairman: Co-chairman, ESD GIS Self-Directed Work Team; Symposium:

Regional Ecological Risk Assessment, International Association of Landscape Ecology World Congress, Ottawa, July 1991; First International Conference/Workshop on Integrating, sponsored by National Center for Geographic Information and Analysis, Boulder, Colorado, September 1991; 63rd Annual Water Pollution Control Federation Conference, sponsored by GIS and Environmental Modeling, Washington, D.C., October 1990; International Symposium on Ecological Indicators, sponsored by EPA, Fort Lauderdale, Florida, October 1990.

Member: Ecology Committee, Water Pollution Federation; Program Committee and Ad Hoc Education, Water Pollution Control Federation; Public Affairs, Ecological Society of America.

Participant: Ecology and Planning: The Landscape Dimension, sponsored by University of California, Sacramento, October 1990; International Symposium on Ecological Indicators, sponsored by EPA, Fort Lauderdale, Florida, October 1990; 63rd Water Pollution Control Federation Conference, Washington, D.C., October 1990; Water Quality 2000 Members Congress, sponsored by Water Pollution Control Federation and 80 Other Organizations, Alexandria, Virginia, June 1991; International Association of Landscape Ecology World Congress, sponsored by IALE, Ottawa, Canada, 76th Annual Meeting Ecological Society of America, San Antonio, Texas, August 1991; International Conference/Workshop on Integrating GIS and Ecological Modeling, sponsored by NCGIA, Boulder, Colorado, September 1991.

Editor: Advisory Board, *The Environmental Professional*, National Association of Environmental Professionals.

Advisor: Daniel A. Levine, Ph.D. candidate, Indiana University, Bloomington.

Ad Hoc Reviewer: Consultant, EPA Science Advisory Board; *The Environmental Professional*; U.S. Man and the Biosphere Program; EPA's Environmental Monitoring and Assessment Program.

Other: Second Annual Women in Science, ORAU and ORNL, Oak Ridge and Knoxville, April 1991.

HUSTON, M. A.

Chairman: Second Annual Walker Branch Watershed Research Symposium, sponsored by DOE OHER, ORNL, Oak Ridge, Tennessee, March 1991; ESA Contributed Papers on Remote Sensing, sponsored by Ecological Society of America, San Antonio, Texas, August 1991.

Participant: Workshop on Bilateral U.S.-U.S.S.R. Biodiversity Research, sponsored by NSF, Moscow, November 1990; Workshop on CERCLA NRDA Regulations, sponsored by Martin Marietta Energy Systems, Inc., Oak Ridge, Tennessee, March 1991; Convention LTER Annual Public Information Meeting, sponsored by NSF, Otto, North Carolina, April 1991; EPA Environmental Biology Review Panel, sponsored by EPA, Knoxville, Tennessee, June 1991; Harvard Forest Biodiversity Workshop, sponsored by NSF and IUBS, Petersham, Massachusetts, June-July 1991; NSF LTER Site Review, NSF, Las Cruces and Albuquerque, New Mexico, July 1991.

Faculty: Adjunct Professor, Ecology Program, The University of Tennessee.

Advisor: Eric Hartzell, B.S. candidate, Ohio University; Aida Solivan, B.S. candidate, University of Puerto Rico; Chris Thoms, B.S. candidate, University of Wisconsin-Stevens Point.

Ad Hoc Reviewer: NSF proposals; *Ecology; Bioscience; Science; American Nature.*

Other: Environmental Quality Advisory Board, Oak Ridge; talks to junior high school science classes, Oak Ridge; science fair judge, Jefferson Junior High School, Oak Ridge.

JACKSON, B. L.

Participant: SAS Users Group International 16th Annual Conference, sponsored by SAS Institute, Inc., New Orleans, February 1991.

JACOBS, G. K.

Participant: Modeling Workshop for the Subsurface Science Program, sponsored by DOE, Germantown, Maryland, November 1990.

Faculty: Adjunct Faculty, Department of Geological Sciences, The University of Tennessee.

Advisor: J. L. Foreman, Ph.D. candidate, The University of Tennessee.

Ad Hoc Reviewer: Geochimica et Cosmochimica Acta; proposal for Copper Development Association.

JAGER, H. I.

Participant: 1991 American Statistical Association Winter Conference on Statistics and the Environment, sponsored by American Statistical Association, New Orleans, January 1991; First International Conference on Integrating GIS and Environmental Modeling, sponsored by the National Center for Geographic Information and Analysis, Boulder, Colorado, September 1991.

JARDINE, P. M.

Member: ORNL Paper Recycling Program; ORNL Sanitary Waste Reduction Team.

Participant: Seminar, University of Virginia, Charlottesville, Virginia, November 1990; American Society of Agronomy Meetings, sponsored by American Society of Agronomy and Soil Science Society of America, San Antonio, Texas, October 1990; DOE Subsurface Science Program Review, Bethesda, Maryland, March 1991; DOE Subsurface Science Program Review, Salt Lake City, April 1991.

Faculty: Committee Member, Civil Engineering, Pennsylvania State University.

Editor: Associate Editor, *Soil Chemistry.*

Advisor: Jack Gwo, Ph.D. candidate, Pennsylvania State University; Virginia Harless, Andy McNabb, and Tonia Melhorn, B.S. candidates, The University of Tennessee, Knoxville.

Ad Hoc Reviewer: Soil Science Society of America Journal; Journal of Environmental Quality; Nature; Soil Science; Advances in Soil Science; Geochimica et Cosmochimica Acta; proposal for Georgia Agricultural Experiment Station.

Other: Recycling Theme Group for the Appalachian Regional Commission Honors Workshop.

JOSLIN, J. D., JR.

Participant: American Society of Agronomy/Soil Science Society of America—Annual Meeting, San Antonio, Texas, October 1990; Southern Appalachian Man and the Biosphere Conference, Gatlinburg, Tennessee, November 1990; Second Annual Walker Branch Watershed Research Symposium, sponsored by DOE OHER, Oak Ridge, Tennessee, March 1991; Air Pollution Workshop, Lake Arrowhead, California, April 1991.

Advisor: Achim Kayser, undergraduate, University of Bayreuth, Germany.

Ad Hoc Reviewer: Physiologia Planetarium; Forest Science; Journal of Applied Ecology; Soil Science Society of America Journal; Canadian Journal of Forest Research.

KANCIRUK, P.

Participant: International Union of Geology and Geophysics, sponsored by IUGG, Vienna, August 1991.

KEARL, P. M.

Participant: Blue Ribbon Panel to Review LANL Site-Wide Hydrogeologic Program, Los Alamos National Laboratory,

Los Alamos, New Mexico, May–August 1991.

Ad Hoc Reviewer: Moffett Field Aquifer Testing Program; Sunset Golf Course Landfill Program.

KIMMEL, B. L.

Member: Advisory Panel, Ecosystem Studies Program, NSF; EPSCoR Scientific Review Panel, NSF Experiment Program to Stimulate Competitive Research; Advisory Committee, Reservoir Research Center, Murray State University, Murray, Kentucky; Advisory Panel, Water Quality, New York City Department of Environmental Protection.

Participant: Remedial Action Program Review Meetings, sponsored by DOE, EPA-IV, TDEC, Energy Systems ER Program, Chattanooga, Tennessee (quarterly); ER Program Monthly Review, sponsored by DOE ER, Energy Systems ER Program, Oak Ridge, Tennessee, Paducah, Kentucky, and Portsmouth, Ohio (monthly); American Nuclear Society, sponsored by American Nuclear Society, Washington, D.C., November 1990; International Seminar on Limnology, sponsored by National Water Commission of Mexico, February 1991; Natural Resources Damage Assessment Workshop, sponsored by Energy Systems ER Program, Oak Ridge, Tennessee, March 1991; ER Program Off-Site Workshop, sponsored by Energy Systems ER Program and DOE ER, Pigeon Forge, Tennessee, March 1991; Ecosystem Studies Program Advisory Panel, sponsored by NSF, Washington, D.C., March 1991; DOE-Headquarters ER Program Review, sponsored by DOE ER, Washington, D.C., May 1991; ESPCoR Scientific Review Panel, sponsored by NSF, Washington, D.C., July 1991.

Faculty: Faculty Associate, Graduate Program in Ecology, The University of Tennessee.

Editor: Editorial Board, *Limnology and Oceanography.*

Ad Hoc Reviewer: Ecological Applications; Limnology and Oceanography; proposals for NSF.

