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**ENVIRONMENTAL SCIENCES DIVISION ANNUAL PROGRESS REPORT
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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, 1987, through September 30, 1988. The report is structured to provide descriptions of current activities and accomplishments in each of the Division's major organizational units. Following the accounts of section activities and program activities is a section devoted to lists of information necessary to convey the scope of the work in the Division.

OVERVIEW

The Environmental Sciences Division (ESD) of Oak Ridge National Laboratory (ORNL) conducts research on the environmental aspects of existing and emerging energy systems and applies this information to ensure that technology development and energy use are consistent with national environmental health and safety goals. ESD performs basic and applied research, environmental assessments, environmental engineering and demonstration, technology and operational support, and program management for the U.S. Department of Energy (DOE), other federal and state agencies, and industry. ESD works collaboratively with a number of federal agencies, universities, and the private sector in accomplishing its programs and hosts a significant number of visiting investigators from universities, industry, and other federal agencies. Offering an interdisciplinary resource of staff and facilities to address complex environmental problems, the Division is currently providing technical leadership for major environmental issues of national concern: (1) acidic deposition and related environmental effects, (2) the global carbon cycle and the effects of increasing concentrations of atmospheric CO₂ and the resulting climatic changes to ecosystems and natural and physical resources, (3) hazardous chemical and radioactive waste disposal research and development, and (4) development of commercial biomass energy production systems. In addition, ESD manages DOE's Carbon Dioxide Information Center and a National Environmental Research Park (NERP). This progress report outlines ESD's accomplishments in these and other areas in FY 1988.

Research in the Ecosystem Studies Section is directed at quantifying how terrestrial and aquatic ecosystems function and respond to the stresses of anthropogenic activities. The Section has primary responsibility for the Walker Branch Watershed, which has been used for the past 20 years to study ecosystem dynamics and mineral cycling in forested landscapes. In addition, the Section is responsible for management of the Oak Ridge NERP and serves as the Division liaison with the Tennessee Valley Authority Ecology Program.

The Environmental Analyses Section develops theory and methods, analytical tools, and numeric data bases to evaluate environmental problems and issues. The Section staff conduct research and 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 on compliance with environmental regulations. Section staff are making major contributions to the 1990 National Acid Precipitation Assessment Program assessment on acidic precipitation.

The Environmental Engineering and Hydrology Section conducts research, development, and demonstration projects that involve advanced waste disposal methods, surface and groundwater hydrology, contaminant transport, and a variety of simulation models. A significant component of the Section's activities is concerned with the Oak Ridge Reservation. The Section focuses on activities that begin with potential sources of contaminants and the engineering methods for their control and then traces the effects that various hydrologic and geochemical processes have on the subsequent transport and fate of residuals. In the process of stabilizing old sites and helping to design new, more effective disposal systems, the underlying science is considered the most important factor.

The Environmental Toxicology Section is involved in basic and applied research designed to elucidate the mechanisms through which contaminants affect biological systems and the ways in which receiving systems affect the availability and distribution of materials to which they are exposed. Research is conducted from the subcellular and biochemical level to the system level with experimental, observational, and simulation studies. Section staff are involved in development of biomarkers and other new approaches to detecting chemical contamination, elucidation of the role of microbial populations in organic materials transport and transformation, and understanding the bases of plant response to physiological stresses including O₃, acid rain, and other oxidants.

Staff of the Geosciences Section conduct basic and applied research directed toward an understanding of the physical and chemical mechanisms that control the movement of material through the lithosphere and atmosphere. Specific projects are carried out in the areas of geochemistry, geology, geophysics, atmospheric science, soils science, and oceanography and involve close interactions with scientists conducting biologic and hydrologic transport studies. The scope of the activities includes field characterization and testing, laboratory experiments, and mathematical and computer modeling. The Section strives to maintain a proper balance between basic and applied studies, and the common theme that relates to the vast majority of the activities is associated with the study of waste materials and by-products from energy production.

The Biomass Production Program (BPP) is a 10-year-old interdisciplinary program of research on plant growth. The BPP includes four divisions at ORNL, more than 25 other institutions (most of which are land grant universities), and several consulting scientists across the country. The BPP mission is to improve the productivity and cost efficiency of specialized energy crops destined for conversion to liquid fuel. ESD manages the BPP for the Biofuels and Municipal Waste Technology Division, a part of the Conservation and Renewables activities of DOE. The BPP has three major components within ORNL: Herbaceous Energy Crops; Short Rotation Woody Crops; and in-house research focused on physiology, nutrient cycling, economics, and data management/synthesis. With the exception of rapeseed for diesel oil production, all energy crops under study are primarily lignocellulosic; that is, they are being developed for organic matter production (cellulose, hemicellulose, lignin, and nonstructural carbohydrates) rather than for oil, special carbohydrates, or protein.

The Carbon Dioxide Research Program administers the Carbon Dioxide Information and Analysis Center (CDIAC), the Carbon Cycle Research Program, and the resource analysis work for the DOE Carbon Dioxide Research Division. ESD has the technical and managerial responsibility for planning and meeting DOE goals in these areas and does so with an in-house technical staff of 10 scientists supported by a group of 20 key university collaborators. The major focus of the program is on maintaining the best quality global data bases and models, analysis of the linkages and feedbacks between the principal components of the global carbon cycle (atmosphere-biosphere-oceans), and evaluation of the impacts of increased atmospheric CO₂ and global warming on the earth's major resources (forests, agriculture, fisheries, coastal zones, and water).

Section Activities

1

1.1 ECOSYSTEM STUDIES

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1.1.1 Introduction

Research in the Ecosystem Studies Section of the Environmental Sciences Division (ESD) is directed at quantifying how terrestrial and aquatic ecosystems function and respond to the stresses of anthropogenic activities. The Section is organized into three complementary groups: Biogeochemical Cycling, Aquatic Systems, and Terrestrial Systems. In addition, the Section is responsible for management of the Oak Ridge National Environmental Research Park (NERP) and serves as the Division liaison with the Tennessee Valley Authority (TVA) Ecology Program.

The Section receives support from three primary sponsors: the U.S. Department of Energy, Office of Health and Environmental Research (DOE/OHER), 34%; the Electric

-
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 5. Maxima Corporation, Oak Ridge, Tennessee.
 6. Tennessee Valley Authority, Knoxville, Tennessee.
 7. Great Lakes College Association/Associated Colleges of the Midwest.
 8. Director, Institute for Environmental Studies, University of Illinois, Urbana.
 9. President, R. G. Otto and Associates, Arlington, Virginia.
 10. Advanced Sciences, Inc., Oak Ridge, Tennessee.
 11. Vanderbilt University, Nashville, Tennessee.
 12. Tennessee Technological University, Cookeville.
 13. Laboratory Graduate Participation Program, Oak Ridge Associated Universities.
 14. Biology Division, ORNL.
 15. Computing and Telecommunications Division, Martin Marietta Energy Systems, Inc.

Power Research Institute (EPRI), 43%; and the National Science Foundation (NSF), 11%. To successfully attain the Section's goals, we interact with a number of outside institutions, including universities, TVA, the National Park Service (Great Smoky Mountains National Park), and the National Oceanic and Atmospheric Administration's Atmospheric Turbulence and Diffusion Division. The four largest projects in the Section are the Walker Branch Watershed Project (DOE/OHER), which is entering its third decade; the Integrated Forest Study (EPRI), which is entering an exciting stage of synthesis and integration; the project on Compensatory Mechanisms in Fish Populations (EPRI), which is just getting started; and the project on Nutrient Cycling, Ecosystem Structure, and Ecosystem Stability (NSF), which is entering an experimental phase to test some initial theoretical and modeling research.

During FY 1988 significant accomplishments were achieved in field and laboratory research, theory and modeling research, and technique development, as researchers

- demonstrated that decreases in soil exchangeable calcium and magnesium in upper slope oak-hickory forests of Walker Branch Watershed resulted from vegetation uptake and acid deposition,
- determined that riparian zone and instream processes regulate nutrient flux from Walker Branch Watershed during periods of base flow,
- illustrated that computer models based on many interacting individual organisms are a powerful new tool in ecological theory,
- showed that linkages between the carbon cycle and the nitrogen and phosphorus cycles damped the perturbation response of a global carbon cycle model, and
- demonstrated that absorption of SO₂ and emissions of volatile sulfur from loblolly pines can be estimated by the use of radioisotope techniques.

Results and discussion related to these and other significant accomplishments are provided in the following summaries.

1.1.2 Technical Summaries

In Situ Solute Transport Studies Provide Necessary Observations for Predicting the Flux of Nutrients in Watersheds

P. M. Jardine

The physical and chemical properties of soil that contribute to nutrient transport are extremely heterogeneous and complex within the landscape. Field experiments on an isolated, undisturbed soil plot (2 by 3 m deep) have been initiated on the Walker Branch forested watershed in order to provide insight into the saturated and unsaturated transport of nonreactive (Br⁻ and NO₃⁻) and reactive (Mg²⁺, NH₄⁺, and dissolved organic carbon) tracers on ridgetop soils. Tracer movement was monitored with coarse and fine fritted glass solution samplers (2.5 and >10 kPa bubbling pressures, respectively) instrumented laterally into the soil (Fig. 1). Coarse frit samplers obtained soil solution from mesopores and macropores, while fine frit samplers obtained soil solution from predomi-

nately micropores. Solution flow was monitored with tensiometers at various depths and with a neutron probe.

During saturated flow, tracer movement was primarily through mesopores and macropores because rapid solution flow bypassed micropore regions. The temporal patterns of NO_3^- and Br^- concentration observed for these large pore classes at selected profile locations were described by the convective-dispersive equation with flux-type boundary conditions. Skewed breakthrough curves indicative of preferential flow were obtained at all measurement positions. Model-fitted velocities agreed well with saturated infiltration rates established in situ for soils of the adjacent forested watershed.

During unsaturated flow, tracer movement was evident through all three pore classes. The rate of tracer movement into and out of the various pore classes was dependent on the duration and intensity of rainfall, with micropores acting as a source for solute transport in mesopores and macropores. Nonreactive Br^- and reactive Mg^{2+} tracers followed a similar path of mobility through the soil, further suggesting that significant preferential flow occurs in mesopores and macropores. Reactive dissolved organic carbon, solubilized from organic matter in upper horizons during rain events, was also rapidly transported to lower profile depths via preferential flow.

Efforts to model the unsaturated transport of nonreactive and reactive tracers through the soil are currently under way. Soil moisture content, matric potential, and fluxes in solution and concentration have been frequently monitored throughout the transport study, thus providing many of the essential characteristics necessary for modeling this complex system.

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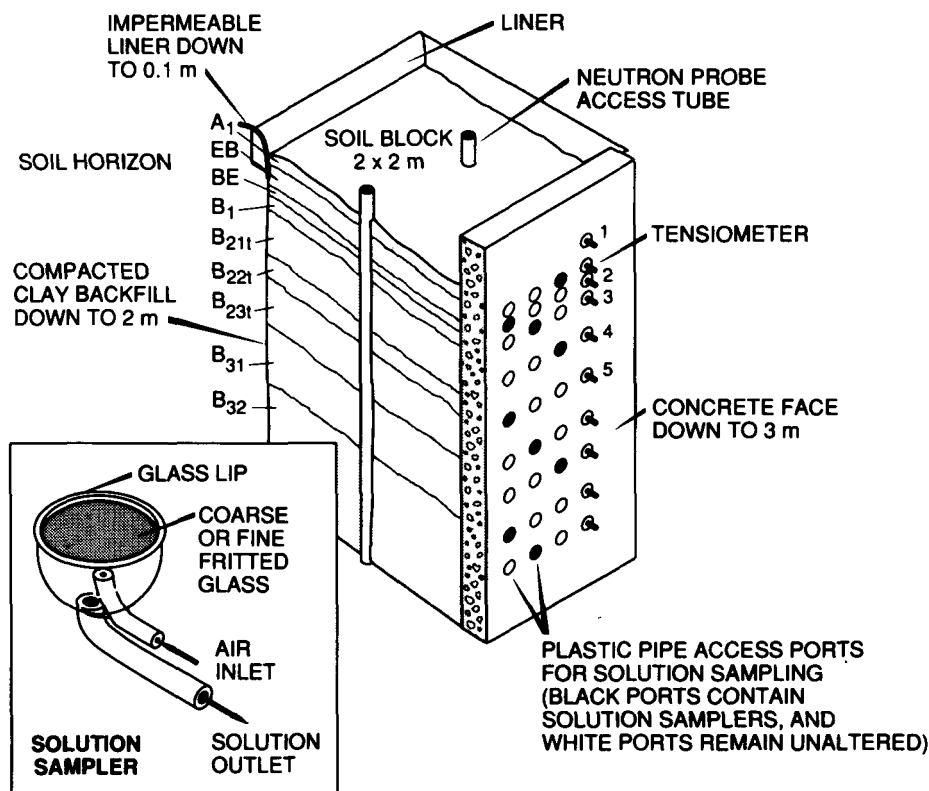


Fig. 1. Cross-sectional diagram of soil pedon facility. The inset illustrates the fritted glass solution samplers used.

Decreases in Soil Exchangeable Calcium and Magnesium in Upper Slope Oak-Hickory Forests of Walker Branch Watershed Are a Result of Vegetation Uptake and Acid Deposition

D. W. Johnson

Considerable concern has arisen about the effects that both acid deposition and intensive forest harvesting have on nutrient depletion and acidification of forest soils. Acid deposition augments natural leaching processes, and intensive harvesting results in the export of nutrients taken up by vegetation. In a series of separate studies on and near Walker Branch Watershed over the last decade, we have documented relatively high rates of calcium export as a result of whole-tree harvesting and significant increases in base cation leaching from soils as a result of acid deposition. More recently, we have noted decreases in soil exchangeable calcium and magnesium in certain nutrient-poor upper slope oak-hickory forests on the watershed over an 11-year period from 1971 to 1982 (Figs. 2a and 2b). This investigation was designed to evaluate the relative roles of vegetation uptake, natural leaching, and acid deposition in causing these soil changes.

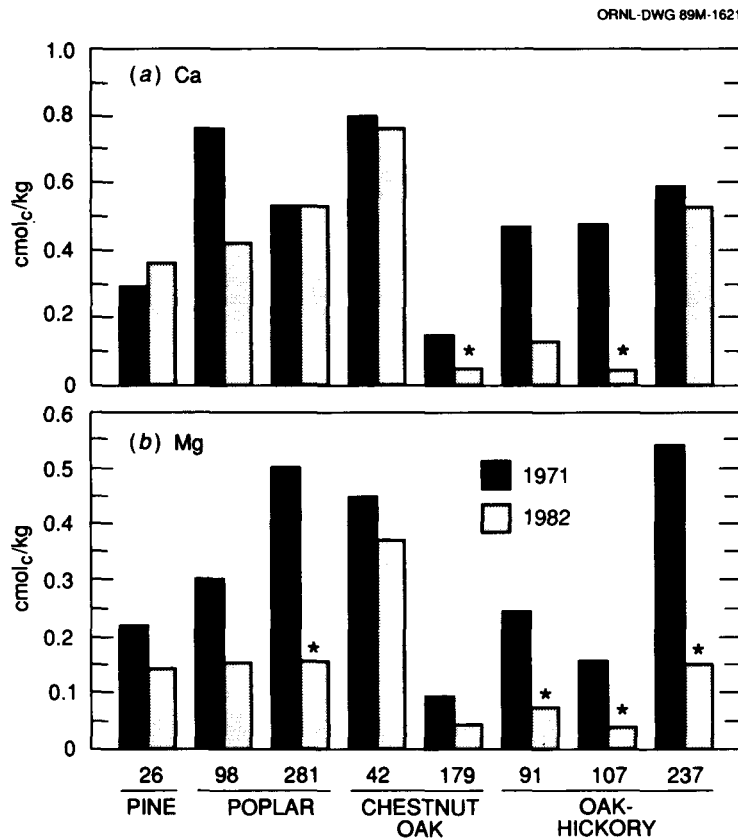


Fig. 2. Changes in the Bt soil horizon of selected plots of Walker Branch Watershed from 1971 to 1982. (a) Changes in exchangeable calcium, (b) changes in exchangeable magnesium. Units are centimoles of charge per kilogram. The most notable decreases occurred in nutrient-poor upslope plots (i.e., plots 91, 107, and 179). The asterisk indicates a statistically significant ($P < 0.05$) decrease during this period.

Tension lysimeter systems were installed in forest plots where soil changes had occurred as well as in plots where no changes had occurred. Soil solutions were sampled on a monthly basis and analyzed for major cations and anions, and ion fluxes through soils were calculated from this and from independently obtained water budget data. Measurements of soil solution fluxes were combined with atmospheric deposition inputs and estimates of vegetation uptake and increment to construct mass balances for these plots.

Mass balance analyses coincided with the trends in soil calcium and magnesium: estimated net exports exceeded soil exchangeable pools by 2–5 times in those plots where soil exchangeable calcium and magnesium decreased, whereas net exports constituted only a fraction of soil exchangeable pools where no changes occurred. In the case of calcium, the vegetation increment was 2–4 times greater than leaching in those plots where exchangeable calcium decreased; however, in the case of magnesium, leaching was greater than the vegetation increment. The anionic component of soil solutions was dominated by sulfate, most of which originated from atmospheric deposition.

These results have several implications. First, they lend some confidence in the mass balance approach to assessing the effects that acid deposition and intensive harvesting have on ecosystem nutrient status. Second, they support the results of mass balance studies suggesting that whole-tree harvesting would significantly deplete soil calcium in these types of ecosystems unless fertilization was practiced. Third, they indicate that acid deposition was the primary cause of the observed magnesium depletion, making this study one of the very few to actually quantify the effects of acid deposition on soil cation status. Finally, these results clearly indicate that the weathering of calcium and magnesium from nonexchangeable pools is not keeping pace with the rates of depletion and that we should watch for potential development of deficiencies in one or both of these elements in these particular forests.

Near-Stream and Instream Processes Regulate Nutrient Flux from a Forested Watershed During Baseflow Periods

P. J. Mulholland, M. A. Huston, and J. W. Elwood

Watershed ecosystems consist of distinct topographic strata (ridges, hillslopes, and valley bottoms). Stream and near-stream riparian zones in the valley bottoms are only a small fraction of the total area of watersheds; however, they may be particularly important in regulating the hydrologic flux of materials leaving watersheds. Although precipitation inputs occur across the watershed, the resulting subsurface and surface drainage is focused by gravity and topography into and through the narrow riparian and stream systems in the valley bottom. Relatively high moisture availability in riparian soils could enhance vegetation growth and nutrient uptake. Colluvial and alluvial transport and downslope litterblow result in the development of organic-rich riparian soils and stream sediments, thereby enhancing nutrient uptake by microbial decomposers. Additional removal of nitrate from drainage water may result from anaerobic decomposition in saturated riparian areas and in the stream.

To determine the influence that biogeochemical processes in the riparian zone have on hydrologic nutrient flux, we compared the chemistry of riparian groundwater to that of

upslope soil water and groundwater discharged via discrete springs in Walker Branch Watershed (Fig. 3). We also compared riparian groundwater chemistry with the chemical composition of the dolomitic bedrock. The influence of instream processes on nutrient flux was determined by computing changes in nutrient concentrations over a stream reach receiving little hydrologic input.

Our results indicate that dolomite weathering is the dominant source of phosphorus and perhaps nitrate in groundwater discharged to the stream. Calcium concentrations in riparian groundwater and in spring discharge are similar, indicating similar bedrock contact for both hydrologic paths. In riparian groundwater, however, concentrations of dissolved organic carbon and ammonium are higher, and concentrations of inorganic phosphorus and nitrate are lower than those in springs. These data indicate that the riparian zone can act as a source for some nutrients and a sink for others as drainage water passes through riparian soils during baseflow periods.

In-stream processes remove inorganic phosphorus and nitrate from water during baseflow periods, thus reducing the export of these nutrients from watersheds. Nutrient removal within the stream is seasonally dependent, with much higher removal rates during the late fall–winter period, when leaf detritus is abundant. These results are consistent with results from the additions of ^{32}P tracer, indicating a tighter cycling of nutrients between the stream water and the stream bottom during periods of abundant leaf detritus.

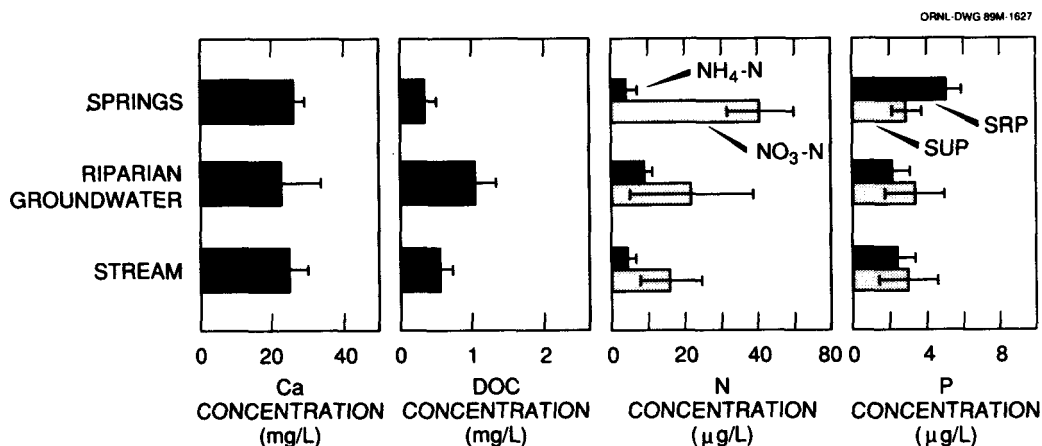


Fig. 3. Concentrations of calcium, dissolved organic carbon (DOC), nitrogen, and phosphorus in springs, riparian groundwater, and the stream during the period December 1987 to May 1988. Histograms represent means of monthly collections from four springs, five streamside piezometers, and the stream. In the fourth histogram, SRP denotes soluble reactive phosphorus; SUP, soluble unreactive phosphorus. (Error bars denote one standard error for each value represented on the histograms.)

Spatial Framework and Data for Walker Branch Watershed Studies Address Scale, Aggregation, and Hierarchy

R. J. Olson, L. K. Mann, V. H. Dale, and K. C. Dearstone

Understanding factors associated with the spatial heterogeneity in landscapes is necessary to develop methods for extrapolating site-specific data to other regions and for estimating associated reliability. Through the examination of spatial patterns at several

scales, the most appropriate scale can be identified for best capturing the heterogeneity in the parameter being extrapolated to broader regions. This project is a component of the Walker Branch Watershed (WBW) Integrated Research Project.

The spatial framework consists of partitioning WBW into spatial units with known characteristics and variability. This stratification allows comparisons between spatial units by both statistical tests and simulation modeling. We are incorporating much of the 20 years of accumulated data from WBW research into a geographic information system to analyze the spatial relationships. Remotely sensed data were collected in 1986 and 1988 at several spatial scales. The spatial units provide a means to test differences in spectral properties that can be associated with the in situ data.

Initial efforts have mapped forest inventory data from WBW, including data on tree mortality from the insect disturbances, in as far as it is related to soils and topographic factors. These maps of the spatial and temporal dynamics on the watershed are being used to plan additional analyses. Determining the prime causes and controlling factors of disturbance patterns on WBW will facilitate the prediction of broad-scale patterns of forest development and succession in relation to climate change, acidic deposition, or other potential disturbances with regional impacts.

Geographic Information System Is Used to Determine Spatial Patterns of Tree Mortality and Potential Impacts on Nutrient Cycling

L. K. Mann, R. J. Olson, V. H. Dale, and K. C. Dearstone

As part of the Walker Branch Watershed (WBW) Integrated Research Project, we are using a geographic information system (GIS) to examine spatial patterns of distribution of forest tree mortality and associated nutrient data. We have stratified WBW into spatial units with known characteristics and variability. Criteria for stratification include slope, slope position, aspect, soil type, vegetation type, past land use, and past disturbances (such as fire). We are examining the relationship of these stratification criteria to changes in the distribution of biomass and nutrients of pine, hickory, and their replacement species in response to extensive outbreaks of pine bark beetle and hickory borer that occurred on the watershed in the early 1970s and early 1980s.

Twenty years of forest inventory data from the west branch of WBW were compared with our stratification criteria by using a GIS. Biomass and nutrient content of both live and dead trees were determined with allometric equations. Using the GIS, we have mapped spatial and temporal patterns of pine and hickory mortality in relation to topographic variables (slope, aspect, and elevation), forest type, soil type, streams, and past land use. These maps clearly demonstrate the relationship of topography, soils, and past land use to species distribution on WBW. Pines were the dominant species in areas that were farmland 50 years ago. These areas have also had the greatest rate of pine mortality. Biomass increment from 1967 to 1987 was greatest on relatively stone-free soils in level areas (Fig. 4). In general, hickories were most abundant on midslopes and had greatest mortality on west and southwest slopes. We are currently evaluating nutrient data to determine which stratification criteria are most useful in predicting the long-term effects that pine and hickory mortality have on site nutrient status and species distribution.

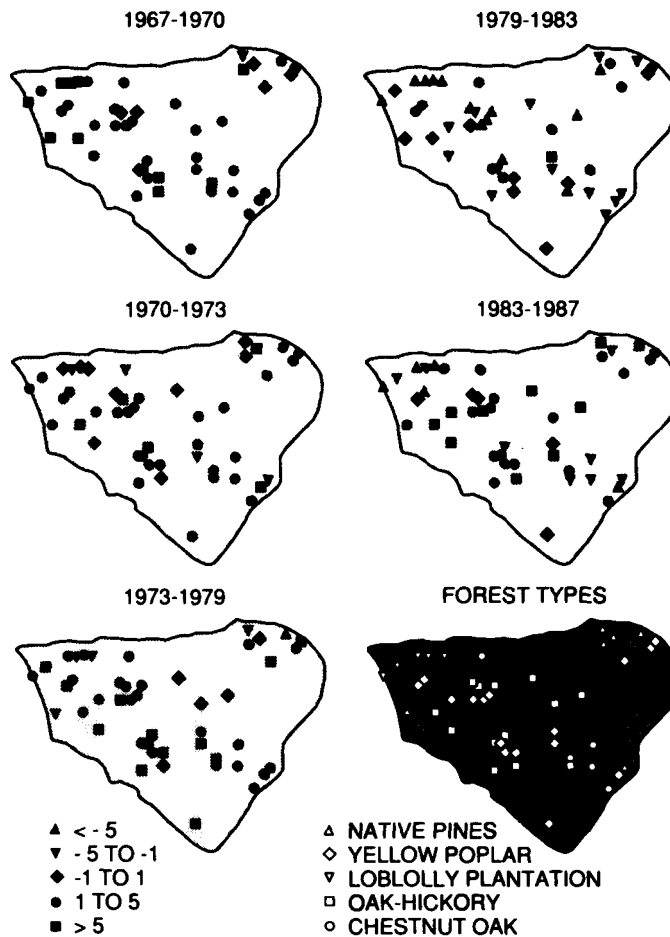


Fig. 4. Biomass increments (in megagrams per hectare per year; solid symbols) and distribution of forest types (open symbols) on the west branch of Walker Branch Watershed. Plots with the greatest biomass increment prior to insect outbreaks were mostly native pines and loblolly plantations. Many of these same areas later had the highest mortality rates. All of the areas with high rates of pine mortality (large negative biomass increment) were in agricultural use 50 years ago.

Spatial-Temporal Scaling Influences Model Predictions of Nitrogen Dynamics in Walker Branch Watershed

S. M. Bartell and A. L. Brenkert*

A model was constructed to simulate nitrogen transport and accumulation in the Walker Branch Watershed. The model was used to examine the influence that measured spatial heterogeneity in vegetation type and topography has on simulated spatial-temporal distributions of nitrogen concentrations in watershed soils, litter, and vegetation. The model was also used to examine the implications of spatial aggregation for the predicted nitrogen distributions. In the construction of the model, a 32- by 32-element grid was superimposed on a subsection of the watershed. This area comprised ridgetop and hillslope forest, riparian vegetation, and a perennial stream. A linear, donor-dependent nitrogen cycling model was implemented for each of the 1024 grid elements or pixels. Nitrogen

inputs, model transfer coefficients, and initial nitrogen values for soil, litter, and vegetation were derived for each pixel by using Walker Branch data. A series of simulations was performed in which heterogeneities were systematically added to the model. These simulations were compared with results from a model consisting of identical pixels, each representing the average vegetation and slope of the watershed.