KING, A. W.

Chairman: Session Moderator, Workshop on Carbon Cycling in Boreal and Subarctic Ecosystems, sponsored by EPA, Oregon State University, Corvallis, September 1991.

Participant: Workshop on Ecological Integrity and the Management of Ecosystems, sponsored by Heritage Resources Center, University of Waterloo, Ontario, Canada, April 1991; International Joint Commission Ecosystem Model Roundtable, sponsored by International Joint Commission, Racine, Wisconsin, July 1991; Annual Meeting, Ecological Society of America, San Antonio, Texas, August 1991; Workshop on Carbon Cycling Boreal and SubArctic Ecosystems, sponsored by Oregon State University, EPA, Corvallis, September 1991; First International Conference/Workshop on Integrating GIS and Environmental Modeling, sponsored by National Center for Geographic Information and Analysis, Boulder, Colorado, September 1991.

KOONER, Z. S.

Ad Hoc Reviewer: Arsenic in Groundwater; LANL Proceedings of Unsaturated Transact of Inorganic Cation in Disturbed Soil Column; *Environmental Geology.*

KORTE, N.

Ad Hoc Reviewer: Environmental Science and Technology; Environmental Management.

KROODSMA, R. L.

Ad Hoc Reviewer: Journal of Wildlife Management; Proceedings of the Southeastern Association of Fish and Wildlife Agencies; *Auk*; The Sixth Crane Workshop.

KSZOS, L. A.

Member: Association for Women in Science; Society of Environmental Toxicology and Chemistry; Water Pollution Control Federation; Sigma Xi.

Participant: Water Pollution Control Federation, Washington, D.C., October 1990; 11th Annual Meeting of the Society of Environmental Toxicology and Chemistry, Arlington, Virginia, November 1990.

Advisor: James Sumner, B.A. candidate, University of New Hampshire.

LAASE, A. D.

Participant: The Use of MODFLOW for Analysis of Ground-Water Flow Systems, sponsored by National Water Well Association, Reston, Virginia, April 1991.

LARSEN, I. L.

Participant: University Research Instrumentation Program, sponsored by DOE, Salt Lake City, March 1991.

Ad Hoc Reviewer: Proposals for DOE.

Other: Tennessee State Science Olympiad Tournament, Oak Ridge, Tennessee.

LEE, K.-L.

Faculty: Share Faculty, Biomedical Graduate School, The University of Tennessee.

Advisor: Anthony Makkinje, Ph.D. candidate, Oak Ridge Biomedical Graduate School, The University of Tennessee.

Ad Hoc Reviewer: Proposals for ORNL and DOE.

LEE, S. Y.

Member: Committee on Southeastern Soil Mineralogy/USDA; Program Committee, Clay Mineral Society; Characterization Group, Uranium Contaminated Soil Integrated Demonstration.

Participant: Clay Mineral Society Annual Meeting, Columbia, Missouri, October 1990; Soil Science Society of America, San Antonio, Texas, October 1990; Symposium on Characterization of Molecular Sieve, sponsored by Material Research Society, Anaheim, California, April–May 1991.

Faculty: Adjunct Associate Professor, Plant and Soil, The University of Tennessee.

Advisor: Kelley Turnage, M.S. candidate, The University of Tennessee.

Ad Hoc Reviewer: Soil Science Society of America Journal; Soil Science; Clays and Clay Minerals; proposal for DOE.

LEMISZKI, P. J.

Other: Lecture, 4th–6th Grade Spring Camp, Athens, Tennessee.

LEVINE, D. A.

Ad Hoc Reviewer: Journal—Water Pollution Control Federation.

LINDBERG, S. E.

Chairman: Working Group on New Initiatives, sponsored by U.S. National Atmospheric Deposition Program, 1990–91; Session on Deposition to Forests, sponsored by Conference on Atmosphere/Surface Exchange Processes, Richland, Washington, June 1991.

Member: U.S. and Soviet Scientists Delegation to select research sites in the Siberian Arctic as part of the Joint U.S.-U.S.S.R. Bilateral Agreement on Environmental Protection; U.S.-Poland Joint Research Committee on Status and Trends of Forest Ecosystems: Climate, Pollution, and Forest Health; Advisory Panel, Air and Deposition Monitoring Group of the EPA program on Environmental Monitoring and Assessment; Honorary Steering Committee, International Conference Series: Heavy Metals in the Environment; Technical Organizing Committee, Eighth

International Conference on Heavy Metals in the Environment; Planning Committee, International Conference on Atmosphere/Surface Exchange Processes; Executive Committee, National Atmospheric Deposition Program/NTN; MAP3S/RAINE Precipitation Chemistry Network; Habilitation Committee, D. Godbold, University of Göttingen; Organizing Committee, Second International Conference on Mercury as an Environmental Pollutant.

Participant: Annual Technical Meeting of the National Atmospheric Deposition Program, San Antonio, Texas, October 1990; U.S.-Poland Workshop to Develop Joint Research on Forest Ecosystems, Key Biscayne, Florida, March 1991; Briefing for State of New York Power Company representatives on atmospheric chemistry and emissions of mercury, New York, March 1991; EPRI Annual Review Meeting of Mercury in Temperate Lakes Project, Palo Alto, California, April 1991; International Conference on Atmosphere/Surface Exchange Processes, Richland, Washington, June 1991.

Editor: Advances in Environmental Science.

Ad Hoc Reviewer: Water Resources Research; Environmental Science and Technology; Atmospheric Environment; Tellus; Water, Air, and Soil Pollution; Springer-Verlag.

LOAR, J. M.

Member: Oak Ridge Reservation Resource Management Organization, Aquatic Resource Group.

Participant: Conference on Environmental Biotechnology: Moving from the Flask to the Field, sponsored by The University of Tennessee, Knoxville, October 1990; The Risks to Clean Water, sponsored by EPA, East Lansing, Michigan, February 1991; Quantitative Ranking of Environmental Problems According to Risk, sponsored by American Chemical Society, New York, August 1991.

Ad Hoc Reviewer: Water, Air, and Soil Pollution; Journal of the Tennessee Academy of Science.

LUXMOORE, R. J.

Chairman: IUFRO Representative, Ecological Physiology of Conifers, sponsored by IUFRO, Abakan, U.S.S.R., August 1991.

Member: Board of Directors, Soil Science Society of America; Physiology Subject Group, IUFRO.

Participant: Annual Meeting of Soil Science Society of America, San Antonio, Texas, October 1990; 17th Annual EPA Hazardous Waste Research Symposium, sponsored by EPA, Cincinnati, April 1991; Southern Global Change Program Workshop, sponsored by U.S. Forest Service, Coweeta, North Carolina, May 1991; Response of Vegetation to Elevated CO_2, sponsored by DOE, Edgewater, Maryland, May 1991; Physiological Ecology of Coniferous Forests Past and Future, sponsored by University of Wyoming, Jackson, September 1991.

Faculty: Faculty Associate, Life Sciences Graduate Program, The University of Tennessee.

Editor: Editor-in-Chief, Editorial Board, *Soil Science Society of America Journal*; Associate Editor, *Tree Physiology*; Editorial Advisory Board, *Modeling of GeoBiosphere Processes.*

Ad Hoc Reviewer: Soil Science; Tree Physiology; USDA; *Soil Science Society of America Journal*; proposal for National Environmental Research Council, UK; proposals for USDA, NSF, and Research Council of Canada; American Society of Agronomy.

Other: Board Member, Tennessee Citizens for Wilderness Planning.

MANN, L.

Member: Southern Appalachian Man and the Biosphere, Natural Resources

Committee; Soil Sciences Society of America; Ecological Society of America.

Participant: Biomass Energy Strategies Workshop, Biofuels Feedstock Program, Oak Ridge, Tennessee, November 1991.

Ad Hoc Reviewer: Canadian Journal of Forest Research; proposals for EMCOMP (USDA).

Other: Soil Conservation Service Board of Supervisors, Roane County.

MARLAND, G.

Member: Advisory Committee, National Institute for Global Environmental Change—South; Policy Implications of Greenhouse Warming;Council on Agricultural Science and Technology, U.S. Agriculture and Global Climate Change.