Detailed analysis of the simulations revealed a time dependence in the sensitivity of soil nitrogen concentrations to the model structure. At scales of 0.1–1.0 year, the best predictor of soil nitrogen was the initial soil nitrogen concentration. At a scale of 10 years, the internal cycling parameters determined simulated soil nitrogen values. At a scale of 50 years, the watershed topography dictated the soil nitrogen distributions. To explore the implications of spatial aggregation, the 1024-pixel model was sequentially collapsed into fewer, larger pixels. These spatial aggregations changed the mean and variance in simulated soil nitrogen concentrations across the watershed subsection. These results caution that watershed heterogeneities must be taken into consideration in the design of experiments and sampling protocols for studying nutrient dynamics in the watershed. Future modeling will focus on rescaling the pixel model in order to examine the implications of storm events not considered by the current model.

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Use of the Oak Ridge NERP Ranks High Among User Facilities at ORNL

P. D. Parr

The 5000-ha (12,400-acre) Oak Ridge National Environmental Research Park (NERP) is 1 of 13 official ORNL user facilities that jointly serve the scientific and technical communities and DOE missions. A 1969 policy statement by the Federal Council for Science and Technology states: "Unique, unusual, and expensive to duplicate facilities at federal laboratories and federally supported research centers should be made available to the national scientific community to the maximum extent practical without serious detriment to laboratory missions"

The facilities maintain records that include the users' names, their affiliations, their project titles, and the number of days they used the facility. During FY 1987 the Oak Ridge NERP was one of the top two ORNL user facilities, with 130 users (or 20% of the total for all such facilities). Researchers from ORNL (39%) and university participants (33%) made up the majority of NERP users. The remainder were from other DOE laboratories (5%), industries (6%), foreign countries (5%), and other categories (12%), which included individuals representing themselves, organizations, or state agencies.

The Oak Ridge NERP ranked far above the other facilities with regard to the number of days the facility was used. User days for the research park were 5164 (42% of the total for all the facilities). Users for the research park are up significantly since 1982, when 28 users were reported. The high level of use of the Oak Ridge NERP not only by ORNL scientists but also by university participants and other outside users demonstrates the importance of the opportunities that the facility can offer and highlights the need to maintain the integrity of the Oak Ridge NERP.

SO₂ Absorption and Volatile Sulfur Emissions from Loblolly Pines Are Estimated Through Isotope Techniques

C. T. Garten, Jr.

Reciprocal fluxes between the atmosphere and forest trees are important to our understanding of the impact that anthropogenically derived sulfur oxides have on forests. Due to limitations in research, uncertainty remains about the role of forest trees as a source of and a sink for reduced sulfur gases in the atmosphere. Radioisotope techniques were used in a field study of loblolly pine (*Pinus taeda*) to estimate the fraction of SO₂ deposition absorbed by foliage and the biogenic emission of sulfur from pine needles (Fig. 5).

Four study trees (8 to 12 m tall) were radiolabeled with microcurie amounts of ³⁵S. Total dry deposition of sulfur to the trees (18 mg/m² per week) was estimated from air concentration data and dry deposition velocities (0.41 and 0.14 cm/s for SO₂ and particles, respectively). The fractional removal of dry deposited sulfur from the pine canopy by rainfall was estimated from throughfall measurements corrected for foliar leaching. Rainfall leaching of internal leaf sulfur was determined through isotope dilution techniques. Biogenic sulfur emissions were measured by enclosing pine fascicles in a chamber and trapping ³⁵S in effluent air.

The throughfall sulfur flux beneath the pine trees exceeded the flux of sulfur in precipitation, indicating that foliar leaching or washoff of dry deposition occurred. The contribution of foliar leaching and dry deposition to sulfate concentrations in throughfall was <10% and >90%, respectively. Under the assumption that all fine and coarse particle sulfur was washed from the leaf surface by rainfall, approximately half of the SO₂ deposition to the canopy was removed by rainfall, and half was internally absorbed.

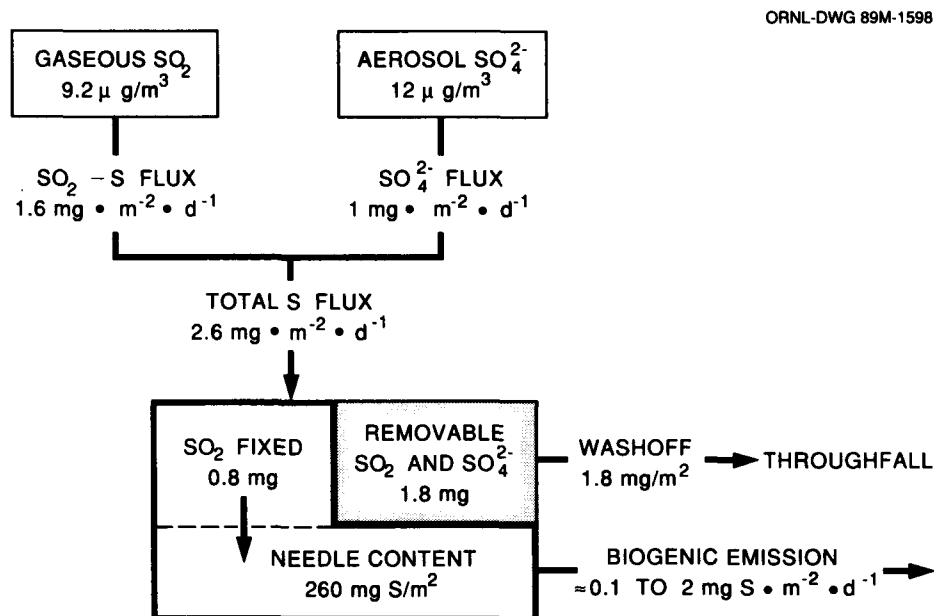


Fig. 5. The fraction of SO₂ deposition absorbed by foliage and the biogenic emission of sulfur from loblolly pine needles.

Sulfur-35 emissions from live pine needles were 3×10^{-5} $\mu\text{Ci/g}$ (dry weight) per day. Radioactivity in the trapping solutions decayed with a half-life of 90 d (consistent with the 87-d half-life of ^{35}S). The mean emission rate, normalized for leaf ^{35}S concentration, was 0.04% per day. Based on the specific activity of ^{35}S in the leaf, the ^{35}S emission rate corresponded to 0.3 $\mu\text{g/g}$ (dry weight) per day. This estimate is 10 times higher than other reported rates of sulfur emission from loblolly pine needles, but it is within the range of published rates of hydrogen sulfide emission from vegetation in response to elevated levels of sulfur.

Calculations for the pine stand indicate that biogenic sulfur emission from the canopy was <5% of the total sulfur deposition to the stand. This conclusion was based on measurements over a 100-d period in the summer of 1987. In this case, the loblolly pine forest appears to be more important as a sink than as a source for atmospheric sulfur.

Study Suggests Food Web Resilience Is Not Always Directly Related to Nutrient Input and Cycling

D. L. DeAngelis, S. M. Bartell, and A. L. Brenkert*

The explanation of the observed structure of ecological food webs has been one of the key issues of theoretical ecology in recent years. Many factors are likely to be involved in determining food web structure. It has been argued that the resilience of food webs to external perturbations is one such factor. "Resilience" in this case means the rate at which an ecological system returns to a steady state following a perturbation. In ongoing work, we are examining the importance of nutrient limitation and cycling in relation to the resilience of food web models.

Food web resilience was investigated by using both a simple abstract food chain model and a complex food web simulation model in which nutrient limitation and recycling occur. The simple model demonstrated that both nutrient input or loading and food chain length have important effects on resilience (Fig. 6). For very small nutrient inputs, resilience was in all cases an increasing function of the rate of nutrient input. However, in food chains in which the autotroph was the highest level, resilience was lower and more constant over a wider range of nutrient input levels than in chains in which herbivores were present. The presence of a carnivore level complicated the dependence of resilience on nutrient input, resulting in cases in which increased input actually led to a decrease in system resilience. These results were interpreted both mathematically and intuitively.

To test the robustness of the results of the simple model, similar investigations were made of a complex aquatic food web simulation model, CASM. The results of the study of the resilience of CASM were in substantial agreement with those of the simple model for systems in which autotrophs and herbivores constituted the highest trophic levels. The simulation was more complex when carnivores were added. The results of both models strongly suggest that resilience may not always increase as nutrient input is increased and that resilience may not always decrease as the number of trophic levels in a food chain increases. These results contradict relationships inferred from earlier work.

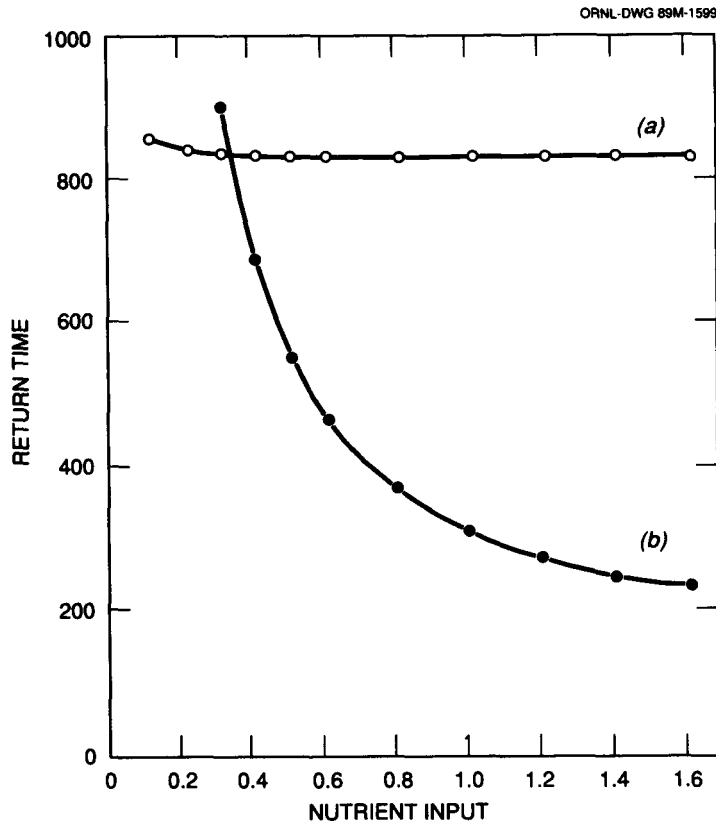


Fig. 6. Return time ($\sim 1/\text{resilience}$) as a function of nutrient input for the case in which (a) the autotroph is the top trophic level and (b) the herbivore is the top trophic level.

The results from our models provide insights into the resilience of different ecological systems to perturbations. In addition to these theoretical studies, eight experimental streams are now in operation at ORNL for testing the results generated from our mathematical models.

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Young and Old Specimens of White Oak (*Quercus alba*) Respond to Climate in the Same Way

T. J. Blasing

Chronologies of tree-ring widths have been used to reconstruct past climate and to investigate putative anthropogenic effects (e.g., effects of CO_2 and acid rain) on tree growth. In such investigations it is assumed that the relationship between climate and tree growth does not vary with tree age. For example, if recent rings of old trees are good indicators of climate, it is assumed they were equally good indicators when the trees were young, say, 200 or more years ago. This assumption is supported by the qualitative observation that climatic stresses produce narrow rings on young and old trees of the same

species at the same site, but quantitative studies of the validity of this assumption have been lacking. Confounding this issue is the observation that trees of a variety of ages appear to have changed in their response to climate sometime about the 1950s. It has been assumed that these changes are due to some external, possibly anthropogenic, cause. However, some of these changes may be due to tree age. Thus it would be useful to determine whether a change in climatic response associated with tree age can be identified so it can be removed before hypotheses regarding other causes are tested.

We began to address this problem by analyzing ring-width chronologies of young (mean age 86 years) and old (mean age 274 years) specimens of white oak at five sites in central and eastern Iowa. White oak was selected because it is (1) widely distributed throughout the eastern United States, (2) of commercial value, (3) long lived, and (4) sensitive to climatic variations. The same climatic data (mean temperature and total precipitation for each month from 1930 to 1977) were considered in relation to young and old trees. The period of climatic data was partly determined by the number of available tree cores, many of which were collected in 1978. Because the young trees and the old trees in the comparisons were from the same stands, site conditions and stand histories were the same for both sets of trees. Standard statistical methods were used to determine whether young and old trees respond to the same climatic variables and also whether the magnitude of the climatic response (percentage of climatic variance in common with ring width) was the same for both age groups.

Young and old trees responded to the same climatic variables. The magnitude of the response was about the same for both age groups. A slightly stronger response occurred for the younger trees, but the difference was small and could be a statistical artifact. Differences in the responses of the two age groups, even if real, were small in comparison with differences in the ages of the two groups of trees.

These findings have two important implications. First, it has been common practice to increase the sample size of recent portions of a tree-ring chronology by including some young trees as well as the relatively few old ones at a particular site. This practice still appears valid. Second, white oak seems an excellent choice of species to investigate for external (not age-related) causes of changes in tree-ring response to climate. However, this research needs to be repeated for other regions to strengthen the above conclusions. In any case, one should not pass up opportunities to account for possible effects of age when investigating causes of variations in tree growth.

Computer Models Based on Many Interacting Individual Organisms Are a Powerful New Tool in Ecological Theory

M. A. Huston, D. L. DeAngelis, and W. M. Post

All mathematical models involve a compromise between computational feasibility and realism. Some simplifications are inevitably necessary to express complex physical or biological systems as theoretical models that can be analyzed by mathematics or computer simulations. Recent changes in the conceptualization of ecological systems, accompanied by continuing advances in computer technology, have led to a new type of ecological model that does not require many of the unrealistic simplifying assumptions used in most of the earlier ecological models. Two simplifying assumptions inherent in most traditional

ecological models at the population, community, and ecosystem levels of organization are (1) all individuals within a population are identical and (2) each individual is influenced by all other individuals, regardless of their spatial proximity. For many ecological systems these assumptions are obviously unrealistic, thus limiting the acceptability and capabilities of models that require such assumptions.

Computer simulation models based on individual organisms offer the possibility of modeling complex systems without the constraints of these unrealistic assumptions (Fig. 7). Such models are being developed by several groups in ESD and applied in the following areas: fish population dynamics, forest succession in tropical rain forests, plant disease susceptibility in agricultural systems, fish movement in thermally stressed environments, and coevolution of predators and prey. This modeling approach has the potential to serve as a major integrative force in the field of ecology, because it uses processes that occur at the level of the individual (such as behavioral and physiological responses) to explain patterns that occur at the population, community, ecosystem, and even landscape levels of organization.

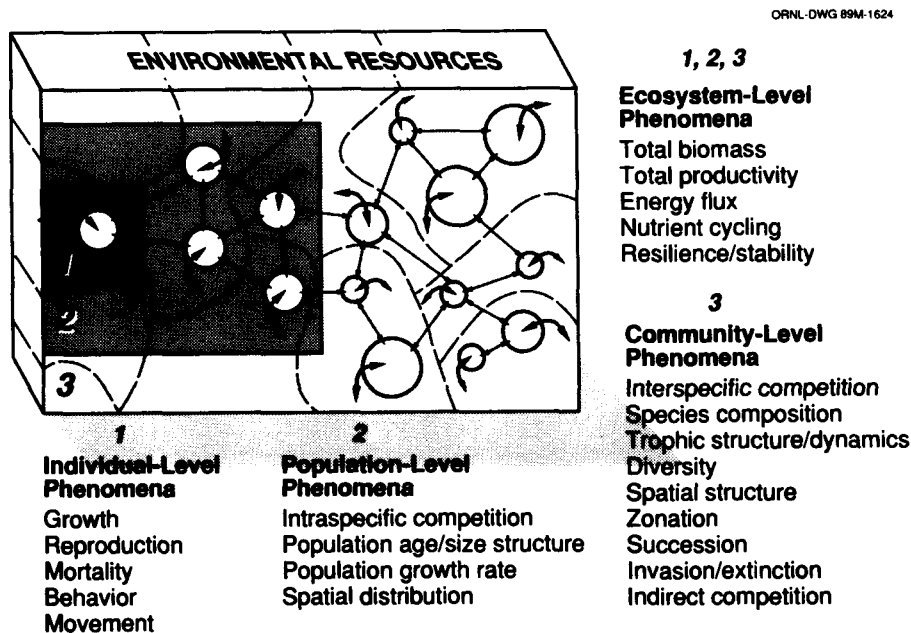


Fig. 7. Graphical conceptualization of an individual-based model. Each circle represents an individual organism, with different species represented by different sizes of circles. The three-dimensional matrix of resources represents the heterogeneity of conditions that affects individual organisms, as well as the local effects of organisms on resources. The broad arrows indicate the feedback between individual organisms and their environment, which is also a major mechanism of indirect interaction between individuals. The thin arrows represent direct interactions. Individual-level processes such as nutrient and energy uptake and physiological responses produce phenomena at (1) the individual level, (2) the population level, (3) the community level, and (4) the ecosystem level, which is the aggregate of phenomena at the other levels.

ORNL Initiates a Long-Term Study on Compensatory Mechanisms in Fish Populations

W. Van Winkle and L. W. Barnthouse

Operations at individual steam-electric and hydropower generating facilities kill or displace substantial numbers of fish. However, such individual losses may or may not be of significance to the populations from which the individuals are removed. The importance of the losses is determined by the interaction of factors such as the proportions killed or surviving, ages and sexes of individuals removed or remaining, and the inherent compensatory capabilities of the fish species. Unfortunately, these interactions are poorly understood. The inability to make quantitative assessments of the significance of fish mortalities to the structure and stability of fish populations and communities is a continuing problem for the electric power industry. Approval of new sites and operational permitting of existing facilities are hindered by this problem, often at considerable cost to individual utilities.

ESD staff, with funding from the Electric Power Research Institute (EPRI), are initiating a 10-year project on Compensatory Mechanisms in Fish Populations (COMPMECH) to improve these assessment capabilities. The COMPMECH Project consists of two parallel and interactive research efforts: the Key Species Program and the Fellowship Program. EPRI's overall goal for the COMPMECH Project is the synthesis of a quantitative model sufficient to predict the direction and relative magnitude of fish population response to anticipated site-specific perturbations. The Key Species Program emphasizes the generation of new data sets tailored to the needs of the modeling framework. The Fellowship Program involves testing and expanding the concepts on which the models are based.

The strategy adopted for achieving EPRI's goal involves developing a general modeling framework, from which specific models of individual fish species can be derived. Species-specific models are used to organize empirical research on the life history and dynamics of several representative fish populations by (1) generating hypotheses to be tested in laboratory and field experiments, (2) providing guidance for future environmental monitoring, and (3) providing new interpretations of existing data.

ESD is responsible for developing the generic framework and the species-specific models. In addition, ESD staff are responsible for coordinating empirical research on the population dynamics of approximately six key species. Each key species project focuses on generating data necessary for the development and testing of individual-based models of a specific fish species. The work performed for each project consists of compilation of existing data, long-term monitoring, measurement of critical process parameters, and, where feasible, field-scale manipulative research.

The insight gained from the COMPMECH Project is expected to permit the development of a new generation of assessment-oriented population models suitable for use by industry scientists.

Multiple-Element Cycle Models Support Analysis of Cross-Scale Issues

W. R. Emanuel

There is substantial temporal and spatial variability in the interactions between terrestrial ecosystems and other global reservoirs. Successful models and analyses contend with this variability in different ways, depending on the scales of interest. A set of multiple-element cycle models is being completed. The models provide the scale flexibility required in global studies while maintaining cross-scale consistency.

A common core set of equations is used to describe terrestrial element cycling in plant and dead organic matter at three spatial scales: (1) forest stand, (2) regional to continental, and (3) global and total cycle. Temporal resolution extending from months (in analyses involving seasonality) to centuries (in analyses involving forest succession) is considered. Plant compartments are organized according to plant types. The assignment of these types, the equations that control plant growth, and the scheme for associating model variables with land areas and their attributes are adjusted according to the scale of application.

At the scale of the forest stand, plant types correspond to species, and vegetation growth is simulated by coupling to an appropriate stand growth model (Fig. 8). At the regional-to-continental scale, plant types define broad functional groups in terms of element cycling characteristics, and the model is geographically referenced by computerized maps. In total cycle models at the global scale, a few plant types represent very large classes, and characteristic response times are emphasized.

Extensive testing is now under way. Model calibration is being refined on the basis of these tests and additional new data. Papers describing this approach are being prepared. During the next year, model experiments will address the influence of nitrogen cycle dynamics on carbon cycling to clarify the role of terrestrial ecosystems in controlling changes in the concentration of atmospheric CO₂.

The hierarchical design of this set of models affords unique capabilities for cross-scale analysis. The importance of forest succession in long-term responses of element cycles is becoming clearer, and methods for treating spatial variability in global-scale analysis are being refined and tested.

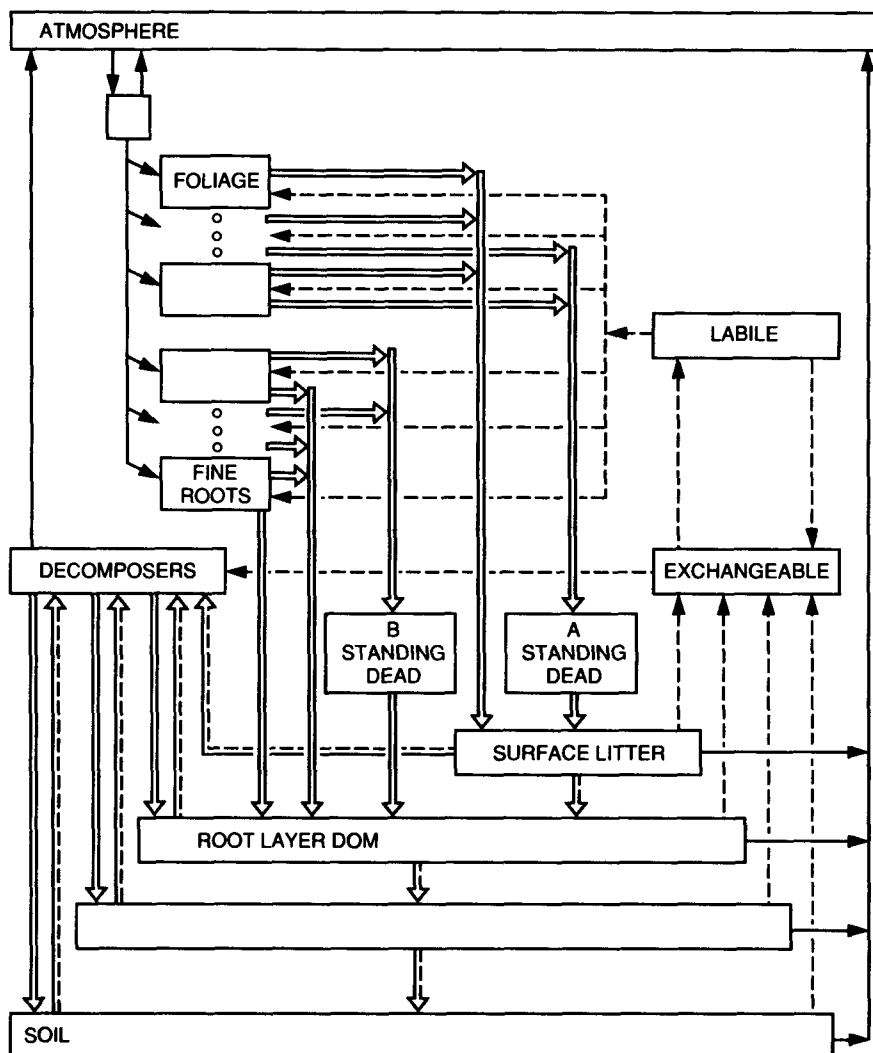


Fig. 8. Core-linked element cycle model compartment diagram. Compartments associated with aboveground and belowground live pools and with dead organic matter (DOM) can be adjusted for each ecosystem type. Double arrows represent fluxes of organic matter in which the element ratios are the same as those of their donor compartments. Solid single arrows are fluxes of carbon alone. Dashed single arrows are fluxes of elements other than carbon.

Linkages with Nitrogen and Phosphorus Cycles Damp the Perturbation Response of a Global Carbon Cycle Model

A. W. King and R. V. O'Neill

The global biogeochemistry of carbon and its role in the "greenhouse effect" are not independent of the biogeochemistry of other elements. The carbon cycle processes of biospheric production and decomposition are inseparably linked with the biogeochemistry of those elements which limit biological processes (e.g., nitrogen and phosphorus). These linkages and interactions can have a direct and significant influence on the global carbon

cycle, and carbon can have a reciprocal influence on the global cycling of limiting elements.

We are investigating the consequences of these interactions through use of a globally aggregated compartment model of linked C, N, and P cycles. The model tracks the annual organic and inorganic fluxes of C, N, and P within and between terrestrial, freshwater, and marine components. The simultaneous C, N, and P limitation of the production and decomposition of organic matter is described by a nonlinear, additive Michaelis-Menten function.

Do the nonlinear biotic interactions between C, N, and P stabilize or destabilize the global system? We explore this question by comparing model perturbations with and without the nitrogen and phosphorus limitation of the carbon cycle. We perturb the system from equilibrium by doubling the annual forcing on atmospheric carbon and simulate the system for 1000 years. Without nitrogen and phosphorus limitation, the organic reservoirs increase rapidly, and, except for soil organic matter, their trajectories are described by damped oscillations. These reservoirs are still increasing at 1000 years. Atmospheric carbon returns to near equilibrium along a damped oscillatory trajectory. With nitrogen and phosphorus limitation, the organic reservoirs increase more slowly, and the trajectories are not oscillatory. Atmospheric carbon increases rapidly and monotonically. In summary, the nitrogen and phosphorus limitations constrain the response of the biosphere and eliminate the unlimited system's oscillatory response to the perturbation.

Additional perturbations must be simulated (e.g., parameter changes and perturbations of state variables), but these results indicate that the nitrogen and phosphorus limitations damp the perturbation dynamics of the global carbon cycle. The nitrogen and phosphorus limitations significantly affect the carbon content of the atmosphere. Nutrient limitations should be considered in the biosphere component of global carbon cycle models used to project future concentrations of atmospheric CO₂, and in biosphere models used to investigate the possibility of global CO₂ fertilization.

1.2 ENVIRONMENTAL ANALYSES

S. G. Hildebrand

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L. J. Allison ³	S. B. Floit ⁵	E. B. Lewis ³	F. E. Sharples
C. F. Baes III	M. J. Gentry ⁷	L. W. Littleton	A. B. Shortlidge ¹⁰
L. W. Barnthouse	L. Godbout ¹	M. K. Lyday ¹³	D. S. Shriner
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J. J. Beauchamp ⁴	R. L. Graham	R. A. McCord	C. F. Sigmon
S. A. Bell	N. A. Griffith	L. K. McDonald	E. D. Smith
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C. C. Coutant	Y. I. Jager	A. E. Rosen	K. D. Van Hoesen ⁷
V. A. Dale	L. J. Jennings	B. M. Ross-Todd	L. D. Voorhees
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1.2.1 Introduction

The Environmental Analyses Section of the Environmental Sciences Division (ESD) develops theory and methods, analytical tools, and numeric data bases to evaluate environmental problems and issues. We prepare 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 on compliance with environmental regulations. The Section is organized in six groups, described briefly here.

The Environmental Systems Analysis Group, formed in September 1988, develops and applies modeling techniques, including simulation, optimization, statistical analysis, and sensitivity and uncertainty analysis, to evaluate environmental problems. It supports environmental impact analyses and resource management projects in the Section and the Division by applying innovative techniques. A major focus of the group is on biotic and abiotic components of water resource issues.

The Environmental Risk Group performs research and assessments to quantify the effects that toxic chemicals, acid deposition, and other environmental stresses have on aquatic and terrestrial biota. Emphasis is on probabilistic methods at the population level.

The Environmental Compliance Group provides technical assistance to various sponsors in their efforts to comply with federal and state environmental laws and regulations. The group uses scientific and regulatory expertise to create information resources, to track and analyze regulatory issues, to develop compliance methodologies, and to prepare input for the development and implementation of environmental compliance policy.

The Environmental Assessment Group prepares impact analyses for use by sponsors within the U.S. Department of Energy (DOE), the Nuclear Regulatory Commission, and the U.S. Department of Defense in their efforts to comply 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 also provide technical reviews and analyses of NEPA documents and related issues for the DOE Office of NEPA Project Support. The Environmental Assessment Group has the goal of applying state-of-the-art assessment tools to complex issues that involve large geographic areas or that are programmatic in scope.

The Regional Resources Group conducts basic research on natural systems, leading to analyses that incorporate spatial and temporal patterns. Scientists develop theory and methods to understand the processes regulating current landscape pattern in order to predict change in pattern as a function of change in environment. Scientists apply regional-scale theory and methods to synthesize information and assess environmental problems at regional to global scales.

The DOE Environmental Survey Group manages the sampling and analysis support that Oak Ridge National Laboratory (ORNL) lends to the DOE Office of Environmental Audit (OEA). The DOE Environmental Survey is a program that reviews DOE sites throughout the United States to identify potential environmental management issues. ORNL provides field sampling teams, chemical and radiological analysis support, and data management support to the program.

The Environmental Analyses Section uses a geographic information system (GIS) that consists of ARC/INFO (IMSI, Inc.) software and various digitizing, plotting, and work station hardware. The forte of the GIS is the easy manipulation, display, and analysis of spatial data such as vegetation cover, soil type, and groundwater plumes. One unique feature of the GIS is its ability to extrapolate point data to regions not sampled and to overlay these various coverages to define new relationships. The GIS is a Division resource that has applications to environmental assessment and remedial action projects, as well as to basic ecological research.

The Section continued its major role as a supporter of the National Acid Precipitation Assessment Program (NAPAP). All such activities during this reporting period concerned two major NAPAP documents, the 1990 assessment and the state-of-science report.

The following summaries of recent accomplishments represent all groups within the Section.

1.2.2 Technical Summaries

ORNL Helps DOE Prepare a NEPA Compliance Guide

L. L. Sigal, G. F. Cada, M. S. Salk, and R. M. Reed

On January 1, 1970, President Nixon signed the National Environmental Policy Act (NEPA) into law. In the ensuing years, compliance with NEPA has become one of the most important policy-setting federal laws for protecting the environment. One of the important goals of NEPA documents is to ensure that requirements of other major environmental statutes and regulations (e.g., the National Historic Preservation Act, the Endangered Species Act, and Executive Order 11988—Floodplain Management) have been adequately considered [Council on Environmental Quality Regulations (CEQ), 40 CFR 1500–1508].

A NEPA review is required for most actions taken by DOE and other federal agencies. The review must be completed prior to any stage of investment or commitment to implementation that is likely to restrict later alternatives. Thus, it is important to integrate the environmental review of an action early in the planning process so that modifications can be made in the project design and/or location to avoid or minimize adverse environmental impacts. The NEPA review process ensures identification and proper consideration of environmental issues, alternative actions, and mitigation measures.

Staff in the Environmental Analyses Section have provided technical assistance to the DOE Office of NEPA Project Assistance in developing a NEPA Compliance Guide to be used throughout DOE. This guide is intended to assist the DOE program and field offices by providing information on NEPA requirements and procedures; requirements of related environmental statutes and regulations that need to be considered during a NEPA review; and the timing relationships between NEPA review, required review of other environmental statutes and regulations, and project planning activities. The guide is divided into four parts. Part I provides guidance for planning NEPA compliance for DOE proposed actions; Part II includes detailed flow charts based on the compliance procedures required by CEQ

regulations and the DOE NEPA guidelines (52 FR 47662); Part III contains brief discussions of the required compliance procedures and examples of NEPA documents; and Part IV contains discussions and flowcharts for related federal environmental statutes that may apply to DOE actions.

The information assembled in the guide, if used properly, will (1) assist DOE program and operations offices in complying with the CEQ and DOE environmental review requirements in a timely fashion, (2) help ensure that projects and programs proceed on schedule, (3) help avoid litigation, and (4) result in DOE's compliance with the letter and spirit of NEPA.

Future Hydroelectric Development at New Dams and Diversions Is Evaluated

M. J. Sale, G. F. Cada, C. T. Hunsaker, J. W. Webb, L. J. Allison, and K. C. Dearstone

An interdisciplinary team from ESD and the Energy Division of ORNL recently completed a national study of the impacts of federal incentives for small (<80 MW) hydroelectric development. This study was carried out under the 1986 Electric Consumers Protection Act (ECPA), which required the Federal Energy Regulatory Commission (FERC) to report to Congress on the effects that financial benefits from the Public Utility Regulatory Policies Act (PURPA) have on projects requiring new dams or diversions. The revisions of federal laws regulating hydroelectric development proposed by ECPA allow new dams to qualify for PURPA benefits only if they cause "no substantial adverse effects," are not located on state-protected rivers, and adopt mandatory terms and conditions set by fish and wildlife agencies. The study identified and evaluated a total of 1,746 potential projects (14,605 MW) that could be affected both by PURPA benefits and by the ECPA legislation. A regional approach was used to assess impacts to areas of the country that have similar ecological and energy-use characteristics, concentrating on five regions where new dams are expected to be developed (the Pacific Northwest, California, the Basin and Range states, the Northeast, and the Southeast). Alternative regulatory approaches to hydroelectric development were analyzed to predict (1) the amount of hydroelectric development stimulated by PURPA benefits and (2) the development eliminated by the new environmental constraints of ECPA. Economic and environmental screens were applied to predict the number of projects that are likely to be licensed and developed successfully under alternative regulations.

The continuation of PURPA benefits without the environmental constraints defined by ECPA would provide incentives for private (i.e., nonutility) development of up to 84 new projects (1524 MW) that would not be developed without PURPA benefits. However, this unconstrained development at new dams would create the potential for substantial adverse environmental impacts to fisheries (especially those which are anadromous or otherwise unique), recreation, and aesthetic resources. The continuation of PURPA benefits with the ECPA environmental constraints would provide incentives for private development of 34 new projects (474 MW) with minimal environmental impacts. The ECPA environmental constraints would effectively preclude the development of 50 projects (1050 MW) that have potential adverse impacts.

This study is the first objective, quantitative examination of the hydroelectric development resulting from federal incentives that were instituted for renewable energy development during the energy crisis of the late 1970s. The study demonstrates that relatively few hydroelectric resources have been or will be developed under PURPA at new dams (Fig. 9). The regulatory changes instituted by ECPA will have the intended effect of protecting environmental resources from the adverse impacts of hydropower development at new dams while encouraging development of valuable and needed, albeit limited, energy resources in the future.

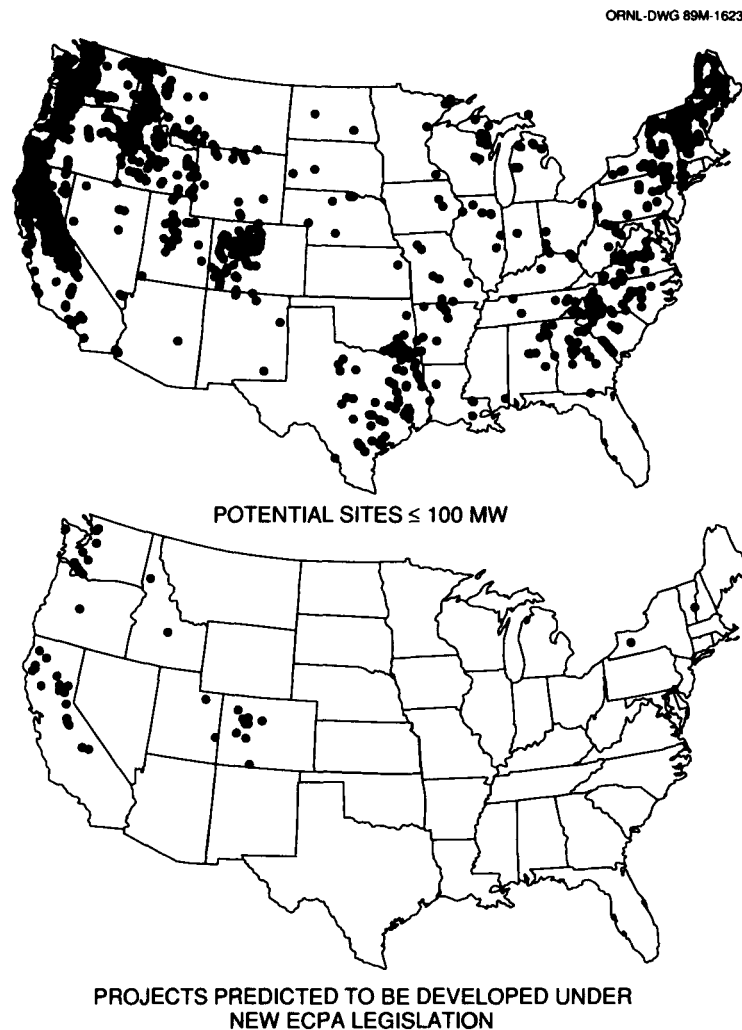


Fig. 9. Potential hydroelectric projects at new dams or diversions evaluated in the Electric Consumers Production Act (ECPA) study.

Cumulative Impacts of Hydropower Development in the Upper Ohio River Basin Are Assessed

S. F. Railsback, M. J. Sale, and C. C. Coutant

The installation of hydropower plants is proposed at 19 dams (18 existing navigation dams and 1 multipurpose dam) in the upper Ohio River basin, including parts of the Allegheny, Monongahela, Muskingum, and Ohio rivers. Five additional plants are already operating or under construction in the area. Aeration at dams can be an important source of dissolved oxygen (DO) in these rivers. Yet the operation of hydroelectric plants at navigation dams can reduce aeration, because water that otherwise would spill over the dam passes through turbines, where little aeration occurs. In the upper Ohio River basin, where navigation dams are close together, the cumulative impacts of hydropower at several dams can be much greater than the impact of a single project.

The first step in assessing the cumulative impacts of hydropower development was to model aeration at each dam. Field measurements of DO under various conditions were obtained and used to develop statistical models of aeration. The DO deficit (the difference between the DO concentration and the saturation concentration) upstream of a dam was found to be a good predictor of the DO deficit downstream of the dam. The relationship between the DO deficits above and below the dams varied significantly.

The second step in the assessment was to use the dam aeration models to predict the systemwide changes in DO concentration that result from hydropower-caused reductions in dam aeration. A DO simulation model for 460 miles of river and 30 dams was formulated, parameterized, and calibrated. The DO model was used to quantify the magnitude and extent of reductions in DO concentration as a result of the proposed hydropower projects; the proposed projects were predicted to cause cumulative reductions of up to 2 mg/L through much of the system during critical conditions.

Results of the model were also used to predict impacts on fish populations. DO concentrations predicted by the model were used as input to a model that predicts growth of fish over a summer season. The fish growth model predicted that growth of channel catfish could decrease by up to 20% as a result of hydropower development. Figure 10 illustrates the modeled decreases in DO concentration and in fish growth in the Ohio River.

The analysis of cumulative impacts indicated that hydropower development can take place without significant reductions in DO only if sufficient mitigation (the construction of aerated spill flows) is required. This conclusion and the recommended spill flow rates for maintaining water quality are included in an environmental impact statement (EIS) prepared by ORNL for the Federal Energy Regulatory Commission. The commission will consider recommendations of the EIS in its decisions on which of 24 proposed hydropower projects to license and what mitigation to require.

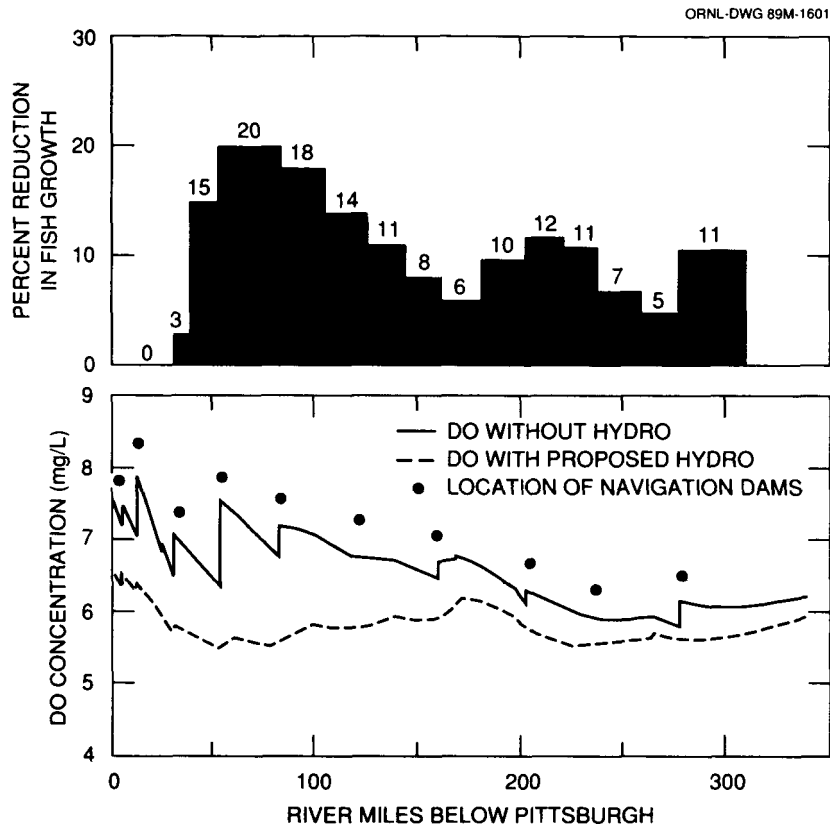


Fig. 10. Changes in dissolved oxygen (DO) concentrations in the Ohio River, and percent reduction in annual catfish growth. Values were obtained from models simulating impacts of proposed hydropower projects without mitigation, under summer temperature and flow conditions.

Environmental Impact of the Innovative Clean Coal Technology Program Is Analyzed

R. M. Reed, C. C. Coutant, G. Marland, J. A. Watts, and J. W. Webb

Staff in ESD and in the Energy Division of ORNL, assisted by Technology & Management Services, Inc. (TMS), have prepared a programmatic environmental impact analysis (PEIA) on DOE's Innovative Clean Coal Technology (ICCT) program. The PEIA was designed to address the impacts of commercializing 19 innovative clean coal technologies by the year 2010.

Ecological issues that were evaluated in the PEIA included the effects that the 19 technologies would have on (1) emissions of SO_2 and NO_x in relation to acidic deposition, (2) loss of habitat from disposal of solid wastes, and (3) CO_2 emissions. The analysis was based on estimates from the Regional Emission Database and Evaluation System (REDES) model developed by Argonne National Laboratory (ANL) specifically for the ICCT program. The output of the model was expressed as differences in the amounts of sulfur dioxide (SO_2), nitrogen oxides (NO_x), and amounts of solid wastes produced in the year 2010 for each technology (under the assumption of maximum market penetration) in

comparison to a baseline year of 1985. The ORNL analysis of impacts addressed two alternatives: (1) the no-action alternative that assumed no innovative clean coal technologies would be implemented and that flue-gas desulfurization would be used on any new plants constructed between 1985 and 2010 and (2) the proposed action that assumed that innovative clean coal technologies would be implemented.

The PEIA found that the proposed action would result in a greater reduction of atmospheric emissions of SO₂ and NO_x than the no-action alternative would. The absolute amount of emissions reduction, however, is uncertain because the mix of technologies that would be commercialized and the locations of these facilities are not known. The analysis found that reductions in SO₂ and NO_x would help ameliorate the effects that acidic deposition has had on surface waters and terrestrial resources, especially in the northeastern United States. The PEIA found that implementation of clean coal technologies would have little effect on global CO₂ concentrations because CO₂ emissions are a function of the amount of coal burned. Because some of the clean coal technologies are more efficient than conventional technologies with scrubbers, some reduction in CO₂ emissions could occur if these technologies were a significant part of the technology mix commercialized by 2010. The PEIA also found that solid waste generation for certain technologies increased as much as 35% by 2010 in comparison with the no-action alternative, but, for others, reductions up to 27% were predicted. Increased generation of solid wastes could result in the loss of habitat and in possible contamination of groundwater and surface water.

The PEIA was used by the DOE Source Evaluation Official in selecting 16 projects to be considered for financial assistance. Two additional analyses of environmental impacts were prepared by the Source Evaluation Team in order to address specific project information that could not be made public because it was confidential or proprietary. The three analyses together provide the necessary analysis for complying with the National Environmental Policy Act. The PEIA will be supplemented, as necessary, for a third round of clean coal solicitations that has recently been approved by Congress, and it will serve as a reference document for NEPA reviews done for specific projects.

Implications of RCRA Regulation for the Disposal of Transuranic and High-Level Waste Are Evaluated

C. F. Sigmon, F. E. Sharples, and E. D. Smith

The Resource Conservation and Recovery Act (RCRA) and its implementing regulations create a complex waste management system to ensure that human health and the environment are protected from releases or potential releases of hazardous chemicals into the environment. Because radionuclides themselves are specifically exempt from RCRA regulation, DOE has historically managed radioactive wastes according to the mandates of the Atomic Energy Act (AEA) only. Regulatory changes occurring over the last 2 years, as well as policy changes within DOE, have made clear the authority of the Environmental Protection Agency (EPA) to regulate the hazardous chemical portion of mixed hazardous and radioactive wastes. However, regulation of mixed wastes under RCRA, especially

those wastes exhibiting higher levels of radioactivity, potentially creates conflicts between the statutory mandates of RCRA and those of AEA that require that personnel be protected from excess exposure to radiation.

To derive the optimal means of ensuring regulatory compliance, we evaluated the potential areas of conflict between the two statutory authorities and assessed the options that might be used to regulate high-hazard radioactive wastes under RCRA without compromising the requirements of AEA. According to the EPA Mixed Energy Waste Study Task Force, the DOE management program for high-level and transuranic wastes did not meet RCRA's requirements for waste characterization, groundwater monitoring, inspection of storage areas, and independent oversight. AEA's waste characterization and inspection requirements are more limited than those of RCRA in order to prevent excess exposure to radiation. Groundwater monitoring may, in some cases, compromise the integrity of geologic formations used for long-term containment of wastes. Independent oversight by EPA could be permitted if inspectors have appropriate security clearances.

We concluded that RCRA provides a number of options by which dual regulation of mixed wastes could be successful. The existing provisions for permitting miscellaneous units, Subpart X of 40 CFR 264, are sufficiently flexible to accommodate procedural changes to minimize excess exposure of personnel to radiation. Subpart X and a variance from requirements that pose a danger to national security or personnel could provide appropriate relief from strict adherence to RCRA with little change in the current regulatory structure. Because of these options, regulating mixed waste under RCRA is not likely to impose major changes in radioactive waste management at DOE facilities. It is, however, likely to create an additional administrative burden.

Dual Regulation of High-Level Radioactive Waste Repository Is Not Necessary to Minimize Risk from the Hazardous Chemical Component of the Waste

E. D. Smith, C. F. Sigmon, and F. E. Sharples

Historically it has been assumed that the radiological hazards of spent nuclear fuel and other high-level radioactive waste (HLW) so greatly exceeded any other hazards posed by these wastes that only the radiological hazard must be considered in their disposal. U.S. policy, established by the Nuclear Waste Policy Act, calls for HLW to be disposed of in a mined geologic repository developed and operated by DOE, with regulatory oversight by the Nuclear Regulatory Commission (NRC). A recent DOE policy, however, declares that management of the nonradioactive hazardous component of any DOE radioactive waste that is defined as "hazardous" under the Resource Conservation and Recovery Act (RCRA) is subject to regulation under RCRA. In light of this development, we (1) evaluated the potential for HLW to be construed as hazardous waste under RCRA, (2) compared the risks posed by the radioactive and nonradioactive hazardous components of HLW, and (3) compared the legal requirements for repository disposal of HLW and the RCRA requirements for disposal of hazardous waste, assessing their probable effectiveness in reducing risks from nonradioactive hazardous chemicals.

Final determination of the RCRA status of a particular waste is not possible unless leaching tests are conducted. From available data on the chemical composition of HLW, however, we estimated that spent fuel from commercial nuclear reactors is unlikely to be classified as hazardous but that some HLW from DOE defense activities might be defined by RCRA as hazardous waste because it contains cadmium, chromium, selenium, or other metals that are classified as toxic.

We used maximum contaminant levels set by federal drinking water regulations as the basis for a crude quantitative comparison of the ingestion risk from the radioactive and nonradioactive components of HLW. Uncertainties associated with this approach are large, but the comparison indicated an enormous difference in risk: the hazard from ingesting each of several individual radionuclides in an arbitrary quantity of a representative HLW exceeds the hazard from ingesting the metals in that same HLW by eight to nine orders of magnitude. In addition, the radioactive component of HLW poses substantial risks in handling (due to the high external radiation field and heat generation capacity).

Considering only the waste isolation features mandated by regulations, we found that an HLW repository that complied with applicable NRC regulations would be far more effective in isolating nondecaying hazardous substances (such as the toxic metals) than a landfill that met RCRA requirements would. This difference is due primarily to the duration of waste isolation. The HLW repository must contain wastes completely for 300 to 1,000 years and meet certain waste isolation goals for 10,000 years, whereas a RCRA landfill must contain wastes completely for only 30 years.

Although some HLW might be classifiable as hazardous waste under RCRA, our analysis shows that risk considerations do not warrant the dual regulation of an HLW repository (i.e., under both NRC rules and RCRA regulations).

Lotus Spreadsheet Model Is Created for Remedial Action Planning for Radioactively Contaminated Soil

C. F. Baes III and J. E. Nyquist*

Remedial actions at ORNL and other DOE facilities will probably involve soils contaminated with radionuclides. Decisions about the handling and final disposition of these soils will be based upon compliance with a standard or dose limit intended to protect human health and the environment. Doses to potentially exposed individuals are estimated by using models that calculate direct exposures and predict intakes of radionuclides that result through the inhalation of air and the ingestion of food and water. A methodology is therefore needed to evaluate the effectiveness of various remedial action options in complying with standards for radionuclides.

The uncertainty in radionuclide distribution among ORNL sites and in long-term decommissioning and closure options required a flexible approach, capable of handling different levels of contamination, dose limits, and closure scenarios. As a result, a commercially available pathway analysis model, DECOM, written in BASIC for an IBM PC/XT or PC/AT, was purchased. Modifications were made to make it more user friendly, to add options, and to make the models consistent with conditions at ORNL. Default parameters and some submodels were changed to accommodate approaches (or anticipated

approaches) used by EPA in regulating remedial actions for hazardous substances under the Comprehensive Environmental Response, Compensation, and Liability Act of 1980.

The result is a LOTUS spreadsheet version of DECOM that has additional capabilities and advantages. The code corrects the infinite plane assumption for external exposures when contaminated areas are of limited size and a cap of uncontaminated soil covers the contaminated soil. A pica exposure pathway has also been added. All calculations are made in the forward direction. The user enters radionuclide concentrations, and the program automatically recalculates the dose each time a parameter is changed. The effect of varying a single parameter can easily be tested; thus the user can conduct a sensitivity analysis. Furthermore, the graphics package built into LOTUS may be used to display results.

The LOTUS spreadsheet version of DECOM provides an easy-to-use dose assessment model that runs quickly on an IBM PC or compatible equipment. By entering soil radionuclide concentrations and varying model input parameters (e.g., the thickness of cap layer and the period of institutional control), the user can explore contingencies and assay the effectiveness of various remedial options. Users may gain valuable insight into the relative importance of various pathways and parameters in predicting doses from contaminated soil, and hence, in complying with radiological standards.

*Health and Safety Research Division, ORNL.

The Effects that Oil Field Wastes Have on Wildlife Are Investigated

G. W. Suter II, G. M. Caton,* M. S. Uziel,* and D. M. Opresco*

The Elk Hills Naval Petroleum Reserve No. 1 (NPR-1) has been an active oil field for over 60 years. During that time various materials involved in oil production and product separation were emitted to the environment or disposed of on-site. During the 1980s the decline of the endangered San Joaquin kit fox (*Vulpes macrotis mutica*) population and its lagomorph prey prompted a number of studies to examine possible causes. ESD was asked to investigate possible toxicological causes.

The first year of the project was devoted to collecting data on the use of materials and on the environmental concentrations of chemicals on NPR-1 and other oil fields. This information was used to identify (1) routes of exposure of wildlife to oil field materials (Fig. 11), (2) materials with potentially toxic properties, and (3) individual chemicals that may contribute to toxic effects. The material and route of exposure that raise the greatest concern are sump waters and drinking, respectively. Oil field waters have been known to cause toxic effects in livestock, and wildlife on NPR-1 are believed to drink from sumps. Although the chemical composition of water consumed on NPR-1 was unknown, none of the component chemicals previously identified, acting individually, appears likely to cause significant toxic effects by known routes of exposure. However, some chemicals used on NPR-1 may have a combined effect that could cause chronic stress to kit foxes.

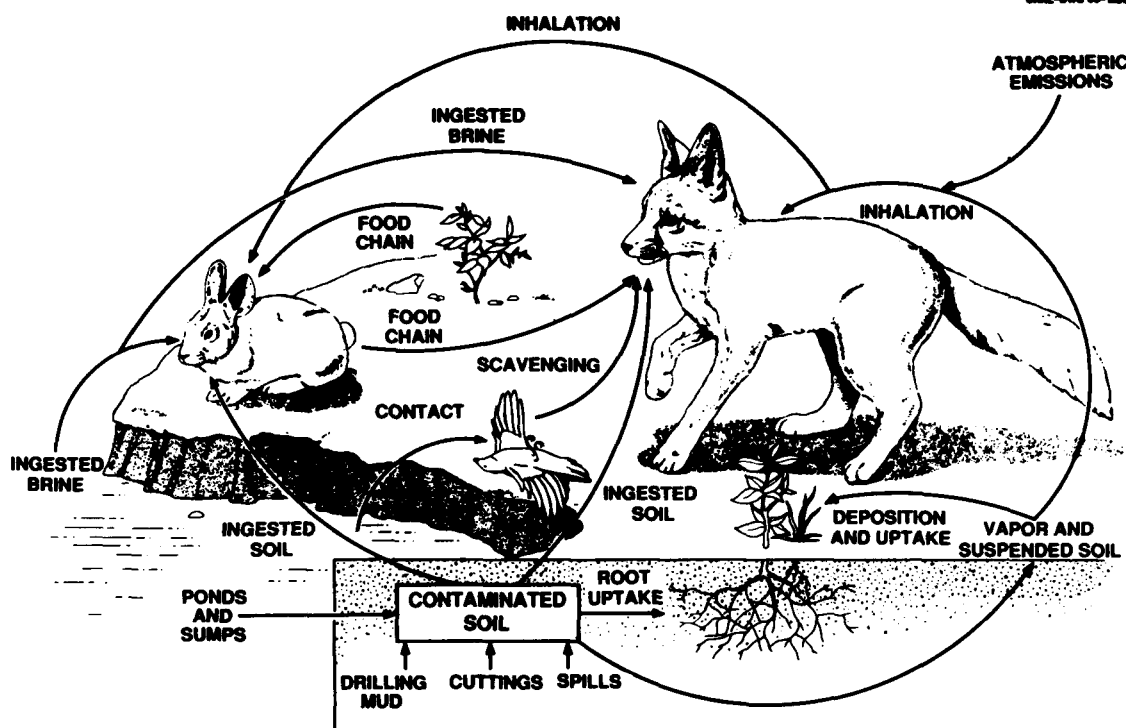


Fig. 11. Routes of exposure to oil field materials.

From these findings, we prepared a monitoring plan, which we are now implementing. Monitoring includes chemical analyses of sump waters, soil, vegetation, and animal tissues. In addition, we are measuring biochemical markers of toxic exposure in wildlife.

*Health and Safety Research Division, ORNL.