Participant: Environmental Challenges for Asian-Pacific Energy Systems, sponsored by Asian-Pacific Development Centre, Kuala Lumpur, Malaysia, January 1991; National Emissions of Greenhouse Gases—An Expert's Seminar, sponsored by OECD/IEA, Paris, February 1991; Unconventional Strategies of Mitigating Global Climate Change, sponsored by EPRI, La Jolla, California, February 1991; Engineering Response to Global Climate Change, sponsored by Engineering Foundation, Palm Coast, Florida, June 1991; Advanced Study Institute on the Global Carbon Cycle, sponsored by NATO, Castelvecchio Pascoli, Italy, September 1991.

Advisor: Susan Thompson, B. S. candidate, Oklahoma State University.

Ad Hoc Reviewer: Energy, The International Journal; Science; Climatic Change; National Wildlife Federation; Greenpeace; EPA.

MARSH, D. J.

Member: Geochemical Society; American Geophysical Union; Sigma Xi.

Participant: DOE High School Honors Workshop, Oak Ridge, Tennessee.

MARSHALL, D. S.

Participant: Fourth Tennessee Water Resources Symposium, sponsored by Tennessee Section, American Water Resources Association, Knoxville, Tennessee, September 1991.

MCCARTHY, J. F.

Chairman: Concepts in Manipulations of Groundwater Colloids for Environmental Restoration, sponsored by DOE, Manteo, North Carolina, October 1990.

Member: American Chemistry Society; Society of Environmental Toxicology and Chemistry.

Advisor: W. Burton, Ph.D. candidate, The University of Tennessee.

Ad Hoc Reviewer: Environmental Science and Technology; proposals for DOE, National Research Council of Canada.

MCCORD, R. A.

Participant: Tennessee Natural Resources GIS Users Meeting, sponsored by TVA, Norris, Tennessee, October 1990; SAS Users Group International, SAS Institute, New Orleans, February 1991; Environmental Research Systems Institute User Conference, sponsored by ESPI, Inc., Palm Springs, California, May 1991.

MCMASTER, W. M.

Chairman: Hydroforum, sponsored by ESD, Oak Ridge, Tennessee.

Member: Association of Ground Water Scientists and Engineers, National Water Well Association.

Participant: Third Tennessee Hydrology Symposium, sponsored by U.S. Geological Survey and others, Nashville, Tennessee, September 1990.

Faculty: Research Associate, Civil Engineering, The University of Tennessee, Knoxville.

MOORE, G. K.

Participant: Containing and Controlling Groundwater Contamination, sponsored by

National Water Well Association, Nashville, Tennessee, July 1991; Fourth Tennessee Water Resources Symposium, sponsored by Tennessee Section, American Water Resources Association, Knoxville, Tennessee, September 1991.

MULHOLLAND, P. J.

Participant: Walker Branch Watershed Program Review, sponsored by DOE/Ecological Research Division, Oak Ridge, Tennessee, January 1991; Second Annual Walker Branch Watershed Research Symposium, sponsored by DOE OHER, Oak Ridge, Tennessee, March 1991; North American Benthological Society Annual Meeting, Santa Fe, New Mexico, May 1991; Ecological Society of America Annual Meeting, San Antonio, Texas, August 1991; Fourth Tennessee Water Resources Symposium, sponsored by the Tennessee Section of the American Water Resources Symposium, Knoxville, Tennessee, September 1991.

Faculty: Adjunct Faculty Associate, Department of Ecology, The University of Tennessee.

Editor: Board of Editors, *Ecology*, *Ecological Monographs*, Ecological Society of America.

Advisor: Terry Flum, Ph.D. candidate, The University of Tennessee; David Genereux, Ph.D. candidate, Massachusetts Institute of Technology; Amy Rosemond, Ph.D. candidate, Vanderbilt University; David Kirschtel, M.S. candidate, University of Louisville; Rachel Smith, B.S. candidate, Earlham College.

Ad Hoc Reviewer: Canadian Journal of Fisheries and Aquatic Sciences; Wetlands, Limnology and Oceanography; Hydrobiologia; Journal of the Soil Science Society of America; Journal of the North American Benthological Society; Journal of Environmental Quality; Archiv für Hydrobiolgie; proposals to NSF, Australian Research Council; book chapter: Aquatic Microbiology-Ecological Processes, T. Ford (ed.), Blackwell Scientific Publishers.

NORBY, R. J.

Participant: Second Annual Walker Branch Watershed Research Symposium, sponsored by DOE OHER, Oak Ridge, Tennessee, March 1991; Carbon Dioxide Workshop, sponsored by DOE, Edgewater, Maryland, May 1991; Technologies for a Greenhouse-Constrained Society, sponsored by ORNL, Oak Ridge, Tennessee, June 1991; Applied and Environmental Microbiology, sponsored by Gordon Research Conference, New London, New Hampshire, July 1991.

Faculty: Adjunct Faculty, Graduate Program in Ecology, The University of Tennessee.

Advisor: Megumi Murakami, B.A. candidate, Carleton College; Daniel B. Stewart, B.S. candidate, Pennsylvania State University; Andrea Tucker, B.A. candidate, The University of Tennessee.

Ad Hoc Reviewer: Tree Physiology; Canadian Journal of Forest Research; Atmospheric Environment; Environmental and Experimental Botany; proposals for DOE and NSF.

NYQUIST, J.

Participant: Kickoff Meeting for Fernald Integrated Demonstration, sponsored by Fernald, Harrison, Ohio, February 1991; High Performance Computing Group, sponsored by DOE, OTD, Washington, D.C., April 1991; Spring Meeting of the American Geophysical Union, sponsored by American Geophysical Union, Baltimore, May 1991; Workshop on Geophysics for Non-Invasive Waste Site characterization, sponsored by DOE, OTD, Dallas, August 1991; Tennessee Water Resources Symposium, Nashville, Tennessee, September 1991.

Faculty: Adjunct Professor, Geophysics and Geology, The University of Tennessee.

Other: Science-by-Mail Scientist.

OLSON, R. J.

Member: Interagency Committee on Environmental Trends, Council on Environmental Quality; GCDIS Catalog Services Subgroup, NASA.

Participant: International Forum on Environmental Information for the Twenty-First Century, sponsored by Environment Canada, Montreal, May 1991; GISDEX: Geographic Information and Spatial Data Exposition, sponsored by Government Computer News, Washington, D.C., July 1991.

Other: (Special assignment) President's Council on Environmental Quality, Washington, D.C., advisor for Environment Trends.

O'NEILL, E. G.

Member: Soil Ecology Society; Ecological Society of America; American Institute for the Biological Sciences.

Participant: Second Annual Walker Branch Watershed Research Symposium, sponsored by DOE OHER, Oak Ridge, Tennessee, March 1991; International Symposium on Soil Diversity and Function: Resolving Global and Microscopic Scales, sponsored by U.S. Soil Ecology Society and EPA, Corvallis, Oregon, April 1991; The Response of Vegetation to Elevated Atmospheric CO_2 Concentration, sponsored by DOE, Edgewater, Maryland, May 1991.

Ad Hoc Reviewer: Crop Science; proposals for USDA Competitive Research Grants Program.

O'NEILL, R. V.

Chairman: Transect Workshop II, sponsored by DOE OHER, Las Cruces, New Mexico, March 1991.

Member: U.S. Chapter of International Association for Landscape Ecology; Ecological Society of America; American Society of Naturalists; Fellow, American Association for Advancement of Science; International Society of Ecological Modeling.

Participant: Annual Meeting of Ecological Society of America, San Antonio, August 1991; Transect Workshop II, Las Cruces, New Mexico, March 1991; U.S.-IALE Annual Meeting, Ottawa, August 1991.

Faculty: Adjunct Associate Professor, Graduate Program in Ecology, The University of Tennessee.

Advisor: Jackie Cunningham, Ph.D. candidate, The University of Tennessee.

Ad Hoc Reviewer: Landscape Ecology, Environmental Management, Ecology; proposals for NSF, EPA, NASA.

PALUMBO, A. V.

Participant: In Situ and On-Site Bioreclamation, An International Symposium, sponsored by Battelle, San Diego, March 1991; Program Review—Biodegradation/Microbial Physiology Subprogram, sponsored by DOE OHER, Washington, D.C., March 1991; Program Review—Deep Microbiology Subprogram, sponsored by DOE OHER, Salt Lake City, April 1991; 91st Annual Meeting of the American Society for Microbiology, Dallas, May 1991; Program Review-RDDT&E Program, sponsored by DOE OTD, Washington, D.C., June 1991.

Advisor: Andrew Arrage, Ph.D. candidate, Virginia Polytechnic Institute and State University; Deborah Quo, Ph.D. candidate, The University of Tennessee; Nanette Olmeda Miro, DVM candidate, School of Veterinary Science, The University of Tennessee; Jeffery Arnold, M.S. candidate, University of Michigan; Adonna Miller, B.S. candidate, George Washington University.

PARR, P. D.

Chairman: Plant Ecology Session, sponsored by Association of Southeastern

Biologist Meetings, Boone, North Carolina, April 1991.

Officer: Treasurer, Association of Southeastern Biologists.

Member: Southern Appalachian Man and the Biosphere, Environmental Education; Association of Southeastern Biologists; Oak Ridge Reservation Resource Management Organization, National Environmental Research Park.

Participant: LTER All Scientists Meeting, Estes Park, Colorado, September 1990; Meeting of the Association of Southeastern Biologists, Boone, North Carolina, April 1990.

PEARSON, S. M.

Member: American Ornithologist Union; Wilson Ornithogical Society; Cooper Ornithogical Society; Behavioral Ecology Society; Sigma Xi.

Ad Hoc Reviewer: Auk, Condor, Animal Behaviour, Journal of Theoretical Biology, Landscape Ecology.

PENG, T.-H.

Chairman: NATO Advanced Study Institute On Global Carbon Cycle, Il Ciocco, Italy, September 1991.

Participant: Marine Algal Productivity and Carbon Dioxide Assimilation Workshop, sponsored by National Research Council Board on Biology, Irvine, California, October 1990; American Geophysical Union 1990 Fall Meeting, San Francisco, December 1990; ASLO Symposium, San Macos, California, February, 1991; The 14th International ^{14}C Conference, Tucson, Arizona, May 1991; U.S. JGOFS Steering Committee, Boulder, Colorado, June 1991; SAVE Workshop, Harriman, New York, July 1991; EPRI Workshop on Carbon Cycle, Carmel, California, July 1991.

Ad Hoc Reviewer: Journal of Geophysical Research; Earth and Planetary Sciences Letter; Global Biogeochemical Cycle; Science; Nature; proposals for Marine Chemistry, Polar Studies, DOE, and NOAA.

POST, W. M., IV

Participant: NATO Advanced Study Institute on Global Carbon Cycle, Il Ciacco, Italy, September 1991.

Officer: President, Knoxville Recycling Coalition, Knoxville, Tennessee.

Faculty: Associate Professor, Graduate Program in Ecology, The University of Tennessee.

Ad Hoc Reviewer: Nature; American Naturalist; Journal of Environmental Quality; Journal of Theoretical Biology; proposals for NSF and DOE.

RAILSBACK, S. F.

Chairman: Annual Conference of ASCE Water Resources Planning and Management Division, New Orleans, May 1991.

Member: Social and Environmental Objectives Committee, ASCE; ASCE Water Resources Planning and Management Division.

Participant: Interagency Research Coordination in Water Quality and Ecology Workshop, sponsored by Interagency Research Coordination Committee, Denver, February 1991; Instream Flows and Recreation Workshop, sponsored by Oregon State University, Corvallis, March 1991; Annual Conference of the Water Resources Planning and Management Division, sponsored by American Society of Civil Engineers, New Orleans, May 1991.

Ad Hoc Reviewer: Proposal for NSF, reports for Niagara-Mohawk Power Corporation.

Other: Adopt-a-River Technical Committee Chair, Tennessee Scenic River Association.

RANNEY, J. W.

Member: Executive Committee, Research Committee, Resource

Management Committee of the Southern Appalachian Man and the Biosphere Program.

Participant: Technologies for a Greenhouse-Constrained Society, sponsored by ORNL, Oak Ridge, Tennessee, June 1991.

Editor: Editorial board member, *Biomass and Bioenergy*, Pergamon Press.

Ad Hoc Reviewer: Book chapter for *Fuels and Electricity from Renewable Sources of Energy*; book for U.N. Conference on Environment and Development.

REYES, O. M.

Participant: Simulation of Subsurface Flow and Contaminant Transport by Finite Element and Analytical Methods, sponsored by Pennsylvania State University, University Park, May 1991.

Ad Hoc Reviewer: Rock Mechanics and Rock Engineering.

ROSE, K. A.

Participant: COMPMECH Workshop on Striped Bass, sponsored by EPRI, Columbia, South Carolina, November 1990; COMPMECH Workshop on Bay Anchovy, sponsored by EPRI, Raleigh, North Carolina, November 1990; COMPMECH Program Review, sponsored by EPRI, Oak Ridge, Tennessee, February 1991; COMPMECH Workshop on California Halibut, sponsored by EPRI, La Jolla, California, June 1991; COMPMECH Workshop on Percids, sponsored by EPRI, Madison, Wisconsin, July 1991.

Ad Hoc Reviewer: Ecological Applications; Ecological Modeling; proposal for National Sea Grant.

ROSEN, A. E.

Member: Association for Computing Machinery.

Participant: Software Developers Conference '91, sponsored by Miller Freeman Publications, Santa Clara, California, February 1991.

RYON, M. G.

Member: Pollution Committee, Southern Division, American Fisheries Society.

SALE, M. J.

Chairman: Fourth Tennessee Water Resources Symposium, sponsored by Tennessee Section, American Water Resources Association, Knoxville, Tennessee, September 1991.

Member: Tennessee Section, American Water Resources Association.

Participant: GEWEX Design Workshop, NASA, NOAA, and USGS, Reston, Virginia, October 1990; COMPMECH Program Review, sponsored by EPRI, Oak Ridge, Tennessee, February 1991; FY 1993 Program Planning Workshop—Utilities Sector, sponsored by DOE, Denver, February 1991.

Ad Hoc Reviewer: Canadian Journal of Fisheries and Aquatic Sciences; proposals for U.S. Fish and Wildlife Service; programs for DOE and Virginia Department of Wildlife and Inland Fisheries.

SALK, M. S.

Participant: 1991 Conference, sponsored by National Association of Environmental Professionals, Baltimore, April–May 1991.

Ad Hoc Reviewer: The Environmental Professional.

SCHRAMM, W. E.

Participant: Environmental Sustainable Development Planning, U.S. Agency for International Development, Washington, D.C., June 1991; Workshop on NEPA/CERCLA at Federal Sites, CEQ and EPA, Washington, D.C., July 1991.

SHAAKIR-ALI, J. A.

Member: American Public Health Association.

Participant: 26th Annual International Graduate Summer Session in Epidemiology, Environmental Epidemiology Section, sponsored by University of Michigan, Ann Arbor, Michigan, July 1991.

SHARPLES, F. E.

Member: AAAS Committee on Science, Engineering and Public Policy.

Participant: Environmental Biology Peer Review Panel, sponsored by EPA, Phoenix, Arizona, December 1990; Workshop on Undergraduate Education in Environmental Sciences, sponsored by Ecological Society of America, San Antonio, Texas, August 1991.

Advisor: Marc Sperber, J.D. candidate, Boston University; Patrick Gann, J.D. candidate, Arizona State University.

Ad Hoc Reviewer: OTA Document.

SHEVENELL, L.

Participant: Simulations of Subsurface Flow and Contaminant Transport by Finite Element and Analytical Models, sponsored by Pennsylvania State University, State College, Pennsylvania, May 1991.

Faculty: Research Associate, Civil Engineering Department, The University of Tennessee, Knoxville.

Ad Hoc Reviewer: Documents for Portsmouth Gaseous Diffusion Plant.

SHRINER, D. S.

Member: Research Task Group, U.S. Forest Service, Southern Global Change Program.

Participant: Annual Meeting of the American Phytopathological Society, St. Louis, August 1990.

Ad Hoc Reviewer: U.S. Forest Service Northern Global Change Program.

SHUGART, L. R.

Chairman: NATO Advanced Research Workshop on Biomarkers, sponsored by NATO, EPA, Procter and Gamble, and Green Peace, Texel, The Netherlands, May 1991.

Member: Technical Committee, Society of Environmental Toxicology and Chemistry.