Sensitivity Analysis of Defense Priority Model Is Performed

L. W. Barnthouse and E. D. Smith

The Defense Priority Model (DPM), developed by ESD for the U.S. Air Force, is a system for ranking contaminated sites according to their relative ecological and health hazards. The U.S. Department of Defense has announced its intent to apply the DPM to facilities operated by all three armed services. To aid users in interpreting the scores obtained, we analyzed the sensitivity of these scores to the DPM weighting scheme, which is based on expert judgments.

In the DPM the relative hazards of contaminated sites are evaluated by means of a scoring scheme in which (1) scores are assigned to various site factors (e.g., depth to groundwater and use designation of potentially affected surface water) influencing the degree of risk posed by a site and (2) these scores are weighted to account for the relative importance of each factor to the hazard of the site. Detailed guidance has been developed

to minimize the influence of subjective judgments on the scores. However, the weighting scheme is necessarily subjective, although it reflects a general consensus among experts regarding the importance of each site factor. Our sensitivity analysis was designed to evaluate the influence of this weighting scheme on the ranking of 28 contaminated sites at three representative Air Force bases: Myrtle Beach in South Carolina, Tinker in Oklahoma, and Edwards in California.

Each site was scored with (1) the normal DPM weighting scheme, (2) a reversed weighting scheme, and (3) equal weights for all factors. Comparison of the rankings produced by the three weighting schemes showed that the relative ranks of the most hazardous sites are sensitive to the weights of the factors. However, nine of the top ten sites according to the normal weighting scheme were ranked in the top ten for the other two weighting schemes as well. The rankings of the ten least hazardous sites were unaffected by the choice of weighting schemes.

Results of the sensitivity analysis indicate that use of the DPM to assign sites to broad categories of low, medium, and high priority should not introduce biases as a result of the weighting scheme. Specific ranks within the high-priority category must be treated with caution because the rankings are sensitive to factor weights. For these sites it would be advisable to consider other information in addition to DPM scores when decisions about remedial action are made.

Relationship Between Changes in Landscape Pattern and Movement of Consumers Is Established

R. V. O'Neill, R. H. Gardner, and M. G. Turner

Landscapes are complex spatial mosaics of forests, fields, and other areas of land use. Human activities, such as fragmenting forests into small patches, can change the pattern. To assess the impact of such changes, one must understand the relationship between landscape pattern and ecological processes occurring on that landscape. In this study we examined the relationship between consumer movement on a landscape and the spatial pattern of critical resources, such as food.

Spatial patterning of resources determines the range of movement of consumers. If critical resources are separated by considerable distances, only those consumers that can traverse such distances can survive. Sparse resources require an organism to operate on a large spatial scale. Percolation theory predicts that an organism can operate freely on a landscape if its critical resource or habitat occupies approximately 60% of the landscape. For a critical resource, such as food, which must be located each day, the theory predicts that a consumer must be able to cover sufficient space each day, say 100 ha, so that 60% of these spatial units contain food. As a resource becomes scarce, the consumer must be able to cover larger unit blocks of landscape.

We have quantified this relationship as a resource utilization scale. A resource utilization scale is defined as the number of steps of unit distance that a consumer must take in a unit time such that the landscape is rescaled into unit blocks, 60% of which contain the resource. Using this approach, we have explored how changes in pattern alter the scale that consumers must adopt. For example, contiguous spatial patterns with the resource

clustered in a small area require larger scales to permit movement between resource clusters.

The study establishes a relationship between landscape pattern and consumer movement. The relationship takes the form of quantitative predictions of the resource utilization scale required to locate and utilize a resource scattered across a landscape. Of particular interest is the possibility of predicting which components of the consumer community would be eliminated with a given change in landscape pattern.

Neutral Model Predicts the Spread of Disturbance Across Heterogeneous Landscapes

M. G. Turner, R. H. Gardner, V. H. Dale, and R. V. O'Neill

The spread of a disturbance (e.g., pest, pathogen, or fire) across a landscape is an example of an important ecological process that is influenced by spatial heterogeneity. Landscape heterogeneity may enhance or retard the spread of disturbances, which often generate new landscape patterns. However, a general theory to predict the effects that spatial heterogeneity has on the propagation of disturbances had not previously been developed.

The expected pattern of disturbance propagation across a landscape was studied by using simple landscape models derived from percolation theory. The spread of a disturbance was simulated as a function of (1) the proportion, p , of the landscape occupied by the disturbance-prone habitat; (2) the frequency, f , of a habitat-specific disturbance; and (3) the spreadability, i , of the disturbance. Effects were estimated from the proportion of habitat affected by the disturbance and from changes in landscape structure (i.e., spatial patterns). Landscape structure was measured by the number of habitat clusters, the size and shape of the largest cluster, and the amount of edge in the landscape. Susceptible habitats that occupied less than 50% of the landscape were sensitive to disturbance frequency but showed little response to changes in disturbance spreadability. Susceptible habitats that occupied more than 60% of the landscape were sensitive to spreadability but less sensitive to frequency. The propagation of disturbance in heterogeneous landscapes depended on the structure of the landscape as well as the spreadability and frequency of the disturbance.

These results have implications for the management of disturbance-prone landscapes. The persistence of rare habitats that are susceptible to disturbance appears to depend upon disturbance frequency (f). The long-term viability of remnant forest stands or other dispersed patches of rare communities (e.g., cedar barrens and granite outcrops) in a landscape may therefore depend on the number of disturbances rather than on their spreadability. A disturbance that is intense locally may eliminate a cluster of a particular type of habitat but have little effect on the persistence of that habitat in the landscape. In contrast, a large number of disturbances of low spreadability over a large region could reduce or eliminate the habitat. Therefore, if a habitat type is rare, management should focus on the frequency of disturbances.

If a disturbance-prone habitat is common in a landscape, management must consider both frequency and spreadability. The effects of disturbance can be predicted at the

extreme ends of the ranges of frequency and spreadability: disturbances of low spreadability and low frequency will have little effect, and disturbances of high spreadability will cause substantial changes. However, at intermediate levels of spreadability, responses can be quite complicated and more difficult to predict. A common habitat can be easily fragmented and qualitatively changed by disturbances of low to moderate spreadability and low to high frequency. Thus, the interaction between p , i , and f may affect the landscape in ways that are counterintuitive. Large tracts of forest, for example, may be fragmented by disturbances of relatively low frequency. Structural changes associated with this fragmentation, such as the increased number of edges, have important implications for susceptibility to other disturbances (e.g., windthrow) and for the distribution and abundance of species.

Regional Forest Productivity and Cover Are Evaluated with Nested Scales of Spectral and Biogeographical Data

R. L. Graham

Many important environmental issues, such as climate change and acid precipitation, are regional or global in nature. Resolving these issues has been difficult in part because of their enormous geographic scale in relation to ground-based measures. Methods are needed for extrapolating ground-based measures to regional and landscape estimates. The objective of our research was to use nested scales of remotely sensed spectral data in conjunction with ground-based biogeographical data to estimate with quantifiable precision forest productivity and cover at landscape and regional scales.

We used a three-stage approach (Fig. 12) with fine-resolution (30-m²) Thematic Mapper (TM) satellite data, coarse-resolution (1.1-km²) Advanced Very High Resolution Radiometer (AVHRR) satellite data, and fine-resolution ground-based forest productivity and cover data. In the first stage, we related ground-based forest productivity and cover data to TM spectral data of similar resolution to develop models that predicted forest cover or productivity on the basis of TM pixel values of surface reflectance. We were successful in establishing this TM/ground-based data link over four widely differing landscapes: southern Illinois, the Great Smoky Mountains in Tennessee, the Adirondack Mountains in New York, and the subalpine zone of the Rocky Mountains in Colorado. The TM models accurately predicted the mean or median forest productivity or cover of a landscape. The fine-scale (pixel-to-pixel) pattern of productivity, however, was not well accounted for by these models. In the second stage, we developed AVHRR models for the midwestern and southeastern regions of the United States to predict forest cover and productivity on the basis of AVHRR surface reflectance pixel values. The AVHRR models, developed by using the TM models, had statistical properties similar to those of the TM models. The predicted forest cover value for an AVHRR scene encompassing five southeastern states had a standard error of $\pm 4\%$. In the third stage, we tested our approach by comparing our regional forest cover and productivity predictions with independent data from the U.S. Forest Service. Our estimates correlated well with those of the U.S. Forest Service (e.g., a correlation of 0.96 for forest cover of 77 counties in Missouri, and a correlation of 0.872 for a 10-state midwestern region composed of 432

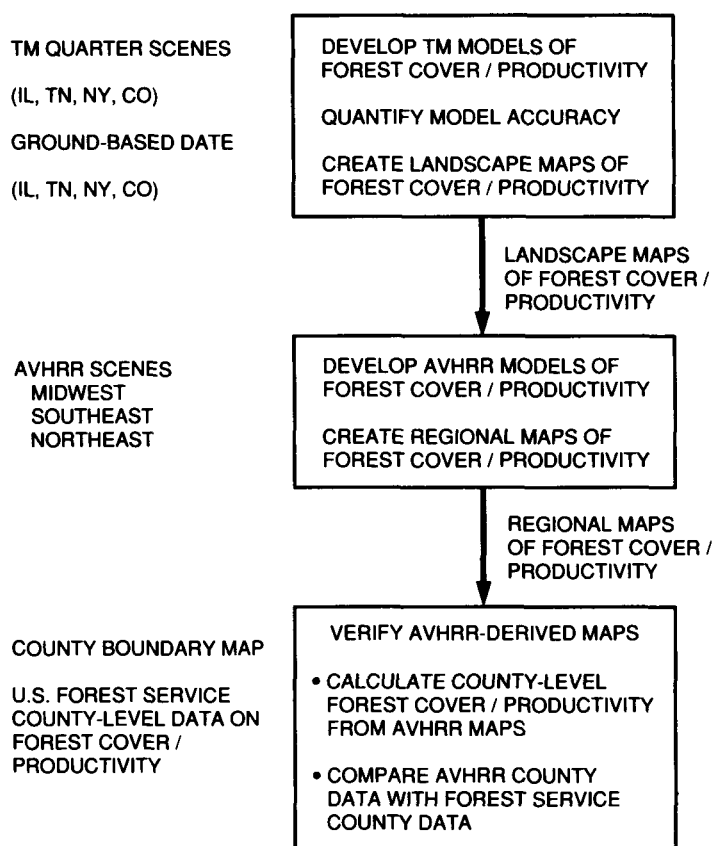


Fig. 12. Three-stage approach to ground-thematic mapper (TM)-advanced very high resolution radiometer (AVHRR) investigations.

counties). In addition, our forest productivity estimates were also very accurate for counties within 300 km of the original TM calibration site. Correlations for counties located 0–100 km, 100–200 km, and 200–300 km from the calibration site were 0.81, 0.77, and 0.69, respectively. In summary, our approach using nested scales of imagery in conjunction with ground-based data can be successful in extrapolating limited ground-based data to derive regional estimates of forest productivity and cover with quantifiable precision. This approach should be most useful in regions of the world with limited ground-based data.

Framework for Regional Ecological Risk Assessment Is Presented and Evaluated

C. T. Hunsaker, R. L. Graham, G. W. Suter II, and R. V. O'Neill

Society requires a quantitative and systematic way to estimate and compare the impacts of environmental disturbances that affect large geographic areas (e.g., acid deposition, non-point-source pollution, and increased global CO₂). To meet these needs, a conceptual framework for regional ecological risk assessment has been developed. Both

forest interior, and water quality). A spatial model was used to evaluate the effect of spatial pattern on regional endpoints, while Monte Carlo techniques quantified risk. Risk was highest for endpoints dependent on landscape pattern. Research needs include regional-scale models, tools for describing spatial heterogeneity, theory and data concerning the effect of spatial heterogeneity on ecological processes, and a better understanding of ecosystem processes important at different geographic scales and of errors associated with data aggregation. This research presents a framework for regional ecological risk assessment and demonstrates the importance of landscape pattern for regional resource management and impact assessments.

Results of the EPA National Stream Survey Show Evidence of Acidification in the Mid-Atlantic and Southeastern United States

J. W. Elwood, M. J. Sale, and H. I. Jager

As part of the National Surface Water Survey, the U.S. Environmental Protection Agency conducted a probability-based survey of the water chemistry of low-order streams considered to be at risk as a result of acidic deposition. The survey covered nine subregions of the mid-Atlantic and southeastern United States, extending from New York and Pennsylvania to northern Florida. ESD was involved in both the management and the analysis of the survey data. The specific objectives of Phase I of the stream survey were (1) to determine the number, length, and area of stream reaches that are currently acidic [acid neutralizing capacity (ANC) ≤ 0] or that could become acidic in the future and (2) to identify regionally representative streams for further study. The survey data base has also been used to assess regional evidence for stream acidification. Randomly selected streams in the target population with a drainage area $<155 \text{ km}^2$ were sampled at an upstream node and a downstream node in the spring during baseflow conditions.

In the combined mid-Atlantic subregions (Pocono/Catskills, northern Appalachians, Ridge and Valley, and Mid-Atlantic Coastal Plain), 7.4% of the target reaches were acidic at their upstream end, and 3% were acidic at the downstream end. In four of the five combined southeastern subregions—Southern Appalachians, Southern Blue Ridge, and Ozark/Ouachitas (Florida is excluded)—fewer than 1% of the target reaches were acidic at either their upstream end or their downstream end when acidic mine-drainage streams were excluded. Florida contained a higher percentage of acidic streams in the target population (39% of the upstream reaches and 14% of the downstream reaches) than any of the other subregions. Almost all streams in the target population of the mid-Atlantic and southeastern United States had an ANC deficit estimated as the difference between the sum of nonmarine base cations and ANC. This finding suggests that some of the ANC has been titrated, that base cations have been stripped from the soils by strong acids, or that both of these processes have occurred. The Mid-Atlantic region has a larger number of streams with an ANC deficit than the southeastern United States does, a pattern generally consistent with the lower rates of atmospheric acid deposition and greater capacity of soils to adsorb sulfate in the Southeast. Except in Florida, the Mid-Atlantic Coastal Plain, and the Piedmont, sulfate alone can account for almost all of the variation in the ANC deficits of the streams in the different subregions. Organic anions and chloride account for most of the ANC deficit in Florida, whereas nitrate accounts for most of the deficit in the Mid-Atlantic Coastal Plain. A comparison of sulfate deposition rates and sulfate concentrations

in eastern U.S. streams not affected by large watershed (bedrock) sources of sulfate shows a strong positive linear relationship, which suggests that sulfuric acid deposition is the primary source of acidity in most streams in the eastern United States.

The results of this survey provide strong circumstantial evidence linking acidic deposition to stream acidification in sensitive areas of the eastern United States. Although fewer than 10% of the survey's target population are currently acidic, the majority of target-population streams exhibit ANC deficits and, therefore, show signs of acidification. The most likely cause of the apparent acidification in the majority of the subregions appears to be sulfuric acid from atmospheric deposition. Organic acids appear to be a major source of acidity only in Florida streams.

Data Management Is Provided for the ORNL Remedial Action Program

L. D. Voorhees

ORNL established a Remedial Action Program in 1985 to provide corrective measures at over 140 sites that have been contaminated with radioactive and/or hazardous wastes. To achieve this goal, numerous studies have been and will continue to be conducted, resulting in a voluminous amount of data. A computerized data base is being developed within ESD to manage these data effectively and efficiently.

The Statistical Analysis System (SAS*) is used by data management staff to organize the data into standard formats. Initial data management has focused on the development of software for electronically transferring and manipulating data produced by a diverse group of investigators. In addition, considerable effort has been given to quality assurance procedures to ensure the accuracy of the data entries and the security of the data. Because a major portion of the remedial investigations will be performed by a subcontractor, specific procedures for sharing data have been defined.

More than 60 data sets covering a wide range of topics currently reside in the data base. The bulk of the data consists of chemical analyses associated with characterization surveys. With more than 45,000 observations of chemical analyses and 19 variables per observation, these data sets alone collectively contain over 850,000 entries. In addition, daily precipitation data and surface water data from several sites in the Oak Ridge area have been compiled from the U.S. Geological Survey (USGS), the Atmospheric Turbulence and Diffusion Laboratory in Oak Ridge, ORNL's Environmental Monitoring and Compliance Department, and investigations within ESD. Well construction parameters on over 1100 wells in the immediate vicinity of ORNL have been obtained in addition to groundwater elevation data from >300 wells monitored by ORNL and 90 wells monitored by the USGS.

This data base provides a unified repository for data generated within and related to the ORNL Remedial Action Program and provides necessary storage, manipulation, analysis, display, and report generation capabilities. Because remedial action activities have gained nationwide recognition as a result of recent environmental legislation, organization of the data base for the ORNL site can serve as a model for management of large and highly diverse data sets at other contaminated sites throughout the United States.

*SAS is the registered trademark of SAS Institute, Cary, North Carolina.

1.3 ENVIRONMENTAL ENGINEERING AND HYDROLOGY

D. D. Huff

T. L. Ashwood	N. D. Farrow	D. S. Marshall	L. E. Stratton
J. C. Barnett ¹	B. J. Frederick ²	W. M. McMaster ²	D. R. Styers ³
W. J. Boegly, Jr.	J. A. Furnari ⁵	M. J. Miller	G. D. Swanson ²
D. M. Borders ²	S. B. Garland II	G. K. Moore ²	A. L. Thomas
C. C. Broders	S. M. Gregory	P. Ottinger ²	B. J. Thomas
P. A. Buntrock	R. C. Haese	G. S. Outlaw ¹	S. J. Thomas ⁵
R. J. Burtnett ³	R. J. Hoeksema ⁷	R. J. Poreda ¹⁰	L. E. Toran ¹²
T. E. Cerling ⁴	A. E. Hunley	R. J. Rhea ³	D. S. Wickliff ¹³
R. B. Clapp	A. F. Iglar ⁸	C. Rudolph ²	I. H. Wiggins ³
J. S. Cox	P. M. Kearl	O. M. Sealand	R. E. Yager ⁵
P. M. Craig ⁵	N. E. Korte	B. V. Shelton	G. T. Yeh
T. B. Crattie ⁶	D. W. Kuehl ⁹	C. B. Sherwood ¹¹	H. H. Zehner ¹
E. C. Davis	J. G. Lewis ¹	D. K. Solomon	

1.3.1 Introduction

The Environmental Engineering and Hydrology Section conducts research, development, and demonstration projects that involve advanced waste disposal methods, surface and groundwater hydrology, contaminant transport, and a variety of simulation models. The Section is administratively divided into groups that address environmental engineering, surface water hydrology, groundwater hydrology, and remedial action program management, although most projects are multidisciplinary and include both modeling and data base management. The representative summaries that follow reflect the diversity of expertise among the Section's staff and the ways that diversity has been brought to bear on problems of national importance. For convenience, the summaries are organized in two

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1. U.S. Geological Survey, Knoxville, Tennessee.
 2. The University of Tennessee, Knoxville.
 3. ASG Consultants, Oak Ridge, Tennessee.
 4. University of Utah, Salt Lake City.
 5. Environmental Consulting Engineers, Knoxville, Tennessee.
 6. Lee Wan and Associates, Inc., Oak Ridge, Tennessee.
 7. Calvin College, Grand Rapids, Michigan.
 8. East Tennessee State University, Johnson City.
 9. SAR Consultants, Portland, Oregon.
 10. Scripps Institute of Oceanography, LaJolla, California.
 11. Consultant, Jacksonville, Florida.
 12. Wigner Fellow.
 13. The University of Arkansas, Fayetteville.

groups, environmental engineering and hydrology, but the synergy between disciplines taxes any scheme to impose a rigid structure. It may be most useful to view the scope of section activities in a framework that begins with potential sources of contaminants and the engineering methods for their control and then traces the effects that various hydrologic and geochemical processes have on the subsequent transport and fate of residuals. In the process of stabilizing old sites and helping to design new, more effective disposal systems, the underlying science is considered the most important factor.

Many projects are coordinated with other sections of the Environmental Sciences Division (ESD); other divisions of Oak Ridge National Laboratory (ORNL), other federal agencies, such as the U.S. Geological Survey (USGS) and the Tennessee Valley Authority (TVA); and collaborators from several universities.

Nearly all of the Section's current activities are related to waste management or remedial action projects at sites on the Oak Ridge Reservation (ORR) through sponsorship by the U.S. Department of Energy (DOE) Office of Defense Waste and Transportation Management and Office of Energy Research. Other sponsors of the Section's projects include the DOE Sedimentary Rock Program and the U.S. Navy. The Section continues to work with the Radiological Survey Group of the Health and Safety Research Division in a program to support the U.S. Air Force Installation Restoration Program (IRP). The ORNL lead group is based in Grand Junction, Colorado, and is supported through the Hazardous Waste Remedial Action Program. The IRP is designed to identify, characterize, and evaluate potential problems with hazardous wastes at military installations.

Significant achievements during FY 1988 include the following:

- environmental engineering
 - production-scale testing of two new techniques for disposal of radioactive solid waste: a tumulus and buried concrete silos;
 - planning for characterization of leachate production from uranium wastes through the use of experimental field lysimeters;
 - management of the successful operation of a uv-ozone treatment plant for groundwater with organic contaminants;
- hydrology
 - identification of the importance of very shallow, subsurface stormflow in the transmission of water and contaminants;
 - confirmation that contaminants in fractured rocks can be transported either as solutes or in association with colloids;
 - adaptation of a groundwater flow model to simulate transport of gases, such as radon and volatile organic compounds, for use in designing a demonstration project on in situ soil venting;
 - generation of scenarios for hypothetical releases of contaminants from ORNL facilities, as a means of assisting emergency response planning and supporting safety analyses for corrective action projects.

Expanded summaries describing these and other activities follow.

1.3.2 Technical Summaries

Tumulus Disposal Demonstration Project Is Evaluated for Low-Level Radioactive Waste Disposal

S. B. Garland II, S. D. Van Hoesen,* and T. F. Scanlan†

As part of a program to evaluate solid low-level radioactive waste (LLW) disposal technologies, an aboveground tumulus facility was constructed in Solid Waste Storage Area 6 (SWSA 6) to provide a full-scale demonstration. The tumulus consists of a concrete pad on which the LLW is placed, a synthetic underpad liner, concrete disposal vaults in which the LLW is contained, and a multilayered cap to be constructed after the pad is filled. The tumulus has several advantages over the past practice of shallow land burial: improved waste confinement, structural stability, containment and monitoring of leachate and radionuclides, and easier waste recovery.

Between April and August 1988, over 80 disposal vaults representing approximately 40% of the facility's capacity were placed on the pad. The facility should remain operational for another 1 to 2 years. Design and operational experience are being evaluated at this time.

Evaluation of the demonstration also will be based on results from two monitoring activities—environmental exposure and worker exposure. Environmental monitoring consists of meteorological parameters, soils, groundwater, pad runoff, and underpad drainage. Figure 14 shows a monitoring specialist recovering a water sample from a monitoring well. In the background is the tumulus facility. The main results from this monitoring are not expected until construction of the cap in a few years. Monitoring of worker exposure consists of measuring contact dose rates on incoming primary containers and disposal vaults, measuring doses received by operations personnel, and conducting routine site surveys. At least 20% of all activities are monitored. To date, monitoring has shown that the workers receive doses well within acceptable limits.

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†Environmental and Health Protection Division, ORNL.

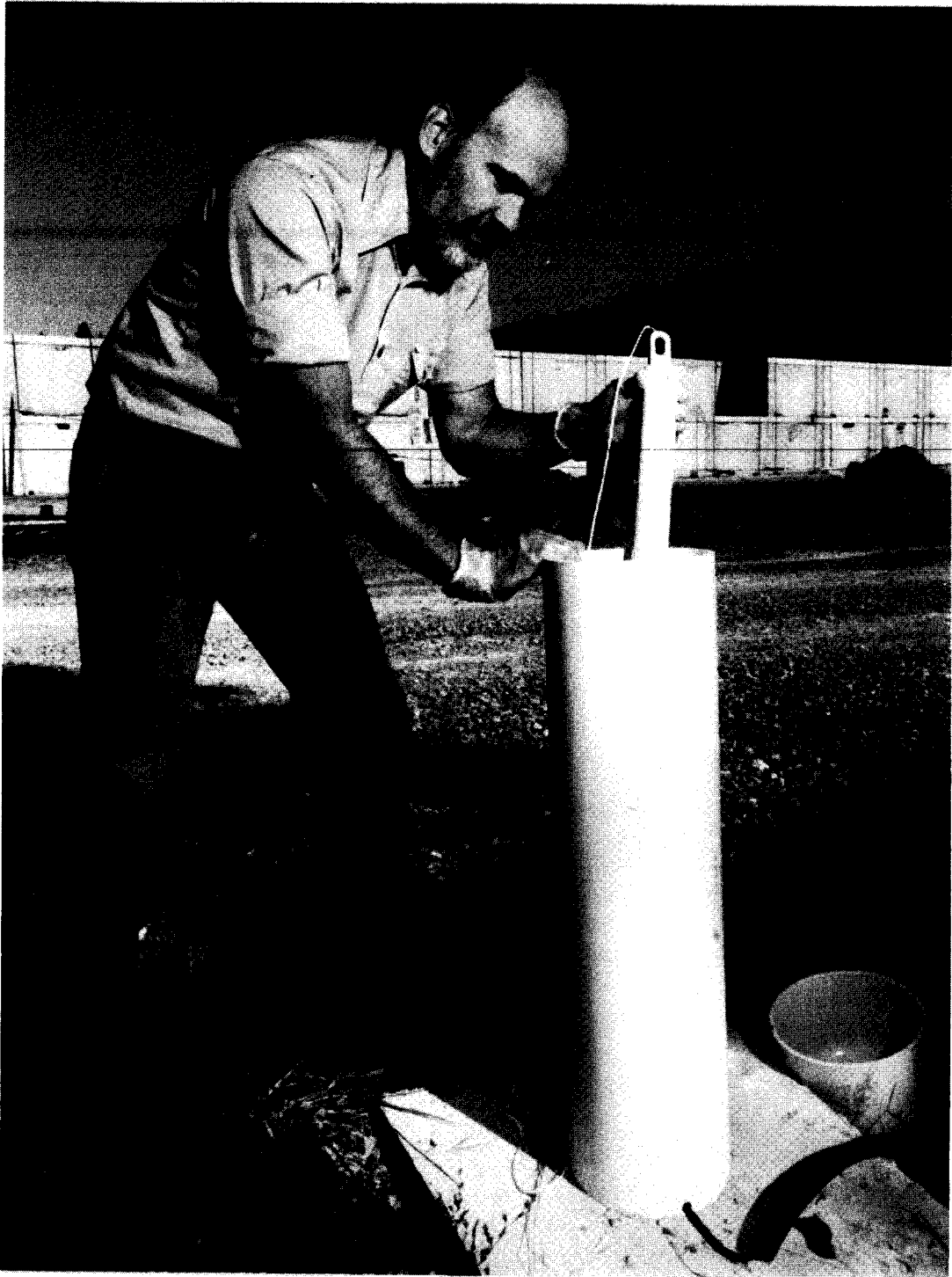


Fig. 14. The recovery of a sample from a monitoring well. In the background is the Tumulus Disposal Demonstration Facility, where low-level radioactive waste is disposed of in concrete vaults.

Performance of Concrete Silos for Low-Level Radioactive Waste Disposal Is Studied

E. C. Davis and J. E. Van Cleve, Jr.

Since the inception of nuclear research and development operations in the early 1940s, ORNL has disposed of low-level radioactive solid wastes in unlined shallow trenches. These trenches, estimated to be approximately 1000 in number, are located in six solid waste storage areas (SWSAs 1 through 6) encompassing 135 acres and lying in close proximity to the main plant area. In May 1986 routine burial in unlined trenches ceased while DOE conducted an investigation concerning the disposal of hazardous wastes [as defined by the Resource Conservation and Recovery Act (RCRA)] in SWSA 6. Disposal operations resumed at the site several months later with the following changes: (1) portions of SWSA 6 would be considered hazardous waste sites, (2) all waste packages destined for disposal would be thoroughly inspected to ensure that they contained no liquids or RCRA hazardous wastes, and (3) all disposal would be made in greater confinement disposal units and no longer in unlined earth trenches.

Initially, greater confinement disposal was attempted through the use of concrete waste silos constructed of precast circular reinforced concrete drainage pipe. The pipe, with 6-in.-thick walls, 8-ft diameter, and 20-ft length, was set vertically into a 20-ft-deep excavation. A 12-in.-thick reinforced concrete bottom was poured into the silo, and a tar seal was applied in the joint between the walls and floor. A 3-in. polyvinyl chloride (PVC) monitoring well was placed in each silo as a means of detecting and sampling intrasilo water. A later silo design called for the silo walls to be made from 20-ft lengths of 8- and 9-ft-diam corrugated metal drainage pipe placed in a 20-ft-deep disposal trench to form concentric cylinders. The 6-in.-thick annular space was filled with concrete, and the silo floor was poured. As silos became filled to capacity (1000 ft³) with radioactive solid waste, reinforced concrete caps were poured over the waste and sloped to facilitate runoff. PVC monitoring wells were allowed to protrude through the cap so that intrasilo water levels could be monitored. To date, 63 such greater confinement waste silos have been constructed, filled, and capped.

A monthly water level monitoring program has shown that 17 of the 63 silos are leaking and accumulating water. An extreme case, silo 526, has 2.09 m of standing water in the bottom. Water sampling and counting for alpha and beta activity indicate that no alpha activity exists but beta activity up to 1000 Bq/L is present in the silo leachate. Because of the extent of this leakage, ESD has undertaken a joint study to (1) improve the design of additional silos, (2) leak test each silo after construction and before filling with waste (as a quality control measure), (3) determine the route by which water enters silos, and (4) determine what type of corrective measure (e.g., in situ grouting through the PVC monitoring well) is appropriate for correcting leaking silos. It is anticipated that, through this monitoring and field demonstration effort, the leakage mechanisms in existing greater confinement silos will be understood and the problem corrected.

Large-Scale Field Lysimeters Will Be Used to Investigate Leaching of Production Wastes Containing Depleted Uranium at the Oak Ridge Y-12 Plant

R. B. Clapp and C. W. Francis

Solid waste management at the Oak Ridge Y-12 Plant has historically centered around land disposal of production wastes containing low levels of depleted uranium. A new and more environmentally based strategy for disposing of these wastes is currently being developed. In support of the new strategy, the Y-12 Uranium Lysimeter Demonstration Project has been initiated to investigate long-term leaching characteristics of six major waste types under field disposal conditions. The multifaceted project involves characterizing the wastes in the laboratory, assessing the chemical and biological toxicity of leachates, and monitoring leaching in the field. Exploratory leaching tests done in the laboratory (under the direction of A. D. Kelmers, Chemical Technology Division, ORNL) indicate a complex pattern of leaching, thus underscoring the need for leaching data under field conditions.

Twenty lysimeters will be built at a site west of the Oak Ridge Y-12 Plant during the late spring of 1989. Construction costs are estimated to be \$478,000. The lysimeters are designed to provide leaching data for 50 years although the current project is limited to 5 years. The waste types that will be tested are production trash; metal turnings and chips; a composite mixture of wastes, uranium oxide, and contaminated soil; and building debris. Three replicates of each waste will be leached in separate lysimeters under natural rainfall conditions. The remaining lysimeters will be used for special tests (e.g., accelerated leaching and landfill simulation). The lysimeters will typically be 3.3 m in height by 2.6 m in diameter and contain about 10 m³ of waste. The volume of leachate generated, the concentration of uranium in the leachate, and other factors (e.g., total organic carbon, pH, and redox potential) will be monitored to more fully reveal how these factors affect the leaching of uranium under landfill conditions. These data, in conjunction with pathways models, will be used to calculate health and environmental impacts resulting from land disposal of untreated uranium-containing wastes. In turn, the modeling results will yield radioactivity limits that will be technically more justifiable than those currently available for landfill disposal.

The project is being funded by the Waste Transportation, Storage, and Disposal Department of the Oak Ridge Y-12 Plant. ESD is providing technical management for the project. ESD personnel have taken the lead role in developing the operating procedures for the field lysimeters and have generated plans for the overall project and for the environmental monitoring at the lysimeter facility. ESD personnel are also performing the biological toxicity tests.

Interflow Rapidly Transports Stream-Deposited Chemicals Through Soils

D. K. Solomon, I. L. Larsen, J. D. Marsh, P. D. Lowry,* and C. R. Olsen

The movement of atmospherically derived chemicals through watershed soils, either to the water table or to surface streams, is important in regulating water composition, leaching soil nutrients, and exposing plant roots or aquatic biota to both nutrients and

pollutants. The rates of lateral movement, via subsurface storm flow (interflow) through intermittently active channels in soils and bedrock, are known to be rapid; therefore, assumptions about local chemical equilibrium between soils and solution have been questioned.

To determine if interflow occurs rapidly enough to significantly transport highly particle-reactive substances, we measured the distribution of atmospherically derived ^7Be in rainfall, stream water, and interflow samples collected from specially designed underground weirs that provide large volumes of water for radionuclide analyses. The ^7Be concentration in Melton Branch interflow (18 mBq/L) is much greater than that in Walker Branch interflow (2 mBq/L), and both are greater than the ^7Be concentration (0.1 mBq/L) expected if rainfall had equilibrated with surface soils. That Melton Branch interflow has higher ^7Be concentrations than Walker Branch interflow is consistent with the soil and bedrock characteristics of the two watersheds. In Melton Branch, the soils form a thin (<1-m-thick) veneer over highly weathered and fractured bedrock, whereas in Walker Branch the soils are well developed and form a thick (typically 10- to 20-m) layer over dolomitic parent material. Concentrations of ^7Be in Walker Branch stream water range from ~1 to 10 mBq/L and are similar to values for interflow.

These results imply that the transport of chemically reactive substances is fast enough during storms to prevent the attainment of chemical equilibrium between the infiltrating rainwater and soils. Consequently, chemical equilibrium models used to quantify the interactions between groundwater and soil will underestimate the mobility of particle-reactive substances unless explicit consideration is given to the kinetics of sorption versus the residence time and velocity of interflow. Other chemical reactions in watershed systems, such as the neutralization of acidic precipitation, may also be affected by rapid lateral movement.

Future work will involve the measurement of a conservative rainwater tracer, ^{18}O , which uniquely tags individual rainstorms and, therefore, can be used with chemically reactive ^7Be to determine the residence time or transport time of interflow and to quantify the fraction of rainwater that moves through a watershed without interacting with the substrate.

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Tritium and Helium Isotopes Are Used to Date Water in a Shallow Unconfined Aquifer

R. J. Poreda,* T. E. Cerling,† and D. K. Solomon

Determining the age of shallow groundwater is very useful for defining hydrologic pathways. This is particularly true in complex systems where traditional methods of defining three-dimensional groundwater movement often require the collection of an enormous amount of data. The use of geochemical tracers to date groundwaters is common in deep aquifer systems where ages between 5,000 and 50,000 years are often determined; however, the use of dating techniques for groundwaters less than ~50 years old has been very rare.

Tritium is an excellent tracer in groundwater systems because it is present in water molecules and thus can be used to trace water movement. Because ^3H undergoes radioactive decay, it is possible to date tritiated water molecules and thus estimate the age of groundwater. However, age determinations based on the decay of ^3H alone require a knowledge of the initial ^3H concentration, a parameter rarely known.

Inert gases are also excellent tracers in water because they do not interact chemically with the system and can be used as tracers from the time of atmospheric exchange. Because ^3H decays to an inert gas, ^3He , it is possible to date the ^3H without a detailed knowledge of the initial concentration by measuring both ^3H and ^3He . Although combined ^3H and ^3He isotope measurements have been used as tracers in the ocean and in lakes, this method has seen little use in studies of groundwater systems..

A total of 15 groundwater samples from depths ranging from 1.8 to 10.4 m below land surface were collected from a low-level solid waste storage area (SWSA 6) near ORNL. Tritium was measured by liquid scintillation counting, whereas ^3He was measured by mass spectroscopy. The results suggest residence times of 0.1 to 6 years for ^3H in this system. These ages were calculated with an ideal model of a closed system and piston flow. The factors that appear to control the age distribution are the hydraulic gradient and the depth of the sample below the water table. Hydraulic head measurements made from a large number of piezometers located in SWSA 6 were used to construct a three-dimensional flow net. Apparent hydraulic conductivities were then calculated for six wells by using Darcy's law with an effective porosity of 0.1. The computed conductivity for five of the wells ranged from 3.3×10^{-6} to 5.3×10^{-6} m/s. Two samples collected at different depths from a single well had much higher computed conductivities: 97×10^{-6} and 18×10^{-6} m/s. These computed hydraulic conductivities compare favorably with hydraulic conductivities calculated from slug tests, which range from 0.2×10^{-6} to 24×10^{-6} m/s for 14 wells within SWSA 6.

These results suggest that the ^3H - ^3He isotope method may be useful for estimating residence times for ^3H in groundwater systems, in determining preferred pathways for fluid migration, and in estimating hydraulic conductivities on a scale different from conventional measurements. These techniques could be especially useful in complex hydrogeologic systems.

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Analyses of Hydraulic Conductivity and Groundwater Chemistry Data Characterize the Shallow Aquifer Near ORNL

G. K. Moore* and D. D. Huff

Groundwater quality has received greatly increased attention in the past few years. The main problem at ORNL involves the mobility of contaminants from past waste storage. This mobility is determined by the hydraulic and geochemical properties of the uppermost aquifer. Identification of the uppermost aquifer is an important first step in determining the risks of groundwater contamination. Over 1500 observation wells have been drilled near ORNL since 1949, over 380 values of hydraulic conductivity have been determined, and the water from many wells has been sampled and chemically analyzed.

Statistical analyses of these data, using cumulative probability plots, show several significant results that otherwise would be obscure.

The hydraulic conductivity data show that water-bearing fractures are very common but that most wells yield water <1 L/min. These data are lognormally distributed. Scant difference in the hydraulic conductivities of regolith wells and bedrock wells suggests a similar type of groundwater occurrence. Furthermore, little difference between wells in the Conasauga and Chickamauga groups suggests that lithologic characteristics are less important than other factors in determining the spatial frequency and aperture of open fractures in the wells.

Comparison of hydraulic conductivity values grouped by well depth and by the depth of packer tests in coreholes shows two distinctive populations. The geometric mean of hydraulic conductivity for the shallower population is 0.040 m/d. The geometric mean of hydraulic conductivity for the deeper population is 0.00064 m/d. These populations may represent a shallow zone of active groundwater circulation and a deeper zone of slow seepage. Shallow groundwater is a calcium bicarbonate type. The deeper population of hydraulic conductivity values apparently is representative of the base of the calcium bicarbonate water zone at levels of ~ 20 – 30 m deep, as well as a transitional sodium carbonate water zone ~ 30 – 60 m deep and a sodium chloride brine ~ 150 m deep. Classification by depth of hydraulic conductivity values from packer tests in coreholes shows smaller geometric mean values at 30–120 m than at shallower or deeper levels. This difference may reflect the swelling and dispersion of clays as sodium in the mineral lattice is replaced by calcium. If so, a change in chemical water type and a statistically significant decrease in fracture permeability indicate the base of the shallow aquifer in the ORNL area.

The data analysis and interpretation show that the uppermost aquifer extends to a depth of ~ 20 – 30 m and contains a calcium bicarbonate type of water. This information can be used in modeling groundwater flow and in assessing risks associated with contaminant transport by groundwater.

*The University of Tennessee, Knoxville.

Hydraulic Conductivity Decreases with Depth in HHMS Wells in Melton Valley

L. E. Toran and R. B. Dreier

The Hydraulic Head Measuring Stations (HHMS) are well clusters that provide data on the transition between shallow and deep groundwater systems and on the nature of the deep system(s). This information is required for characterization of the local hydrologic framework around waste disposal sites, as dictated by state and federal regulatory agencies. Specifically, the information provides a means for defining the bounds of the uppermost aquifer and identifies potential pathways for contaminant migration.

The well clusters consist of 3 wells drilled to depths of approximately 30, 60, and 120 m at 11 locations in Melton Valley at ORNL. Data collected from the wells include geophysical logs, which provide geologic stratigraphy and structure, as well as water levels and well testing, which provide groundwater flow directions and hydraulic conductivity.

Hydraulic conductivity decreases with depth in the HHMS wells. The mean hydraulic conductivity of the deep (120-m) wells is 8×10^{-9} cm/s, and that of the intermediate-depth (60-m) wells is 9×10^{-7} cm/s. In contrast, the highest hydraulic conductivities were 2×10^{-5} cm/s in the shallow wells. One exception to this pattern is a well that was drilled to about 60 m but had a hydraulic conductivity more typical of the deeper wells. Geophysical logs indicated that the well was finished in a fault zone and that it may have been influenced by a lower conductivity region in the fault zone. Thus, fault zones may act as either conduits of or barriers to groundwater flow.

The difference in hydraulic conductivity of about two orders of magnitude in the deepest wells is likely to make the deep zone behave as an impermeable boundary in relation to the upper zone. However, the values of hydraulic conductivity in the 30-m wells are similar to values calculated for wells in the area that are even shallower. This finding indicates that the lower boundary of the "shallow" aquifer is gradational and may extend to depths of 30 m or more, depths greater than earlier expected.

Particle Transport in Fractured Medium Provides Evidence of Multiple Flow Paths

L. E. Toran, J. E. Nyquist,* and A. V. Palumbo

We have studied the effects of fractures on microparticle transport in laboratory sand columns. This research has implications for predicting the role of fractures in contaminant transport, for understanding the influence of microbial transport in bioremediation of contaminated aquifers, and for studying the transport of other microparticles (such as colloids) in porous media.

We designed laboratory sand columns that can include 1-mm-diam tubes to simulate fractures. We injected 1- μ m-diam fluorescent microspheres and a conservative salt tracer both into columns with tubes and into columns without tubes. The output concentration of these tracers is measured as a function of time to obtain a breakthrough curve.

The presence of the tubes provided evidence of multiple flow paths in the column. One flow path involves travel through the matrix alone, whereas other flow paths involve travel through both the matrix and the tubes. When transport occurred through the matrix alone, the quantity of microspheres transported was much lower than when tubes were present. Multiple breakthrough curves for the microspheres were produced when transport through the matrix was almost completely inhibited by chemical sorption. These results are shown in Fig. 15. We hypothesize that these breakthrough curves reflect different lengths of travel through the matrix, with most of the flow path going through the tubes. In most experiments, the microspheres traveled faster than the conservative tracer. The faster travel time is probably caused by filtration of the microspheres in the matrix and by exclusion of travel at the slower velocities in the matrix. However, neither dispersion nor porosity was significantly higher in the "fractured" system than in the "unfractured" system.

Our research using artificial fractures in laboratory sand columns suggests that fractures can significantly increase transport of microparticles and that microparticles may provide additional information about pathways of transport through fractures, information that is not available from soluble tracers alone.

*Health and Safety Research Division, ORNL.

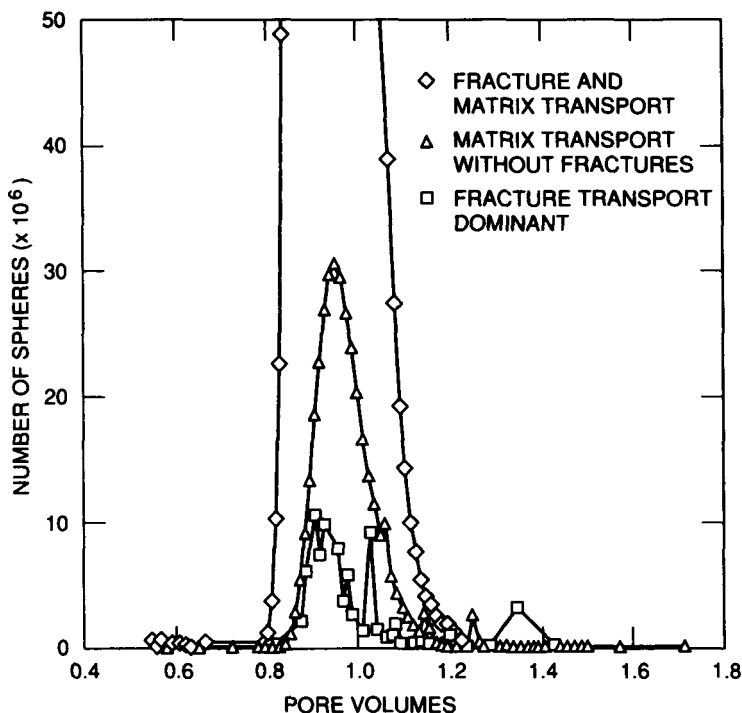


Fig. 15. Breakthrough curves (number of spheres output from the column as a function of time, in pore volumes) for three experiments. The largest breakthrough is obtained for transport through both fractures and the matrix. A smaller breakthrough curve is obtained for matrix transport alone. A spiky breakthrough curve is obtained when matrix transport is inhibited (by chemical sorption) and flow is through multiple fracture pathways.

Arsenic Contamination of Groundwater Is Investigated

N. E. Korte

Groundwater at a midwestern federal facility contains arsenic in concentrations up to seven times the drinking water standard of 0.05 ppm. Extensive employee interviews and records searches, however, have revealed no potential sources of arsenic. Indeed, the arsenic occurs in a complex yet regular pattern that may be indicative of a natural rather than an anthropogenic source. An investigation to explain the presence of arsenic is under way. Elements of the investigation include a review of the site's hydrogeology, a statistical evaluation of the groundwater data, a thorough search of the literature, a study of the site's redox characteristics, and an assessment of possible biological transformations.

The relationships of arsenic with TOX (total organic halogen), sodium, calcium, iron, sulfate, pH, specific conductance, alkalinity, dissolved oxygen, and manganese were examined through the use of statistical techniques. The results showed no significant correlations with any combination of variables. Similarly, ratios of arsenic III/arsenic V were not consistent across the site. Of two methods used to determine the arsenic III/V ratios, one method indicated the possibility of organically bound arsenic. Because arsenic can be mobilized in the environment by biological activity, groundwater samples are being analyzed for organic arsenicals. Arsenic species are being separated by liquid chromatography and analyzed by conventional means.

A review of the site's geology revealed that certain subsurface soil samples show an unusual assemblage in which a dark green reduced clay is stained with an oxidized iron oxide. The iron oxide has been tentatively identified as limonite. Chemical analyses, however, have shown that the specimens vary considerably in both iron and arsenic content. X-ray analyses are being performed to determine the actual identity of these minerals.

This investigation has demonstrated that arsenic is not maintained in solution by any of the parameters routinely measured in the groundwater and its presence cannot be explained on the basis of redox behavior. Rather, the observed high concentrations of arsenic appear to be related to the heterogeneous nature of the alluvium at the site. The possibility that biological reactions are a contributing factor is also being examined.

A Finite Element Model of Air Flow Through Porous Media (FEMAIR) Has Been Developed

G. T. Yeh and D. K. Solomon

The occurrence of gaseous subsurface contaminants such as volatile organic compounds and radon has been widely recognized. Under most natural conditions, only small pressure gradients exist, and thus molecular diffusion has generally been considered to be the primary mechanism for transporting gases in the subsurface. A variety of remediation techniques for subsurface gaseous contaminants have been proposed, including soil venting systems in which subsurface gases are drawn toward a well point under the influence of an applied vacuum. Under such conditions, advection due to pressure gradients can become the dominant transport mechanism.

To investigate the advective flow of subsurface gases toward a withdrawal well, FEMAIR, a finite element model for air flow through a porous medium, has been developed. The computer model solves the equations governing the flow of a compressible fluid in a porous medium by using the Galerkin finite element method. Time derivatives are estimated with finite differences. The fluid is assumed to obey the ideal gas law and to be isothermal throughout the region of interest. Both steady state and transient simulations are possible. The principal output includes the pressure field, velocity field, and boundary fluxes at any point in time or at steady state.

The model is capable of simulations using complex geometries, heterogeneous and anisotropic media, and spatially and temporally distributed sources and/or sinks. A variety of boundary conditions are allowed, including Dirichlet and Cauchy boundaries, both of which can be time dependent. Either a cartesian or a radial coordinate system can be used, and the region of interest can be discretized into quadrilateral as well as triangular elements. Time derivatives can be approximated with either Crank-Nicolson central differences, backward differences, or mid-differences, and the nonlinear matrix can be estimated with exact relaxation, underrelaxation, or overrelaxation. Although only a two-dimensional version is currently available, the conversion to three dimensions is relatively simple.

The model was used to simulate radial flow to a 0.5-m-diam withdrawal well in a sandy formation with an intrinsic permeability of 10^{-11} m². A water table located 15 m below land surface was assumed to represent a no-flow boundary, whereas a constant pressure (Dirichlet) boundary was assumed to exist along the land-surface boundary. The well was assumed to be screened from 6 to 18 m below land surface, and a total withdrawal rate of 0.12 m³/s was simulated. Pressure contour plots are shown in Figs. 16a and

16b for the assumed conditions. The model predicts a maximum pressure drop of about 11.10 kPa near the screened portion of the well. The radius of influence of the well was observed to be about 20 m as a pressure drop of only 0.09 kPa was computed at this distance. Because the conductance of a compressible fluid through a porous medium decreases as pressure decreases, it is possible to reach a point of diminishing return at which large decreases in pressure at the withdrawal well result in only small increases in the gas flux.

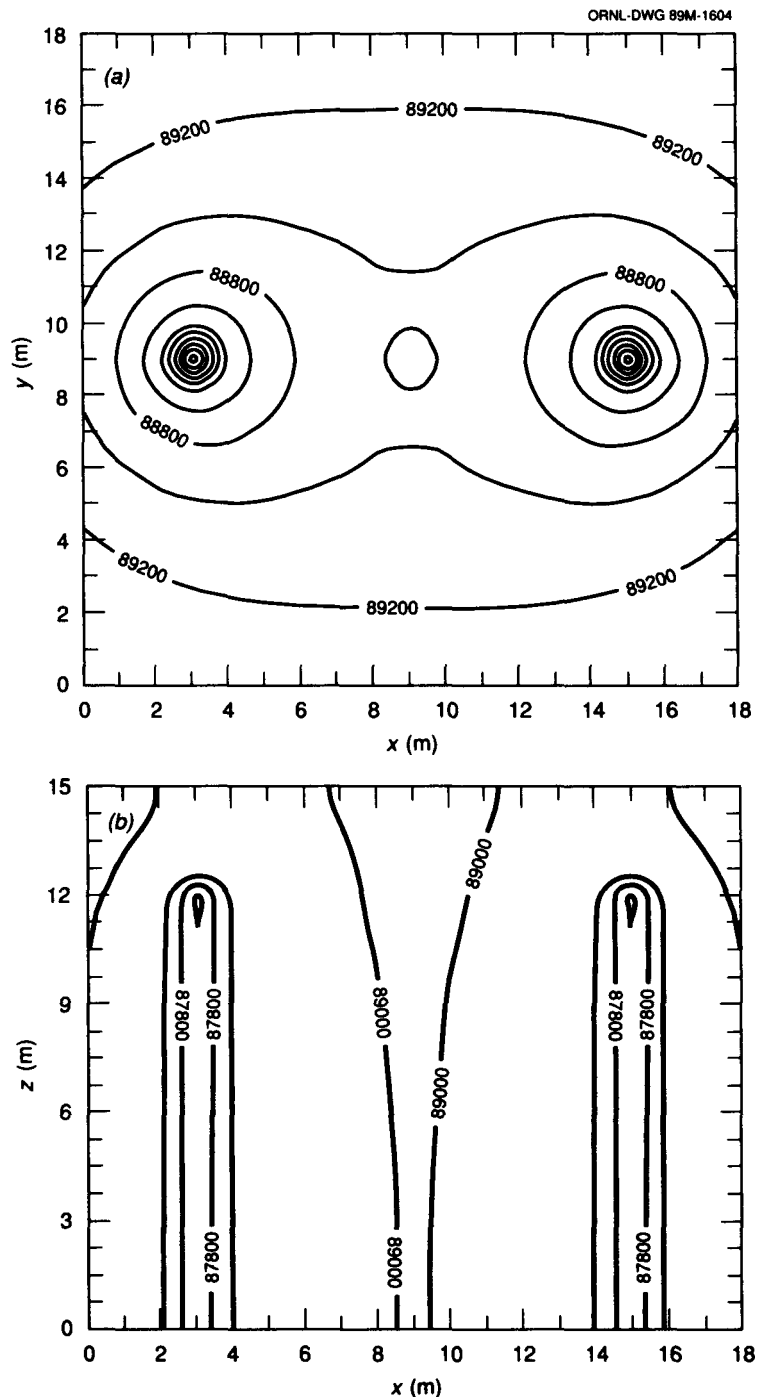


Fig. 16. Pressure contour plots through the center of two screen wells with venting rates of 7.72×10^{-2} kg/s. (a) Plot on the x-y plane, (b) plot on the x-z plane.

Predicting the flow of gases toward withdrawal wells is essential for designing efficient remediation techniques. For example, at Hill Air Force Base in Utah, FEMAIR is currently being used in a project demonstrating in situ soil venting. The results of the model were critical for determining the locations and pumping rates of monitoring wells. Because more than 1000 sites contaminated by volatile organic compounds have been identified by the Air Force alone, the model should be extremely valuable in the future.

An In Situ Technique Is Developed for Measuring Soil-Gas Diffusivity

P. M. Kearl, T. A. Kronk,* and N. E. Korte

Attention has recently been focused on the role of the unsaturated zone in the storage and transport of hazardous waste. At hazardous waste sites, it is common to find unsaturated zone monitoring as part of an early warning system to detect contamination of groundwater. Subsequently, soil-gas surveys are being used to define the extent of a groundwater plume at sites where groundwater contamination has already occurred.

Under isothermal conditions, gaseous diffusion is expected to be the major mechanism for vapor transport because vapor-phase diffusion coefficients greatly exceed those for the aqueous phase. By measuring vapor transport, it is possible to predict the rate of movement of contaminants in the unsaturated zone and to select the proper sampling depths and locations for soil-gas surveys. Quantification of vapor transport rates, however, is still limited.

This study presents a method of measuring the diffusion coefficients of selected organic gases in an uncased borehole. ORNL has developed and licensed a device called an I-GAS chip, which consists of a chemical substance that is sensitive to a particular contaminant. The heat-conducting properties of the substance are affected by the presence of the contaminant. The change in thermal conductivity is directly proportional to changes in contaminant concentration. This system, in theory, is ideal for performing borehole diffusion measurements. The technique is nondestructive, it pulls no vacuum, and no air is circulated in any way. Only a small amount of heat is applied to the chip to make the measurement. We hope to report actual in situ borehole diffusion measurements within a short time. Unlike earlier methods which remove a portion of the gas to analyze the concentration, this method uses a nondestructive technique to measure the in situ concentration of selected gases.

To calculate the diffusion coefficient by using the in situ measurement data, heat flow equations presented by Carslaw and Jaeger are adapted to describe the boundary value problem of gaseous diffusion from a cylinder having a known radius at an initial concentration (C) into the surrounding porous media at a concentration of $C = 0$.

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Travel Time and Dilution of Spills to White Oak Creek Can Be Estimated with a Forecasting Model

D. M. Borders, B. D. Holcombe, and D. D. Huff

After an abnormal release of radionuclides from White Oak Creek late in 1985, we realized that no predetermined criteria existed for the operation of White Oak Dam under such conditions. Furthermore, contaminant transport and dispersion within the drainage system of White Oak Creek and downstream in the Clinch River were not adequately characterized to support requests for modified reservoir releases by TVA.

To provide a framework for data collection and organization, we selected and used a combination of models to simulate typical spill conditions. The Streamflow Synthesis and Reservoir Regulation (SSARR) model has been used to simulate (1) rainfall runoff and streamflows within the White Oak Creek watershed, (2) water levels and storage volumes in White Oak Lake, and (3) the routing of contaminants from ORNL facilities through stream reaches and White Oak Lake to subsequent release at White Oak Dam. SSARR model output includes discharge and contaminant mass flux from White Oak Dam. To predict the fate of these contaminant releases, TVA's Clinch River dispersion model has been employed to calculate the time of travel and the concentrations of contaminants at downstream locations at the water intakes to the Oak Ridge Gaseous Diffusion Plant and to the city of Kingston. The Clinch River dispersion model utilizes SSARR model output as well as TVA data on reservoir elevations and releases to calculate hourly concentrations resulting from contaminants released at White Oak Dam.