Participant: Review of TNT Project, U.S. Army Biomedical Research and Development Laboratory, Fort Detrick, Maryland, November 1990; Review of Biomarkers Program, sponsored by EPA, Cincinnati, December 1990; Review of Gulf Breeze ERL Proposal for National Center for Marine Research, sponsored by EPA, Gulf Breeze, Florida, February 1991; NATO ARW on Biomarkers (Workshop), Texel, The Netherlands, May 1991; Study Group on Environmental Remediation, sponsored by Environmental Health Institute, St. Simon's, Georgia, June 1991; DOE OTD Workshop on Bioremediation, Denver, August 1991; Savannah River Genotoxicology Workshop, sponsored by Savannah River Ecology Laboratory (University of Georgia), Aikens, South Carolina, August 1991.

Faculty: Adjunct Associate Professor, Oak Ridge Graduate School of Biomedical Sciences, The University of Tennessee.

Editor: Ecotoxicology, Chapman and Hall Publishers.

Advisor: Anne Helmenstein, Christina Gettys Hull, and Chris Theodorakis, Ph.D. candidates, The University of Tennessee.

Ad Hoc Reviewer: Archives of Environmental Contamination and Toxicology; Aquatic Toxicology; Marine Environmental Research; Risk Analysis; Cytometry; journal article for International Symposium on Biomarkers of Ecology; journal article for ASTM Symposium on Environmental Toxicology; proposal to Microbiological Associates, Inc.; grant proposal to U.S. Department of Commerce; Ph.D. thesis, University of Mysore, Mysore, India.

Other (Special assignment): North Sea Cruise to sample aquatic species as part as of Integrated North Sea Program, sponsored by the Government of The

Netherlands and The Netherlands Institute of Sea Research, Texel, The Netherlands, August 1991.

SIEGRIST, R. L.

Chairman: Sixth National Conference on On-Site Wastewater Treatment, sponsored by Society of Agricultural Engineers, Chicago, December 1991.

Member: American Society of Civil Engineers; Water Pollution Control Federation; Soil Science Society of America; Committee D-34 on Waste Disposal, American Society for Testing Materials (ASTM).

Participant: Understanding Site Remediation, sponsored by the University of Wisconsin for the Tennessee Valley Authority, National Fertilizer and Environmental Research Center, Muscle Shoals, Alabama, October 1990; Data Sufficiency and Decision Making for Site Remediation, sponsored by the University of Wisconsin, Madison, November 1990; Multi-Stake Holder Workshop on Contaminated Sites, sponsored by the Canadian Council of Ministers of the Environment, Toronto, November 1990; Third International KfK/TNO Conference on Contaminated Soils, sponsored by KfK and TNO, Karlsruhe, Germany, December 1990; Pittsburgh Conference on Analytical Chemistry, sponsored by Varian Press Briefing, Chicago, March 1991; National Symposium on Soil Venting, sponsored by EPA, Houston, April 1991; Data Sufficiency and Decision Making for Site Remediation, sponsored by the University of Wisconsin, San Diego, June 1991; Office of Technology Development Program Review, sponsored by DOE, Germantown, Maryland, June 1991; 33rd Rocky Mountain Conference on Analytical Chemistry, sponsored by USGS and others, Denver, July 1991; Buried Waste Deposits and Polluted Soils, sponsored by Norwegian Centre for Soil and Environmental Research, Aas, Norway, September 1991; 5th Interagency Meeting on Quality Assurance for Environmental Measurements, sponsored by EPA and DOE, Richmond, Virginia, September 1991.

Advisor: Paula Labieniec, Ph.D. candidate, Carnegie Mellon University; Dan Hurst, M.S. candidate, The University of Tennessee.

Ad Hoc Reviewer: EPA; Bioremediation of Environmental Contaminants Consortium, University of Wisconsin, Madison, program review and critique.

Other: Member, Core Planning Group; and Director, Research and Development Initiatives, In Situ Remediation Integrated Program, DOE OTD.

SIGAL, L. L.

Chairman: Third International Task Force on the Application of the Principles of Environmental Impact Assessment on Policies, Plans, and Programs, sponsored by EPA, Washington, D.C., April 1991; Fourth International Task Force on the Application of the Principles of Environmental Impact Assessment on Policies, Plans, and Programs, sponsored by EPA, Geneva, August 1991.

Participant: NEPA Integration: Effective, Efficient Environmental Compliance in the 1990s, sponsored by CEQ, Alexandria, Virginia, March 1991; Lichens as Biomonitors, sponsored by National Park Service, Denver, April 1991; Lichens as Indicators of Air Pollution Impacts at Toxic Waste Sites, sponsored by EPA, Arlington, Virginia, June 1991; CERCLA and NEPA at Federal Facilities, sponsored by EPA/CEQ, Arlington, Virginia, July 1991.

SIGMON, C. F.

Chairman: WATTec, Knoxville, Tennessee, February 1991.

Member: Association for Women in Science; WATTec.

SMITH, E. D.

Chairman: Discussion group leader, CEQ/EPA Workshop on CERCLA and NEPA at Federal Sites, sponsored by CEQ/EPA, Arlington, Virginia, July 1991.

Participant: Hydrogeology and Geomorphology of the Mammouth Cave Area, Kentucky, sponsored by Southeastern Friends of the Pleistocene, Cave City, Kentucky, November 1990.

Ad Hoc Reviewer: Journal of Hazardous Materials.

Other: Member, Environmental Quality Advisory Board, City of Oak Ridge.

SMITH, J. G.

Participant: 39th Annual Meeting of the North American Benthological Society, Santa Fe, New Mexico, May 1991.

Advisor: Dan O'Hallaran, participant in the DOE Teacher Research Associates Program.

Ad Hoc Reviewer: Canadian Journal of Fisheries and Aquatic Sciences.

SOLOMON, D. K.

Participant: Concepts in Manipulation of Groundwater Colloids for Environmental Restoration, sponsored by OHER DOE, Manteo, North Carolina, October 1990; Transport and Mass Exchange Processes in Sand and Gravel Aquifers, sponsored by AECL Research, Chalk River Laboratory, Ottawa, October 1990; American Geophysical Union Fall Meeting, sponsored by American Geophysical Union, San Francisco, December 1990; Second Annual Walker Branch Watershed Research Symposium, sponsored by DOE OHER, Oak Ridge, Tennessee, April 1991; Manipulation of Natural Subsurface Processes for In Situ Remediation, sponsored by DOE OHER, Richland, Washington, July 1991.

Ad Hoc Reviewer: Proposal for DOE.

SOUTHWORTH, G. R.

Member: American Chemical Society; Society of Environmental Toxicology and Chemistry; Sigma Xi.

Ad Hoc Reviewer: Environmental Science and Technology; Water, Air, and Soil Pollution.

SPALDING, B. P.

Participant: In Situ Vitrification Technology Development Activities Review, sponsored by DOE, Pasco, Washington, January 1991; Society of Exploration Geophysicists, sponsored by DOE, Knoxville, Tennessee, March 1991; Office of Technology Development Program Review, sponsored by DOE, Washington, D.C., June 1991.

Ad Hoc Reviewer: Soil Biology and Biochemistry.

STEINMAN, A. D.

Member: Elections and Place Committees, North American Benthological Society.

Participant: Second Annual Walker Branch Watershed Research Symposium, sponsored by DOE OHER, Oak Ridge, Tennessee, March 1991.

Advisor: Ralph Mathes, SEED Project, Fulton High School.

Ad Hoc Reviewer: Freshwater Biology; Hydrobiologia; Ecology; Journal of the North American Benthological Society; Canadian Journal of Fisheries and Aquatic Science; proposals for NSF.

Other: Knoxville Metropolitan Planning Commission; consultant for Environment 2000 Project.

STEWART, A. J.

Participant: North American Benthological Society Annual Meeting, Santa Fe, New Mexico, May 1991.

Faculty: Adjunct Faculty, Graduate Program in Ecology, The University of Tennessee, Knoxville.

Advisor: Phil Neuhoff, B.S. candidate, University of Iowa; Erik Worden, B.S. candidate, Washington State University.

STOW, S. H.

Chairman: International Symposium on High-Level Waste Disposal, sponsored by DOE American Nuclear Society, Las Vegas, April 1991; Commission on Hydrogeology of Hazardous Waste, sponsored by International Association of Hydrogeologists, Hannover, Germany, May 1991; Co-host, Conference of Dense Nonaqueous Phase Liquids at DOE Facilities, sponsored by DOE/ER, Atlanta, July 1991.