An emergency response casebook of spill scenarios has been developed to facilitate the rapid response and decision making required in the event of an accidental release of contaminants into the surface waters of the White Oak Creek watershed. The casebook contains a summary of expected travel times and dilution factors for spills originating from ORNL facilities. It can be used to evaluate possible courses of action, such as closing the gates at White Oak Dam or requesting modification of release schedules at Melton Hill Dam on the Clinch River. The intent of the guide is to provide a set of basic graphs and quantitative methods to serve as a basis for valid decision making. Figure 17 depicts one scenario for a hypothetical contaminant release from ORNL facilities. Under actual spill conditions, the models will be used to provide the flexibility needed to adapt to changing conditions and to supplement information in the casebook. The scope of the casebook will continue to expand as the models are upgraded and additional scenarios are modeled.

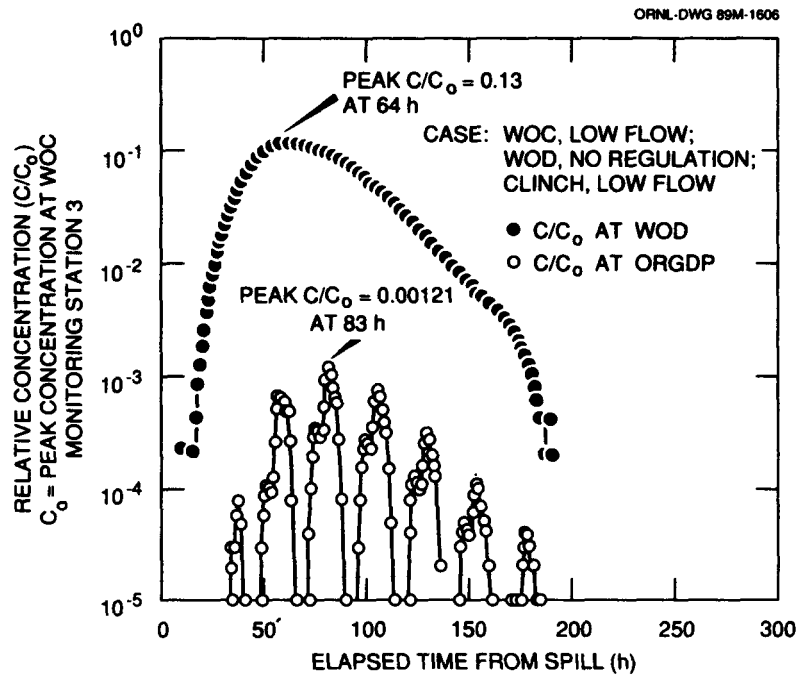


Fig. 17. Relative downstream concentration (C/C_0) of contaminants released from ORNL facilities. Relative concentrations of dissolved materials are shown for White Oak Dam (WOD) and the water intake at the Oak Ridge Gaseous Diffusion Plant site (ORGDP). The contaminant is assumed to enter White Oak Creek (WOC) at a constant rate for a duration of 4 h. The plots represent expected relative concentration vs time since the spill at the WOD and ORGDP sites. The diurnal fluctuations in concentration at the ORGDP site are caused by intermittent power generation at Melton Hill Dam.

1.4 ENVIRONMENTAL TOXICOLOGY

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1.4.1 Introduction

The Environmental Toxicology Section of the Environmental Sciences Division (ESD) is involved in basic and applied research designed to elucidate the mechanisms through which contaminants affect biological systems and the ways in which receiving systems affect the availability and distribution of materials to which they are exposed. Research is conducted from the subcellular and biochemical level to the system level with experimental, observational, and simulation studies. Six groups compose the section and are supported by the Office of Health and Environmental Research of the U.S. Department of Energy (DOE); the U.S. Environmental Protection Agency (EPA); the Electric Power Research Institute; the U.S. Department of Agriculture; the U.S. Department of Health and Human Services; and the remedial action waste disposal projects at Oak Ridge National Laboratory (ORNL), the Oak Ridge Y-12 Plant, the Oak Ridge Gaseous Diffusion Plant, and the Paducah Gaseous Diffusion Plant.

Research in the Toxicological Laboratory Group evaluates the sources of chronic and acute toxicity in wastewaters and streams on the Oak Ridge Reservation (ORR). Development of in situ and laboratory tests for detecting toxicity and elucidating interactions of materials is a major component of this group's activities.

Investigations of the role of molecular, biochemical, and physiological processes that regulate both the accumulation of contaminants and their adverse effects on the environment are conducted in the Biological Chemistry Group. Identification and evaluation of potential biological markers are significant aspects of these studies.

The Physiological Ecology Group is responsible for studies related to the response of vegetation to natural and anthropogenic stresses and the biogeochemistry of contaminants in terrestrial ecosystems. Major emphasis is currently on developing better understanding of the effects that acidic deposition, ozone, and other oxidants have both on individual tree seedlings and on forest stands.

Biogeochemical cycling of contaminants in aquatic environments is evaluated in the Materials Transport and Fate Group. Elucidating the factors controlling contaminant distribution and availability in river reservoir ecosystems is a primary interest. The group is also responsible for ORR's off-site RCRA (Resource Conservation and Recovery Act) Facilities Investigation activities.

18. Selma University, Selma, Alabama.

19. University of Mississippi, University.

The Biological Monitoring and System Recovery Group studies the ORR streams and their response to various waste management and cleanup activities. Long-term monitoring of the biota and evaluation of mechanisms affecting the recovery of the systems are the foci of the effort.

The Environmental Toxicology Modeling Group is developing capabilities for predicting the direct and indirect effects of contaminants released to the environment. Simulation modeling and mathematical tools are used by this and other groups in forecasting the fate and effects of contaminants in the environment.

The following pages contain selected summaries that reflect ongoing efforts of the past year. Four focus on physiology, and three discuss toxicity testing and demonstrate the utility of bioassays in compliance monitoring. The remaining summaries highlight activities in the other four groups. They focus on the utilization of radionuclides to track contaminants in riverine systems, on the development of biomarkers as indicators of exposure and environmental health, and on the use of models for investigating recovery of ecosystems.

1.4.2 Technical Summaries

Stable Carbon Isotope Discrimination ($\delta^{13}\text{C}$) in Loblolly Pine Reveals Cumulative Influence of Ozone on Water Use Efficiency Under Field Conditions

G. E. Taylor, Jr., C. A. Gunderson, N. T. Edwards, and R. L. Coffey*

Whereas the atmospheric value of $\delta^{13}\text{C}$ is -8 per mil, that of most terrestrial plants ranges from -22 to -34 per mil. The more negative $\delta^{13}\text{C}$ values in vegetation are a consequence of the physicochemical discrimination against the heavier $\delta^{13}\text{C}$ isotope in the process of foliar carbon assimilation at the atmosphere-canopy interface. Given the relationship between stomatal conductance and CO_2 assimilation, a comparison of $\delta^{13}\text{C}$ values can reveal subtle differences in water use efficiency, a critical physiological indicator of a plant's ability to acquire and efficiently utilize water and carbon resources. Although patterns of $\delta^{13}\text{C}$ values have been used to investigate a variety of more basic issues in the plant sciences, their application to air pollution issues is fragmentary and limited to studies in highly controlled environments.

The objective of this research was to characterize the pattern of $\delta^{13}\text{C}$ values in loblolly pine (*Pinus taeda*) seedlings grown under field conditions and exposed to different levels of O_3 for two continuous growing seasons. The project investigated how the physiology and growth of woody plants are influenced by interacting stresses of natural (e.g., drought and nutrient limitations) and anthropogenic (e.g., O_3 and acidic precipitation) origin. It is a component of the EPRI-sponsored Response of Plants to Interacting Stresses program.

In the loblolly pine seedlings grown under field conditions, two statistically significant patterns in $\delta^{13}\text{C}$ values emerged. First, as the needles increased in age (0 to 2 years), the mean $\delta^{13}\text{C}$ rose from -24.86 per mil to -28.16 per mil (Fig. 18a). Second, as the O_3 concentration increased (from 21 ppb to 87 ppb, 7-h seasonal mean), the mean $\delta^{13}\text{C}$

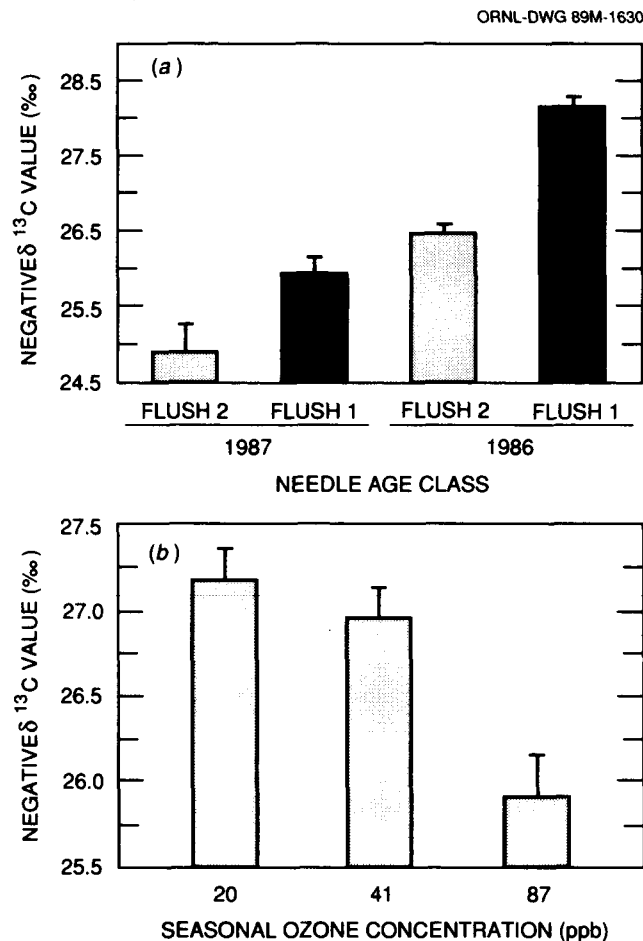


Fig. 18. Ratio of ^{13}C to ^{12}C in *Pinus taeda* foliage ($\delta^{13}\text{C}$ value) as a function of (a) needle age class and (b) seasonal O_3 concentration.

became less negative by +1.20 per mil (from -27.15 per mil to -25.95 per mil) (Fig. 18b). The $\delta^{13}\text{C}$ values did not differ for plants grown in ambient or in charcoal-filtered air. The most pronounced shift in $\delta^{13}\text{C}$ as a function of O_3 treatment was in the youngest needle age class (+2.39 per mil). In conjunction with more intensive studies of stomatal physiology and CO_2 assimilation, these results indicate that exposure of loblolly pine under field conditions to above-ambient levels of O_3 results in foliage being more efficient in water use. A corollary of this observation is that seedlings grown in ambient or charcoal-filtered air are more susceptible to chronic-level drought stress than plants grown in air with elevated O_3 levels.

It is hypothesized that the O_3 -mediated shift in $\delta^{13}\text{C}$ values is a consequence of the pollutant's effects on both stomatal physiology and net CO_2 assimilation. The direction of the shift suggests a greater effect on stomatal physiology than on CO_2 assimilation. This research is unique in its application of carbon isotope techniques to realistic air pollution studies under field conditions using long-lived woody plants. The results confirm the utility

of the technique as an indicator of physiological activity and offer insights into mechanisms of action underlying cumulative O₃ effects on forest trees.

*Roane State Community College, Harriman, Tennessee.

Fractures and Ionic Strength Are Critical Parameters in Determining the Extent of Transport of Bacteria in the Subsurface

A. V. Palumbo and L. E. Toran

We have developed methods for examining the effect of fractures on the transport of bacteria in aquifers. Understanding bacterial transport is a factor in planning in situ bioremediation of contaminated aquifers. Bacteria have been documented to move long distances, up to 1 km; however, published transport models and our own laboratory experiments with sand columns have indicated that even in porous sand the bacteria will be rapidly filtered out and penetration will only extend a few centimeters. In our experiments we used fluorescent latex microspheres of uniform size as surrogates for bacteria and confirmed that sand alone, in the absence of any heterogeneity, was so efficient at removing the bacteria-sized particles during transport that the influence of fractures may dominate over varied mineralogic composition.

Nutrient status will affect both the physical and chemical interactions between the bacteria and the particle surfaces and the surface characteristics (e.g., charge and size of the bacteria). In our experiments, increasing ionic strength significantly reduced particle transport; such reduction could be important in bioremediation efforts because added nutrients could increase ionic strength. We found a high degree of filtration when we used water with an ionic strength typical of groundwater (virtually none of the particles came out of the columns). This finding prompted us to develop techniques to examine the distribution of the retained particles in the soil columns and to determine filtration coefficients. We measured lower retention rates in water of lower ionic strength. Encouraged by these results we decided to look more closely at fracture heterogeneity and ionic strength rather than at soil composition.

Quantification of the effect of fractures has been hampered by an inability to determine the degree of fracture flow in intact soil columns and by a lack of techniques to introduce fractures of known size and density into packed columns. To redress this problem we designed sand columns that included 0.2-mm-diam tubes in the packed sand to simulate natural fractures. These tubes are analogous to fractures that would create preferential low-reactivity flow paths. Although >95% of the microspheres were trapped, a breakthrough curve was detected. Our preliminary results indicate that in the presence of fractures the particles elute slightly faster than chloride (retardation is <1) whereas in homogenous packed columns the retardation is >1. Thus, the particles which are transported out of the columns containing fractures actually moved faster than the bulk of the water.

This research has implications for calculating parameters to predict the effectiveness of bioremediation and for understanding the effects that aquifer properties (e.g., degree of

fracturing) have on the distribution and transport of bacteria. Future efforts will focus on how the fracture characteristics (e.g., diameter, length, and density) and nutrient status, through changes in ionic strength and microbial characteristics, affect the transport.

Water-Use Efficiency of Tree Seedlings Is Increased by CO₂ Enrichment of the Atmosphere

R. J. Norby and E. G. O'Neill

The increasing concentrations of CO₂ and other radiatively active trace gases in the atmosphere are predicted to cause changes in the climate of the earth. Increasing air temperatures and changing precipitation patterns in forest ecosystems will alter the availability of soil water for tree growth. Analyses of the effects of climate change on tree growth need to include the possibility that the direct effects of elevated concentrations of CO₂ will interact with the responses of trees to other environmental resources, including water.

The interaction between CO₂ and water at the individual plant level can be analyzed by using the criterion of water-use efficiency (WUE), the ratio of carbon gain to water loss. We have measured WUE of tree seedlings grown at different levels of atmospheric CO₂ concentration as part of our studies on interactions between CO₂ and other environmental resources. Seeds of white oak (*Quercus alba*) and yellow-poplar (*Liriodendron tulipifera*) were planted in pots containing forest soil, and the seedlings were grown for 6 months in controlled-environment chambers containing ambient CO₂ (~350 ppm) or elevated CO₂ (500 and 800 ppm). The water use of the plants was determined gravimetrically, and the dry matter accumulation was estimated from nondestructive measurements of plant size. Whole-plant WUE (grams of dry matter per liter of water) as a function of CO₂ and time was derived for each plant. Concurrently, instantaneous WUE was measured by analysis of foliar gas exchange and calculation of the ratio of photosynthesis to transpiration of individual leaves.

Whole-plant WUE increased with increasing CO₂ concentration in both species. In the white oak experiment, for example, WUE was 6.3 g/L in ambient CO₂, 9.6 g/L at 500 ppm, and 11.5 g/L at 800 ppm CO₂. This effect of CO₂ on WUE resulted from a combination of increased plant growth in high CO₂ and slightly reduced water use. The physiological basis for the increased growth rate was a stimulation of photosynthetic rate; the relative amount of leaf area, which represents the assimilatory capacity of the plant, decreased slightly. Had the leaf area ratio also increased with increasing CO₂, the ultimate growth stimulation would have been greater, but the significant increase in WUE might not have occurred.

Increased water-use efficiency may be ecologically important in conferring greater drought tolerance to trees, but to test this idea we need methods to measure WUE of forest trees. Our measurements of instantaneous WUE, which were relatively easy to obtain, predicted the comparable longer-term, whole-plant responses well. Extrapolation from foliar gas exchange data may be possible when whole-plant WUE cannot be measured directly. Such extrapolation will greatly improve our ability to evaluate how elevated CO₂ affects the responses of forest trees to changing water resources.

Ectomycorrhizae and Endomycorrhizae Respond Differently to Elevated Atmospheric CO₂

E. G. O'Neill and R. J. Norby

Under projected levels of atmospheric CO₂ enrichment, increases in biomass in unmanaged forests may depend upon enhanced nutrient uptake through the indirect effects that CO₂ has on mycorrhizae (a root-fungus symbiosis). All tree species form mycorrhizae. The symbiosis is usually one of two types, ectotrophic or endotrophic. Ectomycorrhizae are found on all coniferous species and some hardwoods; endomycorrhizae colonize hardwoods and most herbaceous plant species. In both associations, the fungal partner depends upon host photosynthate as a carbon source and, in return, extends a network of fungal hyphae into the soil, thus facilitating tree nutrient uptake. It is hypothesized that, by increasing photosynthesis and carbon translocation, elevated CO₂ indirectly stimulates formation of mycorrhizae and thus increases nutrient uptake.

Using controlled environment exposure facilities in the Plant Sciences Laboratory, we conducted experiments with ectomycorrhizal shortleaf pine and white oak seedlings. Mycorrhizal infection increased when seedlings were grown at 700 μL/L, and the initial carbon sink caused by mycorrhizal establishment appeared to be offset by increased carbon availability. Comparable studies using an endomycorrhizal species (yellow-poplar) showed no change in mycorrhizal colonization.

Responses of the two mycorrhizal types may differ because fungal carbon demand and sink strength vary as a result of different morphology and carbon physiology. Ectomycorrhizae and endomycorrhizae differ in carbon storage forms and in the amount and type of fungal biomass produced in the symbiosis. The size and activity of the hyphal network in the soil, critical to nutrient uptake, may also differ between the two groups and vary within species. Results suggest that ectomycorrhizae are carbon-limited at ambient CO₂, whereas endomycorrhizae are not.

It is important to determine the extent to which mycorrhizal activity in both groups contributes to tree growth at elevated CO₂. To that end, experiments are being developed to measure activity and carbon cost of both mycorrhizal types at elevated CO₂. Because forest trees are dependent upon mycorrhizal symbiosis, a difference in response by ectotrophic or endotrophic species to long-term environmental change may have implications for global carbon cycling and for competition, succession, and species survival under enriched CO₂ conditions.

Interpretation of Fish Response to Acidification Stress Can Differ Depending on Whether Individual or Integrated Biochemical Responses Are Considered

S. M. Adams

Increased acidification of freshwater ecosystems in certain regions of North America has become a serious environmental problem in recent years. Many freshwater systems in acid-sensitive regions have experienced adverse changes in their biota, including disappearance of or major alterations in fish communities. Capabilities are needed for identifying

short-term sublethal responses of fish to acidification stress before adverse effects occur in fish populations or communities. Losses of fish populations from some systems have been attributed to acidification episodes occurring when pH decreases rapidly during rainstorm or snowmelt events. The biochemical and physiological responses that occur in fish during such episodic events should provide early-warning signals of the potential for more severe responses, such as mortality, reduction in growth, or decline in reproductive success. The principal objectives of this research were to (1) investigate the sublethal responses of rainbow trout to varying durations of reduced pH and (2) identify those individual biochemical variables and integrated biochemical conditions that best reflect chronic responses of rainbow trout to acidification stress.

Adult rainbow trout were exposed to pH 4.5 for periods of 6 to 96 h in the laboratory through the use of an automated pH controller system. During experiments the pH in each of five separate tanks was reduced from ambient to pH 4.5 in 2 h then maintained at this level for periods of 6, 12, 24, 48, or 96 h. For each of these five experimental durations, control tanks were maintained at the ambient pH level. At the termination of each experiment, blood samples were taken from each fish, and ten biochemical variables were measured on each sample.

Measurements of electrolyte homeostasis (serum sodium), carbohydrate metabolism (serum glucose), lipid metabolism (triglyceride), and amino acid metabolism (SGOT) proved to be the best indicators of individual biochemical responses of trout to reduced pH. The integrated biochemical response of the trout, as determined by a canonical discriminant analysis procedure, indicated that some adaptation or recovery occurred after 12–24 h of exposure to reduced pH (Fig. 19). This recovery response was not evident from the various biochemical parameters considered individually.

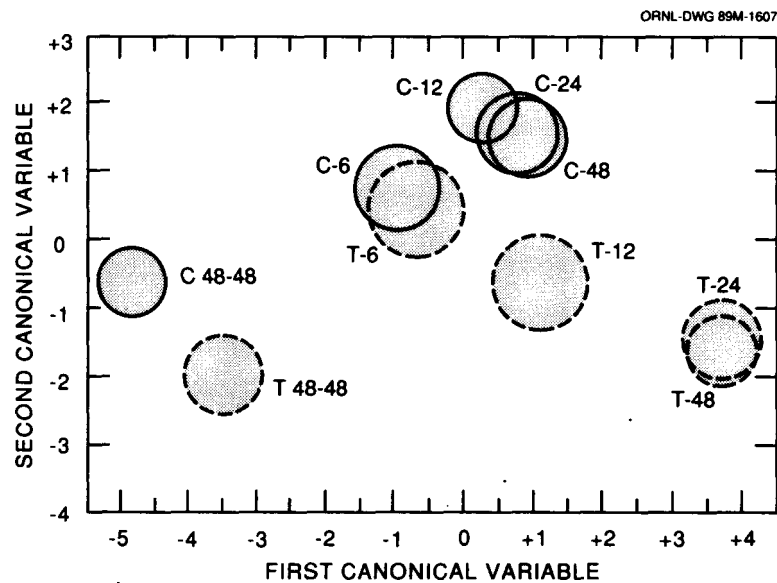


Fig. 19. Segregation of integrated biochemical groups by discriminant analysis. Circles represent the means and the 95% confidence radii of control fish (solid circles) and test fish (broken circles). Numbers within circles are the number of hours the fish are exposed to pH 4.5, with the 48–48 category representing 48 h of exposure followed by 48 h of recovery.

This study is the first to demonstrate that interpretations of fish response to reduced pH can differ, depending on whether individual or integrated biochemical responses are considered. A principal implication of this finding is that individual biochemical variables in themselves may provide limited insight into the effects of environmental stress on growth, reproduction, or success of populations. Investigations that emphasize integrative or multiple biochemical and physiological response measures may provide more meaningful indicators of the effects of ecological stress at higher levels of biological organization.

Red Spruce Growth and Photosynthesis Are Lower and Tissue Aluminum Concentrations Are Higher at High Elevations in the Great Smoky Mountains

C. P. Andersen* and S. B. McLaughlin

High- (1935-m) and low- (1720-m) elevation sites on Clingman's Dome showing different degrees of red spruce (*Picea rubens* Sarg.) decline were selected to characterize physiological factors associated with slow growth of saplings and mature trees at the high site. The research strategy was to document the magnitude of growth changes at the two sites and to explore the physiological basis of observed differences. Analysis of data collected during the first field season is nearly complete, and several differences between sites and seasonal trends reflecting growth strategies have been identified.

Photosynthesis of current year foliage (per gram) ranged from 20 to 40% greater in saplings at the low site in comparison with those at the high-elevation site. Dark respiration was less at the low site, resulting in more favorable carbon balance at the lower site. Greater chlorophyll concentrations at the low site were at least partially responsible for the increased photosynthesis rates. Seasonal changes in photosynthesis were similar at both sites, being lowest in July following shoot elongation and highest in August. High-site saplings retained a larger proportion of ¹⁴C-labeled photosynthate in current and 1-year-old foliage than saplings at the lower site in June, prior to maximum shoot elongation. Additional branches were labeled in August and September, and samples are currently being processed.

Pressure-volume analysis, a measure of plant response to drought, showed that in July saplings at the high-elevation site had lower (more negative) saturated osmotic potentials than those at the low-elevation site, a typical response to water stress. Differences between sites were not significant in August and September. In October and November, saplings at the lower site showed 47% greater solute accumulation (osmoles per kilogram dry weight) than saplings at the high site, possibly reflecting a delay in the physiological changes associated with induction of cold hardiness at the high site. In February, measurements showed a greater degree of desiccation at the high-elevation site than at the low-elevation site.

Nutrient analysis of foliage indicated that phosphorus and calcium concentrations were 26 and 30% lower at the high-elevation site, while aluminum concentrations were ~56% greater at the high site. Increased tissue aluminum at the high site reflected greater soil aluminum concentrations (nearly twofold) present in the upper 15 cm of soil.

The observed differences in growth and physiology at the two sites suggest that chronic, system-level differences are present throughout the year. Physiological evidence of episodic disturbance events (such as gaseous pollutants) has not been observed. Our data, together with information from related studies of soil solution and tree ring chemistry, suggest that high aluminum availability may be a cause of the observed differences in growth at the two sites. During the second field season, additional sites will be established at several elevations to further characterize red spruce growth and physiology.

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Red Spruce Growth, Chlorophyll Concentrations, and Tissue Osmotic Potentials Are Lower at High Elevations in the Great Smoky Mountains

C. P. Andersen* and S. B. McLaughlin

Field and laboratory studies are under way to characterize physiological changes associated with the decline of red spruce (*Picea rubens* Sarg.) at high elevations in the Great Smoky Mountains National Park. The research strategy is to document the magnitude of growth changes at sites experiencing varying degrees of growth decline and to explore the physiological basis of observed differences. The objective of this approach is to evaluate likely mechanisms of action and identify natural and anthropogenic factors influencing the observed growth patterns. Two research plots have been characterized on Clingman's Dome (5650-ft and 6350-ft elevations), and several growth and physiological characteristics are being measured on both mature trees and saplings.

Growth-ring analysis of mature red spruce shows a decline in radial growth during the last 20 years on the upper-elevation site. Radial growth decline is less severe at the lower site, where it appears to be restricted to the last 5 years. Dendrometer bands were installed on ten dominant spruce on each site to follow radial growth trends throughout the season. Periodic measurements showed growth increasing through June, followed by diurnal and biweekly fluctuations corresponding to changing evaporative demands and precipitation events, respectively. Growth analysis of saplings on each site revealed that, during the last 5 years, growth at the lower elevation site was greater than that at the upper elevation site even though canopy coverage is greater at the lower site. Chlorophyll concentrations per unit weight of foliage were higher in seedlings at the lower site, consistent with observations about growth. Measurements of the CO₂ exchange rate and ¹⁴C photosynthate partitioning are currently being analyzed and are expected to reflect the growth trends.

Pressure-volume analysis of current-year tissue revealed that saplings at the upper elevation site had lower saturated osmotic potential in July than saplings at the lower site, a condition typically associated with drought stress. Differences between solute accumulations at the two sites diminished throughout the summer and were not significant in late September. During July and August, saplings at the upper site also maintained cell turgor at lower relative water contents. Saplings did not show any increase in solute accumulation as late as September 29 in response to decreasing fall temperatures.

This study represents the first attempt to characterize spruce physiology at high elevations in the field. Although a majority of the first-year data is still being analyzed, the preliminary results suggest that spruce growth and physiology differ considerably at the 5650-ft and 6350-ft elevations. The next critical step is to fully characterize the magnitude of these differences and to formulate testable hypotheses on the role that natural and anthropogenic factors play in their development.

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Response of Aquatic Ecosystems to Toxicant Stress Is Being Predicted

H. L. Boston, A. J. Stewart, A. R. Johnson, and S. M. Bartell

The task of regulating harmful chemicals in the environment is currently limited by the lack of both a conceptual understanding and the appropriate tools for forecasting risk at the ecosystem level. The objective of this research is to develop procedures for incorporating ecosystem-level behavior into models used by the U.S. Environmental Protection Agency for forecasting ecological risk.

Ecosystems are intact functional units, and the behavior of large-scale properties cannot be predicted from the behavior of subunits. Models that predict ecosystem response to toxic stress therefore must consider the relationship between the structural and functional aspects of ecosystems and ecosystem stability. Stability concepts (resilience and resistance) provide a theoretical basis for predicting and measuring dynamic ecosystem responses to and recovery from toxicant stress. Resistance and resilience are related to the patterns of energy and material flux through the biotic and abiotic components of a system (i.e., the rate structure). Scaling system responses to the rate structure should allow comparisons between different ecosystems.

These efforts rely on an integration of manipulative experiments in tractable but highly interconnected systems and on ecosystem modeling. Our approach is to (1) characterize a system and determine the rate structure (e.g., rates of primary and secondary production, rates of nutrient cycling, and numbers and composition of grazing invertebrates); (2) modify models to reflect system structure and function and then use these models to predict system response to toxicant stress; (3) expose the system to a toxicant; and (4) measure responses to evaluate hypotheses, modify models, and identify parameters that describe system state and predict the relationship between the rate structure and the response. System responses (changes in process rates and biotic structure) are evaluated in relation to the rate structure of unperturbed reference systems. State space analysis and system correlation structure, used as additional tools for evaluating ecosystem response, provide alternate ways of describing system dynamics and thus facilitate the incorporation of ecosystem-level behavior into risk assessment methodology.

A mixture of phenolic compounds is being added to a series of small ponds in a temporally staggered sequence to take advantage of the seasonal changes in ecosystem rate structure (i.e., seasonal shifts from top-down to bottom-up control of energy flow) in determining ecosystem response. Repeated additions of toxicants allow us to evaluate the influence of exposure history. Streams with differing rate structures (chosen according to

differences in primary production, heterotrophy, nutrient inputs, and grazing pressure) will be exposed to acute doses of chlorine during summer and fall, when the rate structures differ. An ultimate goal is to develop scaling rules to extend the predictive power from these small systems to larger, more complex systems.

These studies began in mid-1987 and are currently funded for 3 years. Preliminary results will be available in mid-1988.

Ambient Toxicity Tests Require Nonstandard Statistical Approaches

A. J. Stewart and L. M. Adams

The environmental compliance programs for ORNL, the Oak Ridge Y-12 Plant, and the Oak Ridge Gaseous Diffusion Plant include Biological Monitoring and Abatement Programs (BMAP), under which studies are conducted to evaluate the ecological effects of plant operations on aquatic biota. The BMAP for each plant includes as a key task assessments of ambient toxicity. In this task, water samples from local streams are taken to the laboratory and tested with fathead minnow larvae and a microcrustacean (*Ceriodaphnia*). The tests allow the animals to integrate, for 7-d periods, water quality factors of biological importance. Responses of the animals (survival and growth of the minnows and survival and fecundity of *Ceriodaphnia*) must then be analyzed statistically to quantitatively describe plantwide patterns of ambient toxicity.

Analysis of variance with a posteriori procedures (e.g., Dunnett's test) is commonly used to evaluate biotest results to establish toxicity-based discharge criteria for or compliance of wastewater treatment facilities. However, because few large-scale field studies of ambient toxicity have been conducted, statistical approaches best suited for analyzing ambient toxicity data are unknown. Data from the ambient toxicity component of the ORNL BMAP allow insight into this question.

The ambient toxicity data base for ORNL includes 12 monthly tests of 15 sites. Inspection of the tests' chronic endpoints (growth of the minnows and fecundity of *Ceriodaphnia*) showed little evidence for chronic toxicity at any site. Additionally, the test endpoints (survival, growth, and fecundity) did not correlate with one another. However, total mortality of test animals occurred several times at some sites, showing that these sites suffered episodic bouts of acute toxicity. Analyses of survival showed that parametric tests tended to obscure spatial patterns of toxicity. Bootstrap simulations to detect underlying frequency-distribution curves of test outcomes showed that "bad" sites (i.e., sites where toxicity was evident according to the mean survival of the minnows and/or *Ceriodaphnia*) had bimodal distributions: some tests showed strong evidence of toxicity, but others showed no toxicity. In contrast, tests of "good" sites had outcomes that were distributed unimodally. The 15 sites ordinated well on axes of mean survival versus relative variability ($r = -0.90$ and -0.93 for the fish and *Ceriodaphnia*, respectively; $n = 15$ each). Finally, minnow survival on day 4 of a test was strongly correlated to survival on day 7 ($r = 0.83$, $n = 175$). Collectively, the findings show that (1) episodic events are important in controlling ambient toxicity at ORNL; (2) the toxicity detected was acute, not chronic; and (3) procedures that detect and use differences in degree of skewness or time-specific statistical approaches may be useful for field ecotoxicological analyses.

The International Biospheric Model Validation Study Successfully Uses Data from Chernobyl Accident to Test Model Predictions

F. O. Hoffman, B. G. Blaylock, M. L. Frank, A. J. Schaffroth, and G. G. Killough*

Since October 1985, members of ESD have been consultants to and active participants in an international initiative to test and evaluate the predictive accuracy of mathematical models used for environmental radiological assessment. This program, known as the International Biospheric Model Validation Study (BIOMOVS), is coordinated by the Swedish National Institute for Radiological Protection and is made up of participants representing 36 organizations and 16 countries. Data have been gathered on ^{131}I and ^{137}Cs in Chernobyl fallout for air, precipitation, vegetation, and milk and meat from 13 sites located throughout the Northern Hemisphere and have been used to develop scenarios for testing model predictions. To ensure a process of blind testing, the groups were not given access to observed data until after model predictions had been submitted to the scenario coordinator. In all, predictions have been received from 23 different models.

The results of this study confirm the conclusions drawn from early efforts that used Chernobyl data for model validation at ORNL. Most models, regardless of their degree of complexity, substantially overestimated actual concentrations of ^{131}I in pasture forage and milk at all but two locations (Fig. 20). This overestimation was related both to the failure of these models to recognize the inverse relationship between the amount of rain and the initial vegetational interception of wet-deposited ^{131}I and the amount of rain and to a lower-than-expected transfer of ^{131}I from the cow's diet into milk. Less overestimation was associated with the predictions of ^{137}Cs in forage, milk, and meat. The most accurate model predictions were those first calibrated to fallout data obtained on-site and then extrapolated to all other locations. RAGTIME87, a time-dependent model initially developed at ORNL, demonstrated accuracy comparable to that of models calibrated to

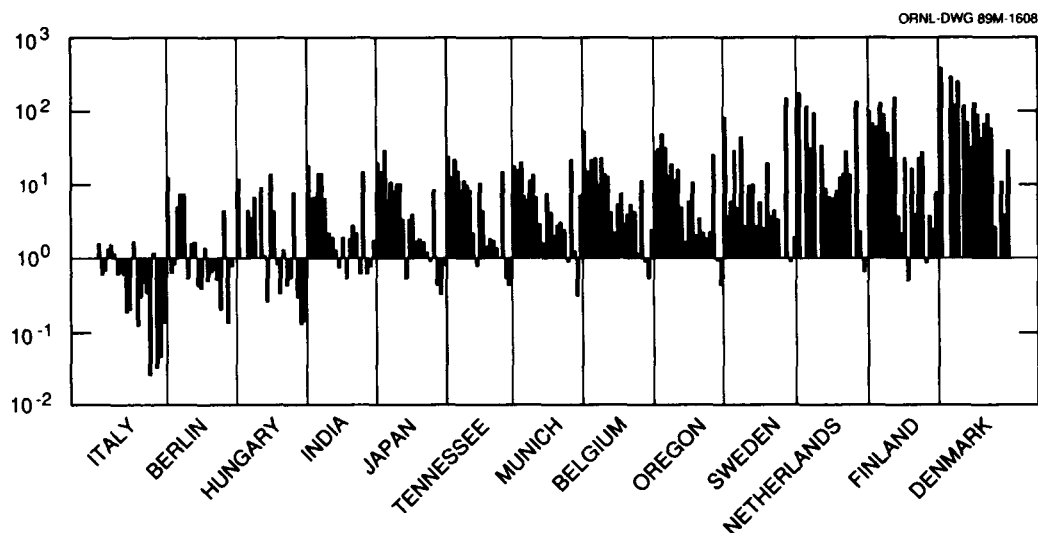


Fig. 20. Time-integrated concentrations of ^{131}I in milk. The bars represent the results of the 21 models for each site. At most sites the concentration was overestimated, sometimes by one or two orders of magnitude.

Chernobyl data (Fig. 21). RAGTIME87, which was not calibrated to Chernobyl data, utilized results from recent ORNL field research on vegetational interception and retention of soluble and insoluble forms of radioisotopes in rain. In solution, ^{131}I is less effectively retained on vegetation during a period of wet deposition than either a reactive cation like ^{137}Cs or insoluble particulates.

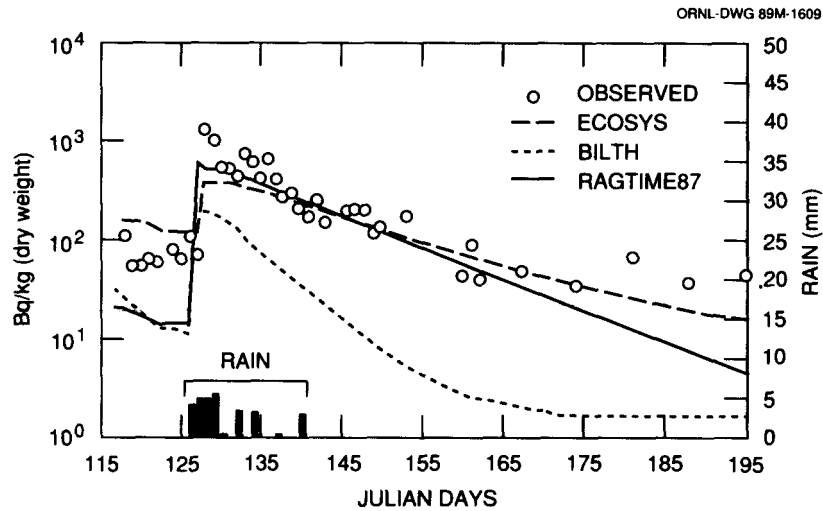


Fig. 21. RAGTIME87 predictions for ^{137}Cs in Denmark forage. These are compared with the results of two models (ECOSYS and BILTH) calibrated to Chernobyl data. Note the effect of rain on the forage concentration of ^{137}Cs .

Once normalized for the time-integrated concentrations in air and the imposed dietary restrictions on grazing animals, the concentrations of Chernobyl ^{131}I and ^{137}Cs showed surprisingly small variability between locations (about a factor of 3). For the two sites where overestimation was not evident, subsequent analyses have identified flaws in the test data for these locations. These results imply that, even if the physical or chemical form of ^{131}I and ^{137}Cs in Chernobyl fallout changed during atmospheric transport from Europe to Asia to North America, such changes did not result in major differences in the deposition of these radionuclides from the atmosphere and in the subsequent transfer of these radionuclides to cow's milk.

The extent to which these results can be used to improve the assessment of future accidental releases of ^{131}I and ^{137}Cs is currently under investigation. Assurances must be given that the ecological behavior of Chernobyl-derived ^{131}I and ^{137}Cs is not unique to the Chernobyl accident. Such assurances are prerequisite to extrapolation of the BIOMOVs results to model predictions of future reactor accidents.

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The Degree to Which Pasture Vegetation Intercepts and Retains Radioactive Materials in Rain Has Been Quantified with Mechanical Rain Simulators

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

In humid climates, wet deposition associated with convective storms is often the dominant mechanism for scavenging particulate substances from the atmosphere. During the summer of 1987, a series of field experiments was conducted for the National Cancer Institute to investigate the degree to which pasture vegetation intercepts and retains soluble and insoluble radioactive materials deposited by rain. These experiments employed mechanical rain simulators to reproduce rain intensities ranging from 0.23 to 2.03 mm/min and droplet sizes similar to those associated with moderate to severe thundershowers. Applications of simulated rain varied from approximately 1 to 30 mm.

Similarities were observed between the initial interception of three size classes of insoluble particles (3-, 9-, and 25- μm -diam polystyrene microspheres) and a reactive cation ($^7\text{Be}^{2+}$). For these substances, approximately 20 to 50% of the total amount of radioactivity deposited in rain was initially intercepted and retained by vegetation sampled above 5 cm of the ground surface. Only minor differences were attributed to the amount and intensity of simulated rain and the type of pasture vegetation sampled. Major differences, however, were noted in the interception of anionic substances ($^{131}\text{I}^-$ and $^{131}\text{IO}_4^-$): the fraction intercepted decreased in almost direct proportion to the amount of rain. In contrast, postdeposition retention showed no differences between the insoluble particles or the cationic substances and the anionic substances when the initial deposits (through rain simulation) were subsequently exposed to natural weathering processes, including natural rain events. Contrary to what one would normally expect, neither the amount of rain nor the growth dilution was identified as an important factor controlling the postdeposition retention of any of these materials.

The extrapolation of these results to other soluble and insoluble substances and to other vegetation types implies that a nonnegligible fraction of material in wet deposition will be intercepted and retained on the vegetation surface at even the highest intensities of precipitation. In addition, the removal of these materials from vegetation will at best be only poorly correlated with the amount of rain falling in events successive to the period of initial deposition. Thus, comparisons of measurements of rain falling through a canopy (throughfall) and measurements of rain falling into a canopy may significantly underpredict the net amount of materials deposited from both wet processes and dry processes. Estimates of dry deposition made by using throughfall measurements are currently based on the assumption that the postdeposition retention of materials deposited by rain is negligible and that successive rainfall will effectively remove all of the materials previously deposited on the plant surface.

Lakewater Chemistry in the Upper Midwest Is Not Affected Extensively by Atmospheric Deposition

R. B. Cook

The glaciated terrain in the Upper Midwest (northern Minnesota, Wisconsin, and Michigan) contains the largest density and diversity of lakes in North America, outside of Florida. Surficial geology is resistant to geochemical weathering, resulting in low concentrations of solutes in lake water. The region receives a gradient in atmospheric deposition, with higher deposition of SO_4^{2-} , NO_3^- , and H^+ in Upper Michigan. However, the levels of deposition are lower than those observed in eastern North America.

The effects of acidic deposition on softwater lakes in the Upper Midwest were assessed from data collected in large-scale synoptic surveys of lakes and data collected during intensive studies of individual lakes. Factors affecting lakewater chemistry in the Upper Midwest include atmospheric deposition; hydrologic lake type; watershed production of cations and dissolved organic matter; and watershed and in-lake retention of nitrate, ammonium, and sulfate. For example, lakewater chemistry exhibits a west-to-east decline in acid-neutralizing capacity and pH, which is the direct result of a west-to-east decline in base cation concentrations and an increase in SO_4^{2-} concentrations. This trend illustrates the importance of the watershed supply of base cations in the west and the increasing atmospheric deposition in the eastern portion of the region. Dissolved organic carbon (DOC) also declines from west to east, reflecting the prevalence of wetlands in the western part of the region. These DOC concentrations and spatial patterns are not consonant with the hypothesis that organic acids cause the low pH in Upper Michigan.

The strong observed relationship between lakewater chemistry and the depositional gradient of sulfate and hydrogen ions is consistent with the hypothesis that atmospheric deposition has a major influence in governing the acid-base chemistry of these lakes. However, paleolimnological investigations of lakes across the region and analyses of historical lakewater chemistry do not suggest that there has been a recent trend in acidification. Because the levels of atmospheric deposition are lower in relation to other regions in eastern North America, the acidification of surface waters in the Upper Midwest is not as extensive as in other regions of eastern North America and has probably amounted to decreases in acid-neutralizing capacity smaller than 10 to 20 $\mu\text{eq/L}$ for the most sensitive lakes.

Accumulation and Retention of ^{137}Cs from ORNL Are Quantified for the Clinch River and Watts Bar Reservoir System

I. L. Larsen, C. R. Olsen, B. L. Kimmel, C. J. Ford,* and K. C. Dearstone

From the late 1940s through the 1960s, a large quantity of fission products was produced and processed at ORNL. Many of these fission products, which included ^{137}Cs (half-life = 30 years), were retained in impoundment basins and became associated with suspended particulate material and the sediments. During periods of large storm events, along with the drainage of White Oak Lake (one of the impoundment basins) in 1956, a

portion of these contaminated sediments was resuspended and transported to the Clinch River and impounded in Watts Bar Reservoir.

In an attempt to quantify the amount of ^{137}Cs that has been retained in the reservoir sediments, approximately 60 sediment cores and 180 surface grab samples were collected and analyzed for their radioactive components. The vertical distribution of ^{137}Cs in the sediment cores collected from Watts Bar Reservoir is strongly correlated with the historical release record of ^{137}Cs originating from White Oak Lake (Figs. 22a and 22b). Such cores exhibit a large subsurface peak concentration of ^{137}Cs . The depth of this subsurface peak, as well as the thickness of ^{137}Cs -contaminated sediment, varies with the rate of sediment accumulation. In areas of rapid sediment accumulation, such as in the upper portion of the reservoir and along the old river channel, the highest ^{137}Cs concentrations occur at sediment depths as great as 1.5 m. In areas of less sediment accumulation, such as along the reservoir margins, the highest ^{137}Cs concentrations often occur closer to the sediment surface. When lake levels are lowered, this distribution may significantly affect exposure

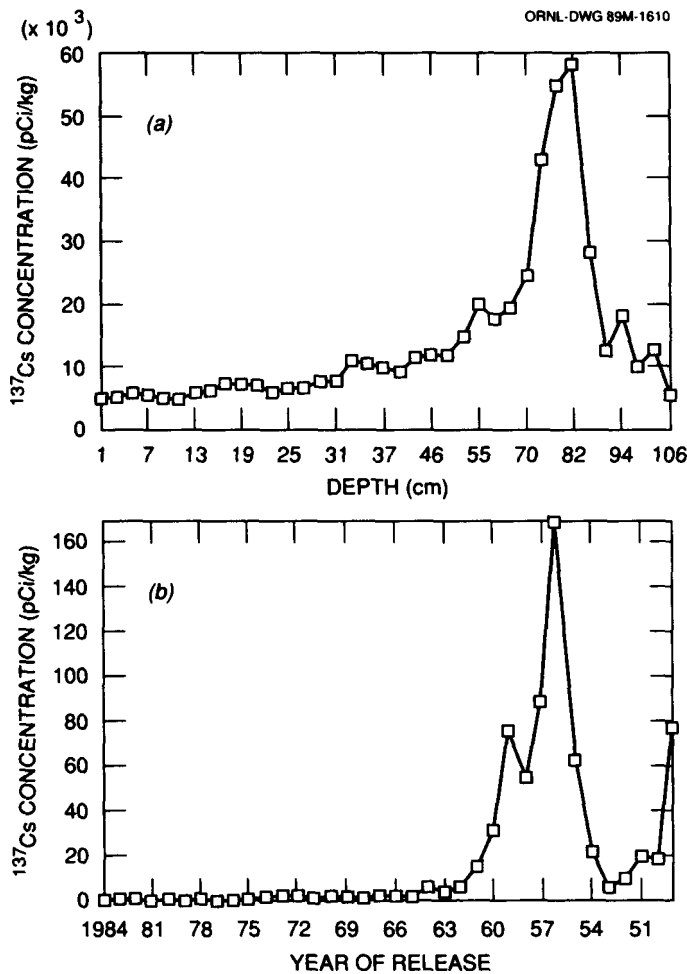


Fig. 22. Measurements of ^{137}Cs (a) in sediment cores from Watts Bar Reservoir and (b) in releases from White Oak Lake to Watts Bar Reservoir from 1949 to 1984.

and uptake by aquatic organisms, which live in or feed on surface sedimentary material, as well as affecting humans.

The total accumulation of ^{137}Cs in Watts Bar Reservoir sediments was estimated by measuring the inventory of ^{137}Cs in each sediment core and in the surface grab samples and by integrating these data over the entire reservoir ($\sim 115 \text{ km}^2$). Initial results of this integration reveal that about 290 Ci of ^{137}Cs resides in the sediments of Watts Bar Reservoir, of which $<5\%$ is attributed to fallout from atmospheric testing of nuclear weapons. Releases of ^{137}Cs from White Oak Lake (decay corrected to 1986) into the Clinch River have introduced an estimated $\sim 335 \text{ Ci}$. This indicates that about 85% of ^{137}Cs from White Oak Lake has been sequestered within the sediments of Watts Bar Reservoir. These results demonstrate that the reservoir serves as an effective trap for the accumulation of particle-reactive substances originating from ORNL and that they are accumulating in the benthic environment.

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Toxicity Tests Indicate Poor Water Quality in Mitchell Branch and Potential Sources of Toxicants

L. A. Kszos*

As a condition of the modified National Pollutant Discharge Elimination System permit issued to the Oak Ridge Gaseous Diffusion Plant (ORGDP) on September 11, 1986, a Biological Monitoring and Abatement Program was developed for the receiving stream (Mitchell Branch). Four discharges [effluents from the K-1407-B holding pond and storm drains (SDs) 170, 180, and 190] and water from six ambient sites were evaluated for toxicity from October 1986 to December 1987. Toxicity was measured by using 7-d static renewal tests (test solutions were replaced daily) based on the survival and growth of fathead minnow larvae and the survival and fecundity of a microcrustacean (*Ceriodaphnia*).

Toxicity was detected in all four discharged effluents. Full-strength effluent from the K-1407-B pond was chronically toxic in eight of ten tests with *Ceriodaphnia* and two of eight tests with fathead minnows. Mean survival of *Ceriodaphnia* was $\leq 40\%$ in seven of ten tests. The cause of toxicity in effluent from the K-1407-B pond has not yet been identified, but it appears to be related to periods when concentrations of calcium are high. Effluent from SD 170 was toxic at full strength in three of three tests. Full-strength effluent from SD 180 and SD 190 was periodically toxic. The toxicity of the SD effluents appears to be due primarily to high concentrations of chlorine; in 8 of 12 tests, total residual chlorine (TRC) was $\geq 0.10 \text{ mg/L}$. However, the dechlorination of SD effluents did not always reduce the toxicity. This lack of effect indicates the periodic presence of other toxic constituents.

In the ambient toxicity tests, the site located above ORGDP operations (1.43 km above the confluence with Poplar Creek) was toxic to fathead minnows but not to *Ceriodaphnia*. The source of this toxicity is not yet known, but it is hypothesized to result from a fungal pathogen. Water in the midreach section of Mitchell Branch (below the discharge point of SD 170 to just below the discharge point of SD 190) was periodically toxic

to both test organisms, showing the strong influence of the effluents from the K-1407-B pond and from SDs 170, 180, and 190 on Mitchell Branch. Mean survival and reproduction of *Ceriodaphnia* in water from Mitchell Branch correlated negatively with concentrations of TRC, and, in at least half of the tests with water below the discharge point of SD 170, no fathead minnows or *Ceriodaphnia* survived. These findings, plus the high variability in the survival of the test animals and the lack of consistent evidence of chronic toxicity, indicate that the ambient toxicity pattern exhibited in Mitchell Branch may be controlled primarily by episodic releases of one or more toxicants, particularly chlorine. On a positive note, there was little evidence of chronic toxicity in water from the site furthest downstream of operations (0.12 km upstream from the confluence with Poplar Creek), where concentrations of TRC are typically zero.

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Postclosure Remedial Actions at the S-3 Ponds May Not Improve Ecological Conditions in Bear Creek

G. R. Southworth

Past disposal of nitric acid wastes in the headwaters of Bear Creek has produced a plume of contaminated groundwater that contributes to the surface flow of Bear Creek. The infiltrating groundwater produces elevated concentrations of dissolved salts throughout most of Bear Creek and episodic toxic conditions in its upper reaches. Closure of the S-3 ponds, mandated by the Resource Conservation and Recovery Act, requires the consideration of postclosure remedial actions. Proposed actions at this site include (1) undertaking no remedial action, (2) capping the pond to prevent further infiltration of rainwater, and (3) capping the pond and installing groundwater wells to withdraw and treat the most contaminated region of the plume as well as prevent its further dispersal.

Because these remedial measures have the potential to sustain or cause adverse ecological effects in Bear Creek, an evaluation of the ecological consequences of the proposed actions was conducted. Chemical and ecological monitoring data, as well as results of toxicity tests on Bear Creek surface water and S-3 plume water, were used in conjunction with estimates of the effects that remedial actions would have on surface flow and solute concentrations to estimate likely environmental changes in Bear Creek and East Fork Poplar Creek, the receiving stream for the treated water removed from the S-3 plume.

Predictions of future solute concentrations in Bear Creek under each proposed action varied widely between three alternative methods of estimation: (1) using a groundwater transport model, (2) calculating the empirical rate of change in nitrate concentration from well data, and (3) calculating the mass balance of nitrate exported in Bear Creek surface flow versus that remaining in the plume. The no-action option resulted in either very rapid (several-year) improvement in water quality or relatively slow (decades-long) improvement, depending on the method used to predict future water chemistry. Aggressive actions involving groundwater withdrawals predict more rapid improvement in water quality at downstream sites where substantial ecological recovery has already occurred but would dewater headwater reaches where plume toxicity is now evident. Groundwater removal

also posed risks to East Fork Poplar Creek, where the discharge of treated plume water would probably consume much of the stream's capacity to assimilate effluent.

In view of the large uncertainty associated with the rate of dispersion of the S-3 plume and the likelihood that plume withdrawal may replace one adverse impact with another, the option of capping the S-3 site without installing a groundwater recovery system was viewed as the procedure most likely to improve ecological conditions in Bear Creek without impacting aquatic habitat by flow reductions or effluent additions. If future monitoring demonstrates that additional remedial actions are necessary, this option would not preclude their eventual implementation.

Carbon Allocation Patterns in Loblolly Pine Vary with Season

M. B. Adams, G. E. Taylor, Jr., N. T. Edwards, and B. L. Skaggs*

The mechanisms by which air pollutants affect tree growth and vigor are ultimately a consequence of changes in physiological processes such as photosynthesis, carbon allocation, respiration, and biosynthesis. A better understanding of important physiological processes is therefore necessary to evaluate air pollution effects. Ozone (O_3) is one of the major phytotoxic air pollutants and has been shown to influence the growth of loblolly pine, although the mechanisms have not been elucidated. The objectives of this study were (1) to determine the seasonal patterns of allocation of photosynthetically fixed carbon in loblolly pine and (2) to quantify the influence of elevated concentrations of O_3 on whole-plant carbon allocation.

Loblolly pine seedlings were exposed to either ambient or double the ambient O_3 levels in open-top chambers at the Air Pollution Effects Field Research Facility during the 1987 growing season. Seedlings were labeled with ^{14}C and subsequently harvested at five sampling dates during the growing season to determine the patterns of carbon allocation to foliage, stems, and fine and coarse roots. Respiration and maintenance costs were also quantified.

Carbon allocation varied significantly according to sampling dates. Allocation to respiration and maintenance was highest in May and June, reaching 50–60% of net CO_2 assimilation. Allocation to these components then declined sharply in July, when carbon retention by the foliage was at a maximum. Another major shift in the pattern of allocation occurred in the autumn, when photosynthate allocation to fine roots increased at the expense of the foliage. The proportion of current photosynthate allocated to coarse roots and stems declined over the growing season but was consistently low. Relative carbon allocation to a plant component was highest when the growth of that component was at a maximum.

Seasonal allocation patterns were similar for trees exposed to either ambient or double the ambient O_3 levels, and differences between treatments were not statistically significant. For O_3 -treated trees, mean allocation of carbon to respiration was higher, whereas allocation to fine roots in the fall was lower. It is hypothesized that the increase in carbon allocation to respiration is a consequence of repair of O_3 -damaged tissue in needles.

These results point to the significance of pronounced seasonal patterns in photosynthate allocation. These patterns must serve as a basis for determining how environmental

stress influences whole-plant carbon budgets. The most pronounced patterns were the seasonal specificity in photosynthate allocation to maintenance and respiration and to fine roots. Continued O₃ fumigation of loblolly pine seedlings over the next two growing seasons will offer an opportunity for further evaluation of the effects that O₃ has on loblolly pine growth and physiology, including photosynthesis and carbon allocation.