Member: Education, Nominations, Geology and Public Policy committees; Geological Society of America; DOE OTD Advisory Task Force on Education; The University of Tennessee Advisory Board for Geosciences; Science-Math Deans Advisory Board, Auburn University.

Participant: Annual Meeting of the Geological Society of America, Dallas, October 1990; American Association for the Advancement of Science, Washington, D.C., February 1991; Southeastern Section Geological Society of America, Baltimore, April 1991; Annual Meeting of the American Association of State Geologists, Saratoga Springs, New York, May 1991.

Faculty: Adjunct Professor, Geological Sciences, The University of Tennessee.

Editor: Editorial Board, *Environmental Geology and Water Sciences.*

Ad Hoc Reviewer: Proposals for NSF.

STRATTON, L. E.

Participant: DOE HQ Review of ORNL Environmental Restoration and Waste Management (EM) FY 1993 Budget Submission, sponsored by DOE, Oak Ridge, Tennessee, February 1991; Conference of Radiation Control Program Directors, sponsored by DOE, Wichita, Kansas, May 1991.

SUTER, G. W., II.

Chairman: Rapporteur and Plenary Speaker, OECD Workshop on the Extrapolation of Laboratory Aquatic Toxicity Data to the Real Environment, sponsored by Organization for Economic Cooperation and Development, Crystal City, Virginia, December 1990; Chesapeake Bay Ecological Risk Assessment Workshop, sponsored by EPA and Chesapeake Research Consortium, Solomons, Maryland, May 1991.

Member: Board of Directors, Society for Environmental Toxicology and Chemistry; Ecosystem Valuation Forum, EPA/Conservation Foundation; Group E-47 on Aquatic Toxicology and Environmental Fate, American Society for Testing and Materials.

Participant: EPA Workshop on Recommendations for Revising the National Water Quality Criteria Guidelines, Crystal City, Virginia, December 1990; Ecosystem Risk Assessment and Monitoring Workshop, sponsored by National Academy of Sciences, Airlie, Virginia, February-March 1991; Workshop on Implementation of Natural Resource Damage Assessment, sponsored by DOE, Oak Ridge, Tennessee, March 1991; NATO Advanced Research Workshop on Strategy for Biomarker Research and Application in the Assessment of Environmental Health, Texel, The Netherlands, May 1991.

Advisor: David Macintosh, M.S. candidate, Indiana University; Geoffry A. Kerchner, B.S. candidate, Harvard University.

Ad Hoc Reviewer: Environment Canada; *Risk Analysis; Aquatic Toxicology and Risk Assessment; Environmental Toxicology and Chemistry*; International Symposium on Ecological Indicators; *Environmental Management*; EPA .

TIMMINS, S. P.

Participant: American Society of Photogrammetry and Remote Sensing,

sponsored by ASPRS ACSM, Baltimore, April 1991; First International Conference on Integrating GIS and Environmental Modeling, sponsored by NCGIA, Boulder, Colorado, September 1991; Second Annual Walker Branch Watershed Research Symposium, DOE OHER, ORNL, Oak Ridge, Tennessee, March 1991.

TOLBERT, V. R.

Chairman: ORNL Conference for College Women, Knoxville, Tennessee, May 1991.

Member: North American Benthological Society; Exhibits Committee, Sigma Xi; Admissions Committee, Association for Women in Science; Awards Committee, Association of Southeastern Biologists; Audit Committee.

Participant: North American Benthological Society Annual Meeting, Santa Fe, New Mexico, May 1991.

Advisor: Hans J. Eckman, B.S. candidate, University of Georgia, Athens; Theme Group Advisor, DOE High School Honors Program.

Other: Teacher Enrichment Class in Ecology, Cedar Bluff Intermediate School, Knox County.

TORAN, L. E.

Participant: American Geophysical Union Spring Meeting, sponsored by American Geophysical Union, Baltimore, May 1991; Cooperate Partnership Workshop, sponsored by Partnership in Computer Science (DOE), Columbia, South Carolina, June 1991; Groundwater Transport Workshop, sponsored by Partnerships in Computer Science (DOE), Oak Ridge, Tennessee, August 1991; Tennessee Water Resources Symposium, sponsored by American Water Resources Association, Knoxville, Tennessee, September 1991.

Faculty: Adjunct Faculty, Geology and Geophysics, The University of Tennessee.

Editor: Ground Water.

Ad Hoc Reviewer: Water Resources Research; Geochimica Cosmochimica et Acta.

TRABALKA, J. R.

Member: Task Group 9, Scientific Committee 64, National Council on Radiation Protection and Measurements.

Participant: Observational Approach Workshop, sponsored by DOE, Environmental Restoration Program, Oak Ridge, Tennessee, May 1991.

TSCHAPLINSKI, T. J.

Participant: Biofuels Subcontractors Workshop, sponsored by DOE, Baton Rouge, Louisiana, February 1991; Second Annual Walker Branch Watershed Symposium, sponsored by DOE OHER, Oak Ridge, Tennessee, March 1991; Marker-Aided Selection, sponsored by DOE, Gatlinburg, Tennessee, June 1991; American Society of Plant Physiologists—Annual Meeting, sponsored by American Society of Plant Physiologists, Albuquerque, New Mexico, July 1991; Biofuels Subcontractors Workshop, sponsored by DOE, Davis, California, September 1991.

Advisor: Denise P. Kay, B.S. candidate, University of Michigan; Daniel B. Stewart, B.S. candidate, Pennsylvania State University; Michael Kirk, Junior High School Teacher, University of Wisconsin.

Ad Hoc Reviewer: Proposal to USDA-Competitive Grants Program.

TURNER, M. G.

Member: Committee on Federal Acquisition of Lands For Conservation, National Academy of Sciences; Directorate on Temperate Ecosystems, U.S. Man and the Biosphere Program; Councillor-at-Large, U.S. Association of the International Association for Landscape Ecology; Future Meetings Committee and Vision Committee, Ecological Society of America.

Participant: Invited Participant, Wetland and Riparian Ecotones in Landscape Dynamics: A Workshop on Applying Theory, Data, and Methods, sponsored by the U.S. Man and the Biosphere Program, Oak Ridge, Tennessee, September 1990; First Annual Southern Appalachian Man and the Biosphere (SAMAB) Conference, Gatlinburg, Tennessee, November 1990; Symposium, Application of Ecological Models to Natural Area Preserve Design and Management, Annual Meeting of the Ecological Society of America, San Antonio, Texas, August 1991.

Faculty: Adjunct Assistant Professor and Assistant Professor, Graduate Program in Ecology, The University of Tennessee.

Editor: Editorial Board, *Climate Research.*

Advisor: Nathan Schumaker, Ph.D. candidate, University of Washington.

Ad Hoc Reviewer: Ecology; Landscape Ecology; Wetlands Ecology and Restoration; IALE (Chapman and Hall); National Park Service; Elsevier; Springer-Verlag; Cambridge University Press; NSF; U.S. Man and the Biosphere Program; USDA Forest Service; USDI Fish and Wildlife Service.

TURNER, R. R.

Participant: Symposium on Decontamination of Heavy Metals in Soil and Groundwater, sponsored by American Chemical Society, Atlanta, April 1991; Annual Program Review of Mercury in Temperate Lakes Project, sponsored by EPRI, Palo Alto, California, April 1991; Genetic and Microbial Ecology of Biofilms Review, sponsored by EPRI, Knoxville, Tennessee, March 1991.

Advisor: Sharon Kindon, Ph.D. candidate, The University of Tennessee.

Ad Hoc Reviewer: Environmental Toxicology and Chemistry.

Other: Event Supervisor, Science Olympiad, Museum of Science and Energy, Oak Ridge, Tennessee.

TURNER, R. S.

Participant: Integrated Assessment Writing/Review Workshop, sponsored by NAPAP, Washington, D.C., October 1990; Second Annual Conference on Acid Rain in Asia, Asian Institute of Technology, DOE, World Bank, Bangkok, Thailand, November 1990; Scientific Evaluation of NAPAP's Final Report, sponsored by Air and Waste Management Association, Pittsburgh, December 1990; Walker Branch Watershed Program Review, sponsored by DOE OHER, Oak Ridge, Tennessee, January 1991; NAPAP Planning Workshop, Washington, D.C., April 1991; TVA/ORNL/NASA Freshwater Initiative Planning Workshop, sponsored by TVA, Norris, Tennessee, July 1991; Fourth Tennessee Water Resources Symposium, sponsored by American Resources Association, Knoxville,Tennessee, September 1991.

Ad Hoc Reviewer: Soil Science Society of America Journal; Journal of Environmental Quality; proposals for EPA; reports for EPA, NAPAP, and State of Maryland.

TUSKAN, G. A.

Chairman: Marker-Aided Selection Workshop, sponsored by Biofuels Feedstock Development Program and Weyerhaeuser, Gatlinburg, Tennessee, June 1991; Moderator, 21st Southern Forest Tree Improvement Conference, sponsored by Southern Forest Tree Improvement Committee, Knoxville, Tennessee, June 1991.

Participant: Southern Biomass Conference, sponsored by Louisiana State University, Baton Rouge, January 1991; U.S.-Canadian Poplar Council Meeting, sponsored by East Forest/Domtar Inc., Ottawa, August 1991.

Advisor: Cheng-gwo Wang, Ph.D. candidate, North Dakota State University; Ting Wee, M.S. candidate, Northern Arizona University.

Ad Hoc Reviewer: Proposals for USDA Plant Genome Program, New York State Energy Research and Development;

project reviews for USDA Forest Service, Grand Rapids, Minnesota, and Lincoln, Nebraska.

VAN HOOK, R. I.

Chairman: Technologies for a Greenhouse-Constrained Society, sponsored by DOE, Oak Ridge, Tennessee.

Member: Chairman of Public Affairs, Association of Ecosystem Research Centers; Executive Committee on Southern Appalachian Man and the Biosphere Cooperative; ORNL-TVA-UT Research Consortium.

Participant: U.S. Alternative Fuel Council Meeting, sponsored by DOE, Denver, February 1991; DOE Office of Foreign Intelligence Workshop, Washington, D.C., March 1991; NRC Workshop on Environmental Chemistry, sponsored by NAS-NRC, Washington, D.C., May 1991.

Faculty: Adjunct Faculty Member, Ecology Program, The University of Tennessee.

Editor: Editorial Board, *Biomass; Forum.*

VAN MIEGROET, H.

Member: ESD Education Committee; Association for Women in Science, East Tennessee Chapter; ORNL Representative, Wesleyan College Steering Committee; ORNL-ESD Representative, Southern Forest Environment Research Council.

Participant: International Conference on Acidic Deposition, sponsored by Royal Society of Edinburgh, Glasgow, United Kingdom, September 1990; Annual Meeting Soil Science Society of America, October 1990; First Annual Southern Appalachian Man and the Biosphere, sponsored by SAMAB and TVA, Gatlinburg, Tennessee, November 1990; Southern Biomass Conference, sponsored by Louisiana Department of Agriculture and Forestry, Baton Rouge, Louisiana, January 1991; 13th Biennial Southern Forest Tree Nutrition Workshop, sponsored by University of Georgia, Athens, May 1991; Southern Forest Environment Research Council, Virginia Polytechnic Institute and State University, Duffield, Virginia, June 1991; Gordon Research Conference on Forested Catchments, sponsored by Gordon Research Center, Plymouth, New Hampshire, July 1991; U.S.-Poland Research Exchange Planning Meeting, sponsored by Bowling Green State University, Gatlinburg, Tennessee, July 1991; UT/NPS Cooperative Research Symposium, sponsored by National Park Service, The University of Tennessee, Knoxville, Tennessee, September 1991.

Faculty: Lecturer and Adjunct Assistant Professor, Department of Forestry, Wildlife, and Fisheries, The University of Tennessee.

Advisor: Susan E. Lindahl, ORAU-Graduate Student Research Participation Program, The University of Tennessee; Ivan Rivera Torres, B.S. candidate, SEED Summer Student Project, University of Puerto Rico.

Ad Hoc Reviewer: Journal of Environmental Quality; Soil Science Society of America Journal; Ecology; Canadian Journal Forest Research; Water Resources Research; EPA.

VAN WINKLE, W. W.

Chairman: Symposium on Individual-Based Approach to Fish Population Dynamics: Theory, Process Studies, and Modeling Approaches, sponsored by American Fisheries Society, San Antonio, Texas, September 1991.

Officer: Treasurer, Oak Ridge Chapter of Sigma Xi.

Member: Oak Ridge Chapter of Sigma Xi; Scientific Advisory Committee for NOAA's Coastal Ocean Program/Coastal Fisheries Ecosystems; Technical Advisory Committee for NOAA's South Atlantic Bight Recruitment Experiment (SABRE).

Participant: EPRI-COMPMECH Program Workshops on California Halibut, sponsored by the Los Angeles County Museum, Los Angeles, October 1990; Bay Anchovy, sponsored by Carolina Power and Light and North Carolina State University, Raleigh, North Carolina, November 1990; Striped Bass, sponsored by South Carolina Electric and Gas and South Carolina Wildlife and Marine Resources Department, Columbia, South Carolina, November 1990; Striped Bass, sponsored by the California Department of Fish and Game, Stockton, California, February 1991; Smallmouth Bass, sponsored by the Ontario Ministry of Natural Resources, Maple, Ontario, March 1991; Percids, sponsored by the University of Wisconsin, Madison, July 1991; Smallmouth Bass, sponsored by the Ontario Ministry of Natural Resources, Algonquin Provincial Park, Ontario, September 1991; Larval Fish Conference, sponsored by Early Life History Section of the American Fisheries Society, Los Angeles; Annual Meeting, sponsored by American Fisheries Society, San Antonio, Texas, September 1991; EPRI Review of the COMPMECH Program, sponsored by ORNL, Oak Ridge, Tennessee, February 1991.

Faculty: Adjunct Faculty, Graduate Program in Ecology, The University of Tennessee.

Advisor: Mark Clark, Ph.D. candidate, The University of Tennessee.

Editor: Associate Editor, COMPMECH News, EPRI.

VON DAMM, K. L.

Member: Alvin Review Committee, University National Oceanographic Laboratories.

Participant: American Geophysical Union Fall 1990 Meeting, San Francisco, December 1990; Alvin Review Committee Meeting, sponsored by UNOLS, San Francisco, December 1990; Altantis II/Alvin Oceanographic Research Cruise, sponsored by National Science Foundation, Pacific Ocean, March–April 1991; Alvin Review Committee Meeting, sponsored by UNOLS, Woods Hole, Maine, June 1991.

Faculty: Research Associate Professor, Department of Geological Sciences, The University of Tennessee.

Advisor: Kathy Fraracci, M.S. candidate, The University of Tennessee; Rhett Moore, M.S. candidate, Indiana University.

Ad Hoc Reviewer: Nature; AGU Quadrennial National Report; *Geochimica et Cosmochimica Acta*; proposals for NSF.

VOORHEES, L.

Member: Oak Ridge Reservation Resource Management Organization, DOE.

Participant: SAS Users Group International 16th Annual Conference, sponsored by SAS Institute, New Orleans, February 1991.

WALTON, B. L.

Member: Board of Directors, American Board of Toxicology; Past Presidents Council, Society of Environmental Toxicology and Chemistry.

Faculty: Adjunct Faculty, Graduate Program in Environmental Toxicology and Ecology Program, The University of Tennessee.

Advisor: Todd A. Anderson, J. Ken Greer, and Anne M. Hoylman, Ph.D. candidates, The University of Tennessee.

Editor: Editorial Board, *Environmental Toxicology and Chemistry.*

Ad Hoc Reviewer: Environmental Toxicology and Chemistry; Journal of Environmental Quality; Canadian Journal of Microbiology.

WATKINS, D. R.

Participant: Oak Ridge Model Conference, sponsored by DOE, Oak Ridge, Tennessee, October 1990.

WATTS, J. A.

Chairman: Technical Program for WATTec 1991, The Technical Professional—Staying Current/Staying Competitive, sponsored by WATTec, Inc., Knoxville, Tennessee, February 1991; Technical Program/Education Session, Meeting the Challenges of the 21st Century, sponsored by Association for Women in Science, Washington, D.C., June 1991.

Member: Board of Directors, Science-In-Action Eduction Committee, WATTec, Inc.; Advisor, Discovery Place "A Matter of Energy" Exhibit, WATTec, Inc.; Education, East Tennessee Chapter of AWIS.

Participant: High School Honors Workshop in Environmental Sciences, Chairperson, sponsored by DOE, Oak Ridge, Tennessee, July 1991.

Advisor: Angela T. Bednarek, B.S. candidate, Notre Dame University; Jesselle M. Christenson, teacher, DOE-TRAP Program; DOE High School Honors Program.

Other: Volunteer, Knoxville Zoological Gardens.

WEBB, J. W.

Member: U.S. Delegation and Report Preparation, Task Force on Environmental Impact Assessment for Policies, Plans, and Programs, U.N. Economic Commission for Europe.

Participant: U.N. Economic Commission for Europe Task Force on Environmental Impact Assessment for Policies, Plans, and Programs Third Meeting, sponsored by EPA, Washington, D.C., April 1991; U.N. Economic Commission for Europe Task Force Final Meeting, sponsored by EPA, Geneva, August 1991; NEPA/CERCLA Integration Workshop, sponsored by EPA/CEQ/DOE, Washington, D.C., July 1991; Subcontract Renewal Technical Review Committee, sponsored by Martin Marietta Energy Systems, Inc., Oak Ridge, Tennessee, September 1991.

Other: Boy Scouts, Conservation of Bats, Oak Ridge.

WHITE, T. W.

Chairman: Co-chairman, ESD GIS Self-Directed Work Team.

Participant: CDIAC Program Review, sponsored by Carbon Dioxide Research Program, DOE, Oak Ridge, Tennessee.

Advisor: Kevin Birdwell, M.S. candidate, Murray State University; Richard Daniels, M.S. candidate, Miami University; Kimberly K. Chapman, B.S. candidate, East Tennessee State University.

WICKER, L. F.

Participant: 11th Annual Meeting of the Society of Environmental Toxicology and Chemistry, Washington, D.C., November 1990.

WICKLIFF, D. S.

Participant: SPECTRUM 90, sponsored by American Nuclear Society, Knoxville, Tennessee, September–October 1990.

Advisor: Diannia Brown, SEED student, high school graduate.

WINEMILLER, K.

Participant: COMPMECH Review, sponsored by EPRI/ORNL, Oak Ridge, Tennessee, February 1991; American Society of Ichthyologists and Herpetologists, sponsored by ASIH, New York, June 1991; Smallmouth Bass Workshop, sponsored by COMPMECH Program (EPRI/ORNL), Algonquin Park, Ontario, Canada, September 1991; American Fisheries Society Meeting, San Antonio, Texas, September 1991.

Faculty: Research Associate, Ecology Program, The University of Tennessee.

Ad Hoc Reviewer: Ecology; Acta Oecologia; North American Journal of Fisheries Management; Copeia; research proposal for NSF.

WRIGHT, L. L.

Chairman: Biomass Energy Strategies Workshop, sponsored by EPA/DOE, Oak Ridge, Tennessee, November 1990.

Member: Membership Committee, Association for Women in Science, Oak Ridge Chapter; Sigma Xi.

Participant: Biofuels Feedstock Program Review, sponsored by DOE, Nashville, Tennessee, January 1991; Southern Biomass Conference/SRWCP Contractors Meeting, sponsored by DOE, TVA, and others, Baton Rouge, Louisiana, January 1991; Biomass Power Strategies, sponsored by Solar Energy Research Institute, Golden, Colorado, January 1991; EPRI Biomass Working Group Meeting, sponsored by EPRI, Nashville, Tennessee, April 1991; National BioEnergy Conference, sponsored by DOE, Coeur d'Alene, Idaho, March 1991; Conference on Forests and Global Change, sponsored by American Forestry Association, EPA, Arlington, Virginia, June 1991.

Advisor: David Lortz, M.S. candidate, Colorado State University.

Ad Hoc Review: Canadian Journal of Forest Research.

WU, Y.

Member: Ecological Society of America; International Association for Landscape Ecology.

Participant: Annual Meeting of the Ecological Society of America at San Antonio, Texas, sponsored by Fort Lewis College (Colorado), San Antonio, Texas, August 1991; Patch Dynamics Workshop, sponsored by NSF, Ithaca, New York, June–July 1991.

WULLSCHLEGER, S. D.

Member: American Society of Agronomy; Crop Science Society of America.

Participant: American Society of Agronomy, San Antonio, Texas, November 1990; Response of Vegetation to Elevated Atmospheric CO_2, sponsored by Smithsonian Environmental Research Center/DOE, Edgewater, Maryland, May 1991; American Society of Plant Physiologists, Albuquerque, New Mexico, July 1991; Second Annual Walker Branch Watershed Research Symposium, sponsored by DOE OHER, Oak Ridge, Tennessee, March 1991.

Ad Hoc Reviewer: Crop Science; Agronomy Journal; HortScience.

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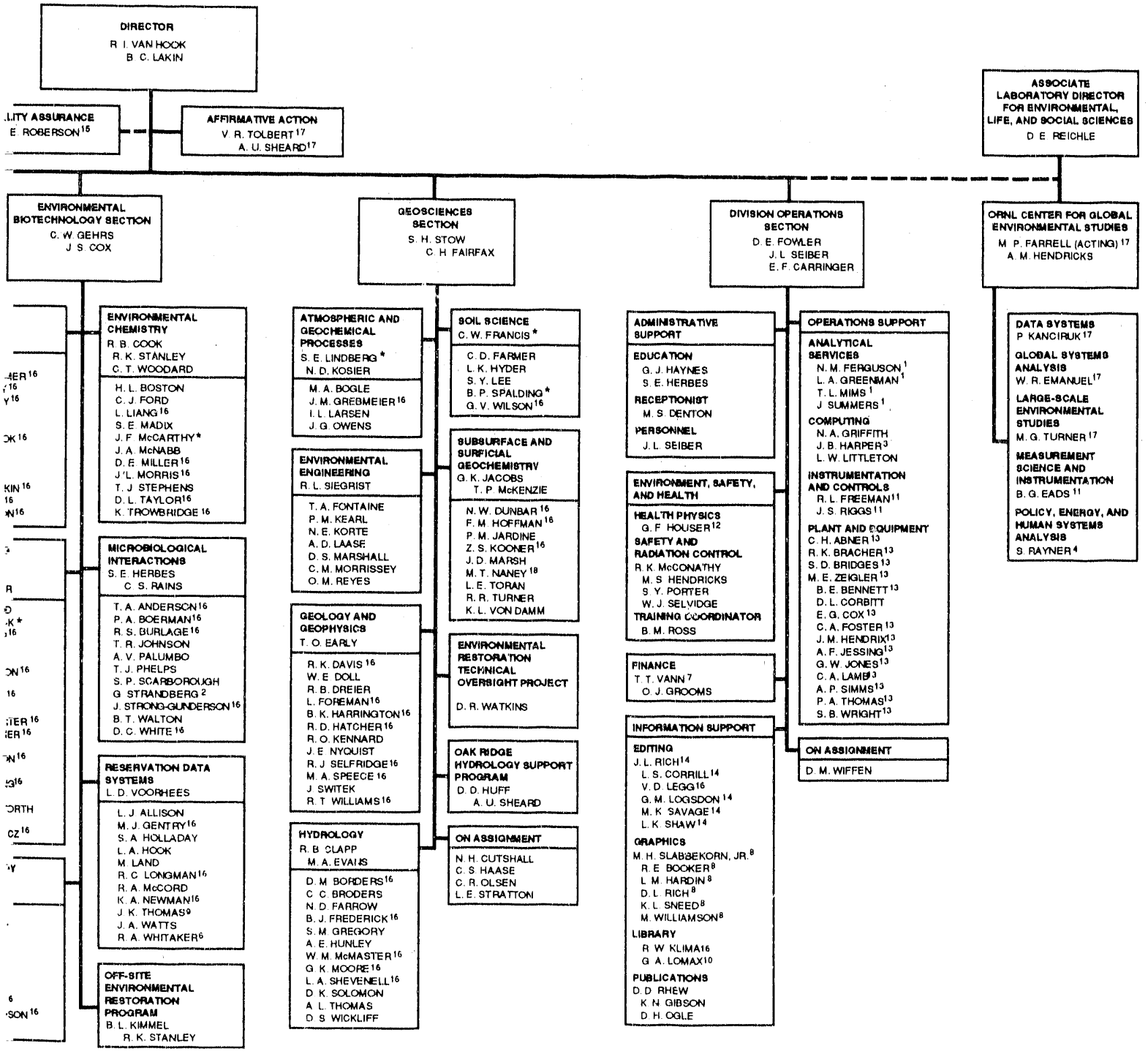

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