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Resilience of Aquatic Ecosystems Is Predicted with Simulation Models and Field Experiments

A. R. Johnson

Aquatic ecosystems are exposed to a variety of disturbances, both natural and anthropogenic. For an ecosystem to persist, it must be resilient, that is, capable of recovery at a rate faster than the typical frequency of disturbance. Such considerations are important, for instance, in the setting of water quality criteria, which must specify not only the magnitude but also the duration and frequency of allowable impacts. The focus of this work is on developing a theoretical basis for quantifying ecosystem resilience, and applying the theory to the recovery process in aquatic ecosystems exposed to toxic chemicals. A two-pronged approach has been adopted, consisting of studies of simulation models and pond ecosystems.

For a certain class of simulation models (i.e., linear models), the problem of quantifying resilience is easily solved. The temporal dynamics of recovery in a linear system are summarized by a set of numbers called the eigenvalues of the system. However, ecosystems can be significantly nonlinear. How does one quantify resilience in a nonlinear system? Although eigenvalues cannot be computed directly for a nonlinear system, it is possible to derive a linear model that locally approximates the nonlinear system. The eigenvalues derived from this linear approximation should quantify the resilience of the system, at least over a certain range of conditions. Alternatively, resilience may be correlated with the turnover rates of certain system components, with primary productivity, or with other measurable ecosystem properties. The utility of a number of predictors of resilience is being evaluated with an aquatic ecosystem model (Fig. 23).

The experimental studies also under way involve exposing pond ecosystems to a toxicant (a phenolic mixture) and allowing them to recover. The data collected in these experiments will be used to evaluate how effective the methods developed in the simulation studies are when they are applied in a field situation.

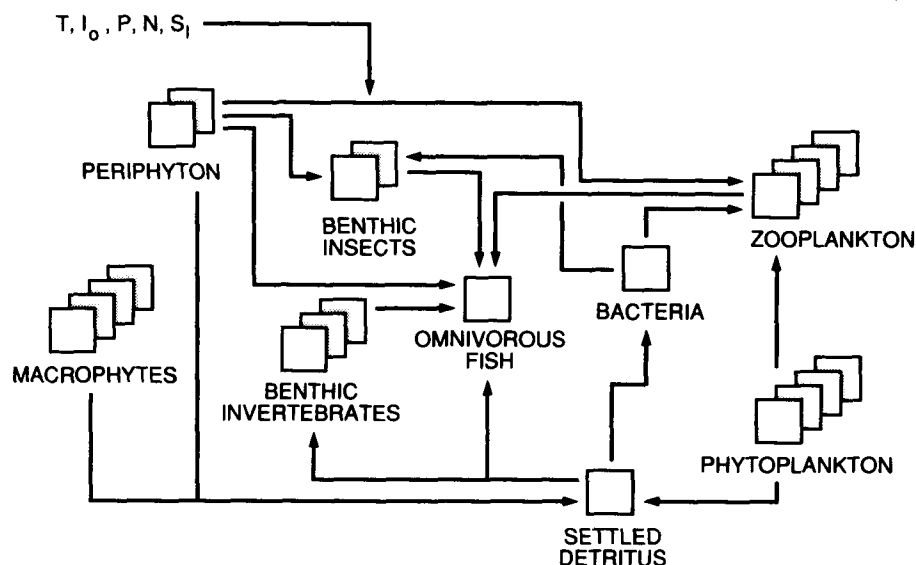


Fig. 23. Aquatic system model.

Habitat Depth Predicts Fish Size in Small Streams on the Oak Ridge Reservation

B. C. Harvey

Identification of consistent relationships between animal communities and habitat characteristics may be useful in both basic and applied biology. In undisturbed headwater streams on the Oak Ridge Reservation (Ish Creek, Gum Hollow, and Mill Branch), a strong positive linear relationship exists between the maximum depth of pool habitats and the maximum size of fish these pools contain: pool depth alone explains 68% of the variation in the maximum size of fish in 268 pools ($P < 0.0001$). This pattern is independent of species composition. Deviation from this pattern at sites subjected to episodic contamination (e.g., Fifth and White Oak creeks at ORNL, which contain disproportionately small fish) may reflect (1) very low rates of recolonization by relatively large fish and/or (2) a disturbance frequency that prevents individuals from growing to sizes characteristic of fish at undisturbed sites. Deviation from the pattern of larger fish in deeper pools may therefore be used to identify those reaches of a stream subjected to contamination that might not be detected by using standard biomonitoring parameters such as fish density or biomass.

The processes responsible for generating the observed relationship between fish size and stream pool depth in noncontaminated streams were explored in four 7- to 14-d experiments conducted in an upper reach of White Oak Creek. Survival of fish was measured in shallow pools (maximum of 10 cm) and deep pools (maximum of 40 cm); each pool was about 4 m² in area. The pools were stocked with creek chubs (*Semotilus atromaculatus*) in one experiment and with central stoneroller minnows (*Campostoma anomalum*) in three experiments. The fish were 100–150 mm long. Fish were confined in

the 16 pools (8 of each depth) by plastic screen fences. In each experiment, fish survival was significantly lower in shallow pools than in deep pools; loss rates in shallow pools averaged about 10% per day. Raccoons and green herons were each observed removing fish from shallow pools on two occasions during the experiments.

The results of the experiments reported here show that for adult stream fishes in shallow pools, the risk of predation from mammals and birds is strong and is at least partly responsible for the highly significant relationship between pool depth and fish size. Additional experiments have shown that juvenile fishes are less susceptible than adult fishes to predation by mammals and birds. The high rate of predation by mammals and birds on stream fishes also suggests that stream-borne contaminants may readily enter terrestrial food webs through this trophic link.

Sublethal Chlorine Exposure and Its Relation to Oxygen and PCB Uptake Are Studied in Rainbow Trout

M. C. Black and J. F. McCarthy

Intermittent high concentrations of chlorine have been measured in the upper reaches of East Fork Poplar Creek above New Hope Pond. Fish exposed to sublethal chlorine concentrations exhibit hypoxic responses, including hyperventilation and bradycardia, indicating inefficient oxygen exchange at the gills, possibly as a result of histopathological damage to the gill lamellae. These compensatory mechanisms expose the gills to more oxygen and may enable fish to meet their respiratory demand; however, as respiratory-water contact is increased, exposure to chlorine and other waterborne toxicants is also increased.

In this study the effect of chlorine exposure on the histopathology and respiratory physiology of fish gills was quantified and related to oxygen and toxicant uptake. Yearling rainbow trout (*Salmo gairdneri*) were exposed to a sublethal concentration (0.04 mg/L) of chlorine in a large flowthrough tank. Gill tissue from trout, removed at intervals over a 24-h exposure period, was examined microscopically for histopathological damage. In separate experiments trout were exposed to a polychlorinated biphenyl (PCB) congener (2,2',4,4'-tetrachlorobiphenyl, 2,2',5,5'-tetrachlorobiphenyl, or 2,2',3,3',5,5'-hexachlorobiphenyl) both with and without the addition of chlorine (0.04 mg/L) in a fish metabolic chamber. The effect of chlorine on respiration and uptake was quantified by comparing respiratory functions and uptake measurements made with no chlorine present with those made in the presence of chlorine.

Preliminary histopathology results indicate that rainbow trout exposure to 0.04 mg/L of chlorine for greater than 12 h resulted in the following types of damage to gill lamellae: increased mucous cell production, thickened epithelial cells, decreased vascular surface area, and, in some cases, fusion of lamellae, lamellar aneurysms, and separation of epithelial and vascular spaces. A less efficient oxygen exchange should result from each of these types of gill lesions because of an increased diffusion distance across the gill lamellae.

These results are consistent with the decreases in oxygen and PCB uptake efficiencies measured with the metabolic chamber exposures. The trout were able to partially compensate for the lowered uptake efficiencies by increasing respiratory volumes and/or rates. As

a result of respiratory compensation, no significant changes occurred in oxygen consumption and PCB dose in comparison with significant reductions in oxygen and PCB uptake efficiencies (approximately a 45% decrease) by the gills after a 24-h exposure to chlorine. Oxygen uptake in trout was linearly correlated with PCB uptake for all fish (pooled data). These results suggest that fish can compensate physiologically for gill tissue damage caused by a sublethal pulse of chlorine. As a result of respiratory compensation, the uptake of other hydrophobic toxicants (such as PCBs) that diffuse across gill membranes may not be significantly altered by episodic exposures to chlorine.

Hepatic Enzyme Activity and Liver Condition Denote Stress in Redbreast Sunfish, *Lepomis macrochirus*, from East Fork Poplar Creek

B. D. Jimenez, M. S. Adams, and A. O. Oikari*

Polycyclic aromatic hydrocarbons and polychlorinated biphenyls that commonly occur in municipal and industrial effluents can be taken up by organisms either directly from the water or indirectly through the food chain and from sediments. It has been demonstrated that these pollutants can induce a series of hepatic enzymes [mixed-function oxidase (MFO) system] which transform them to polar compounds that are more readily excreted from the organism. Several MFO activities and electron transport enzymes are being measured in fish as indicators of pollution in East Fork Poplar Creek (EFPC) as part of the Biological Monitoring and Abatement Program at the Oak Ridge Y-12 Plant.

The quantities and activities of hepatic enzymes in redbreast sunfish as well as the liver somatic index were measured in EFPC and Brushy Fork, a reference stream near Oak Ridge. Comparisons between sexes, seasons, and sampling sites were performed. Fish collected in the vicinity of industrial and municipal outfalls exhibited higher quantities and activities of hepatic enzymes than the fish collected at the reference stream. MFO activities in redbreast sunfish varied seasonally, with higher activities occurring in fall and summer than in winter. Laboratory experiments have shown that these differences can be attributed to the effects of water temperature. The lowest MFO activity in female redbreast from the reference site was found during late spring and summer. The low enzyme activity levels coincide with the spawning season for this species, suggesting a hormonal influence on the MFO activity in female fish. Regardless of the season, however, fish from EFPC had higher MFO levels of activity than fish from the reference site. Although male fish collected in the fall from EFPC immediately below New Hope Pond at the Y-12 Plant have higher MFO activity than fish from the reference site, they exhibited the lowest activity within the EFPC system. A detailed examination of internal organs (anterior and posterior kidneys, heart, and liver) in these fish revealed a high incidence of parasites, which suggests that fish inhabiting the site closest to New Hope Pond are severely stressed. The incidence of parasites in the various organs decreased downstream from the New Hope Pond site. These findings suggest that the parasite load in fish inhabiting areas closest to New Hope Pond could be affecting MFO activity, either by damaging liver cells or by creating a dilution effect on hepatic microsomal proteins. In addition, laboratory studies showed that hepatotoxic agents can affect the response of MFO activity in fish

livers. The livers of fish injected with a higher dose of hepatotoxicant (allylformate or carbon tetrachloride) lose their ability to respond to organic pollutants (Fig. 24). The combination of these laboratory results and field observations could account for the low levels of MFO activity associated with fish collected close to New Hope Pond. This study illustrates the importance of analyzing a number of variables in order for biomarker measurements to be interpreted properly.

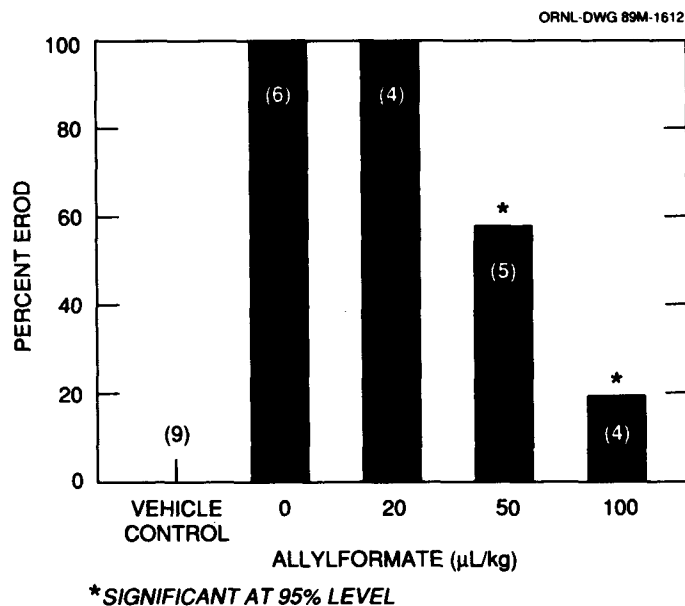


Fig. 24. The effect of hepatotoxicant on EROD activity in livers from sunfish. Controls were injected intraperitoneally with either corn oil or saline solution with the same volume of carrier. Each bar represents the mean EROD activity for the treatment, and the number of observations is shown in parentheses.

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1.5 GEOSCIENCES

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1.5.1 Introduction

Staff of the Geosciences Section in the Environmental Sciences Division (ESD) conduct basic and applied research directed toward an understanding of the physical and chemical mechanisms that control the movement of material through the lithosphere and atmosphere. Specific projects are carried out in the areas of geochemistry, geology, geophysics, atmospheric science, soils science, and oceanography and involve close interactions with scientists conducting biologic and hydrologic transport studies. The scope of the activities includes field characterization and testing, laboratory experiments, and

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mathematical and computer modeling. Many of the Section's activities are interdisciplinary in nature and are closely coordinated with other sections in the Division and with staff at other national laboratories. The Section consists of four groups: Geology and Geophysics, Geochemistry, Environmental Chemistry, and Soil Science.

The Section strives to maintain a proper balance between basic and applied studies, and the common theme that relates to the vast majority of the activities is associated with the study of waste materials and by-products from energy production. Some of the leading research on basic principles of materials movement and behavior has focused on dry deposition of oxide materials on forest canopies and the exchange of carbon between the atmosphere and oceans. State-of-the-art fundamental research has also been conducted on the impact that acidic deposition has on the availability of cations in soils and the resulting availability and detrimental impact of the cations on forests. In addition, Section staff have focused on the basic principles of aqueous chemistry and the potential for groundwaters to influence contaminant mobility. Investigations have been initiated to assess the influence that fractures and other porous features in rocks have on groundwater flow and contaminant migration; these studies have wide applicability to waste management activities on the Oak Ridge Reservation (ORR), as well as elsewhere. These on-site activities have provided a number of unique opportunities for characterizing the behavior of materials in the natural environment, particularly mercury geochemistry and the movement of organic contaminants in soils and aquatic systems. In addition, the larger-scale behavior of fission products in riverine systems south of the ORR has been quantified. A significant part of the Section's research activities is directed toward geochemical characterization of high-level nuclear waste materials in rock media; the Section has been the home for a program studying the use of shales as a possible repository for waste. Finally, fundamental and innovative computer-based investigations have been instrumental in helping to provide faster and more competitive modeling of contaminant transport simulations that have applicability to many of the other studies in ESD.

The Geosciences Section is fortunate to have a wide variety of sponsors. About 40% of the Section's activities are associated with on-site characterization for waste management and remedial actions at Oak Ridge National Laboratory (ORNL), the Oak Ridge Y-12 Plant, and the Paducah Gaseous Diffusion Plant; this support is principally from the Office of Defense Waste and Transportation Management. Another large contributor to the Section is the Office of Civilian Radioactive Waste Management; approximately one-quarter of the activities are related to the nation's program for permanent geologic disposal of high-level waste. In recognition of this, the Division has assigned a staff member as liaison at U.S. Department of Energy (DOE) Headquarters in Washington, D.C. The Office of Energy Research provides a significant portion of the support directed toward fundamental study of the behavior of inorganic materials in soils and the shallow subsurface. Other sponsors in FY 1988 included the Nuclear Regulatory Commission; the Electric Power Research Institute; the DOE Office of Environment, Safety, and Health; the DOE Hazardous Waste Remedial Action Program; the DOE Office of Basic Energy Sciences; and the National Science Foundation.

Significant achievements during FY 1988 include the following:

- Studies found that soil availability of aluminum to trees has increased with increasing atmospheric deposition of sulfur and nitrogen, diminishing the uptake of calcium and inhibiting tree growth.
- Geochemical modeling of groundwaters from shales showed that there is a very sensitive relationship between rock and aqueous chemistry.
- Investigation revealed that snowpacks are important reservoirs for accumulating trace substances from the atmosphere and serve as sources of releases during thaws.
- Strontium-85 tracer studies confirmed that hydraulic transport occurs dominantly through fractures in rocks underlying some old surface impoundments.
- Research demonstrated that a generic relationship between thrust faulting and fracture development on the ORR will provide the initial basis for fracture-flow investigations.
- Comparisons showed that RISC computers provide unusually high performance at a very low cost.
- Experiments showed that ionic mercury can be biologically reduced to the elemental state and released from aqueous systems by volatilization.
- Successful modeling of dry deposition of sulfate and forest canopy scaling factors was demonstrated.
- The Sedimentary Rock Program completed a series of investigations aimed at geochemical characterization of shale for repository purposes.

Expanded summaries describing these and other activities follow.

1.5.2 Technical Summaries

Forests in Mountainous Terrain Experience Higher Rates of Atmospheric Deposition than Low-Elevation Forests

S. E. Lindberg, D. Silsbee,* D. A. Schaefer,† J. G. Owens, and W. Petty‡

A common characteristic of many reported forest decline phenomena is their tendency to occur initially, more frequently, and more severely at high-elevation sites. Forests on mountain slopes are characterized by physical conditions that may lead to higher ambient rates of atmospheric pollutant loading than are present at their lower-elevation counterparts. Mountainous terrain is conducive to orographic precipitation, high wind speeds, and cloud immersion and is often populated by coniferous vegetation having relatively high foliage surface area. If the concentrations of elements in precipitation and air are comparable at high and low elevations, these physical factors should result in higher atmospheric deposition to mountainous sites. Quantifying these differences is important in analyzing the spatial distribution of forest decline.

We have established deposition measurement sites in the southern Appalachian Mountains, where meteorological and chemical data are being collected on an event basis so we can compare the rates of wet and dry deposition in indigenous coniferous forests. The high-elevation site is in a spruce (*Picea rubens*) forest at an elevation of 1800 m in the Great Smoky Mountains National Park, and the low-elevation site is in a pine (*Pinus taeda*) forest at an elevation of 300 m, 90 km to the northwest. These sites are part of a larger-scale study of the effects that deposition has on forest nutrient cycling, a study which includes eight additional sites in North America and Europe.

During 1986–1988, meteorological measurements confirmed the expected differences in atmospheric exposure conditions. Precipitation at the spruce site was approximately 2 times that at the pine site; the mean wind speed during dry periods was 2.8 times higher at the spruce site; the amount of time of cloud or fog immersion at the spruce site exceeded that at the pine site; and the mean wind speed in the clouds at the spruce site exceeded that at the pine site by a factor of 50. Estimates of foliar surface areas indicate that the spruce stand has a leaf area index 2 to 4 times higher than that of the pine stand.

On the basis of chemical data collected over 2 years, the atmospheric concentrations of many particulate species and HNO_3 vapor at the sites are comparable, whereas the SO_2 levels are lower in the mountains than in the valley (Fig. 25). The precipitation chemistry is characterized by generally lower concentrations of all ions in the mountains in comparison with the valley, perhaps due to dilution by increased rainfall. The most striking difference occurs in the chemistry of fog and clouds. Fog in the valley is generally a neutral

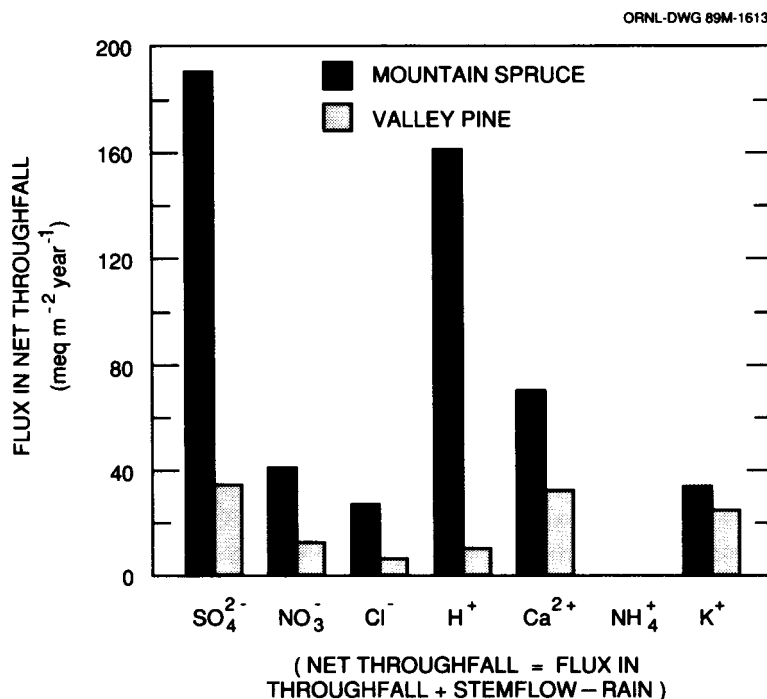


Fig. 25. The effect of elevation on net throughfall: annual fluxes at a mountain spruce forest and at a valley pine forest.

solution, dominated by SO_2^{4-} salts of Ca^{2+} and NH_4^+ . Cloud water impinging on the mountains is an acidic solution, dominated by H_2SO_4 and HNO_3 .

Throughfall (TF) fluxes measured at each site support the hypothesis that deposition increases as elevation increases. Both TF concentrations and fluxes are significantly higher at the spruce than at the pine site; for storms sampled simultaneously at both sites, TF fluxes are 2 to 5 times higher at the mountain site. Calculation of net TF (TF flux minus rain flux) for these events suggests that dry and cloud-water deposition are primarily responsible for the enhancement in the mountains. Continued measurements at these sites will allow quantification of the relative importance of various deposition processes, each of which interacts differently with vegetation surfaces.

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Spatial Variability in Rates of Dry Deposition and in Forest Canopy Scaling Factors Can Be Determined from Analysis of Throughfall

S. E. Lindberg, D. A. Schaefer, and J. G. Owens

Critical problems in quantifying dry deposition include spatial and temporal representativeness in measured or modeled fluxes, as well as scaling from point measurements to the landscape. Micrometeorological approaches are limited to flat terrain and short time scales and are not applicable to coarse particles. Quantifying coarse-particle deposition (e.g., calcium and magnesium) is necessary to understand foliar leaching of cations, a phenomenon that has been linked to forest decline. Surrogate surfaces can be used to measure particle fluxes but do not reproduce foliage.

Analysis of throughfall (TF) beneath forests provides a solution to these problems. We developed a method to separate net TF (TF flux minus rain flux) into its component parts—foliar leaching and dry deposition washoff—by using limited data from Walker Branch Watershed. A linear regression model of net TF in the antecedent period and the rain duration furnishes coefficients for canopy-average rates of dry deposition and leaching. The model is now being applied to data from forests of different species and elevations in order to determine spatial variability in dry deposition within forests and to develop factors that can be used to scale inert surface fluxes of coarse particles to the full canopy (Fig. 26). With this model, annual rates of dry deposition of SO_4^{2-} were determined for two forests in the southern Appalachians. Replicate samplers at each site were 10–15 m apart, collecting TF as wet-only events. The mean dry deposition at an 1800-m spruce stand ($19 \mu\text{eq}\cdot\text{m}^{-2}\cdot\text{h}^{-1}$) exceeded that at a 300-m pine stand by one order of magnitude, reflecting higher dry deposition in the mountains as a result of higher wind speed and greater canopy surface area. The model provides two measures of uncertainty in these rates: the standard error (S.E.) of each dry deposition coefficient (temporal variability) and the S.E. of the overall mean rate of dry deposition (spatial variability). Together, these standard errors suggest that the uncertainties in the average rates of annual dry deposition are 30–80% (± 2 S.E.) because of “real-world” variability.

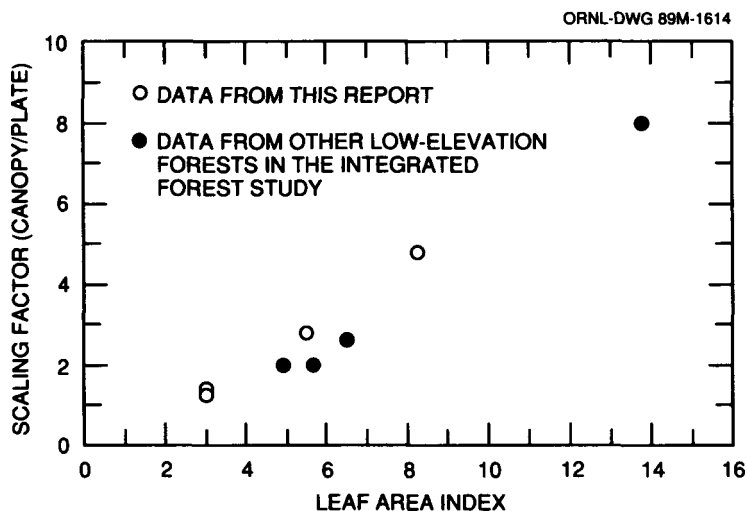


Fig. 26. Relationship between canopy leaf area index and scaling factor for coarse aerosol dry deposition.
 Source: S. E. Lindberg, D. Silsbee, D. A. Schaefer, J. G. Owens, and W. Petty, "Atmospheric Conditions in Forests of the Appalachian Mountains," in *Acidic Deposition in Mountain Terrain*, ed. M. Unsworth, D. Reidel, Dordrecht, The Netherlands, 1988.

Scaling factors for relating particle dry deposition on inert surfaces with fluxes to the forest canopy are determined from the regression data for calcium, which is a coarse-particle tracer (mass median diameter $> 2 \mu\text{m}$) with no vapor phase component. The ratio between the mean rate of dry deposition of calcium on polycarbonate plates and the mean rate of dry deposition of calcium on the forest canopy, determined from the TF model, represents a generic scaling factor for coarse-particle dry deposition. The plate/canopy factors for eight forests range from 1.4 to ~ 8 and are related to the canopy surface area index (SAI) ($r = 0.90$).

Our results establish confidence in the model and its assumptions because the scaling factors were physically bounded between 1 and the canopy SAI. The fact that the ratios are so strongly related to SAI is further encouragement that the model is predicting reasonable rates of dry deposition. As this TF model is applied to data from other forest stands, its utility will increase. The scaling factors and their spatial variability will be useful in developing and testing models of regional dry deposition.

Sedimentary Rock Program Evaluates Shales as Potential Hosts for High-Level Radioactive Waste Disposal

G. K. Jacobs and S. H. Stow

The objective of the Sedimentary Rock Program (SERP) has been to investigate shale for its potential as a host for a nuclear waste repository. A previous ranking of the major sedimentary rock types (shale, sandstone, chalk, anhydrite, and carbonate) with respect to geology, geochemistry, hydrology, thermal performance, rock mechanics, natural resources, and waste package degradation suggested that, of these five sedimentary rocks, shales

offer the greatest potential for the safe isolation of radioactive wastes. Shales are composed primarily of clay minerals (smectite, illite, and kaolinite), with lesser quantities of quartz, calcite, pyrite, feldspar, and organic matter (Fig. 27). Because the characteristics of shales span a broad compositional and textural range, detailed studies on their hydrologic, geochemical, and thermomechanical properties have been undertaken to identify possible relationships between the geologic attributes of shales and the safety aspects of a repository.

SERP is a multidisciplinary program involving several divisions at ORNL (Environmental Sciences, Chemical Technology, and Chemistry), Lawrence Berkeley Laboratory, and several consultants and universities. The major emphasis at ORNL has been on the geochemistry of different types of shale. The geochemical activities performed at ORNL during the past year include (1) geochemical modeling with EQ3NR/EQ6 to elucidate rock-water interactions important to the performance of waste packages, (2) characterization of mineral transformations and the nature of organic matter in shales, (3) determination of sorption properties of shales under a variety of conditions, and (4) development of improved contaminant transport models that more realistically account for geochemical interactions and flow in fractured rocks. These four aspects are important to the corrosion of canisters, the dissolution and release of radionuclides from waste forms, and the subsequent migration of contaminants away from the repository. Hydrologic aspects being investigated include (1) the determination of the permeability of shales under elevated pressures and temperatures, (2) experiments to measure the transport properties of single fractures, and (3) the development of models for flow through single fractures. DOE has recently mandated that the tuff formations of Yucca Mountain in Nevada be the only site

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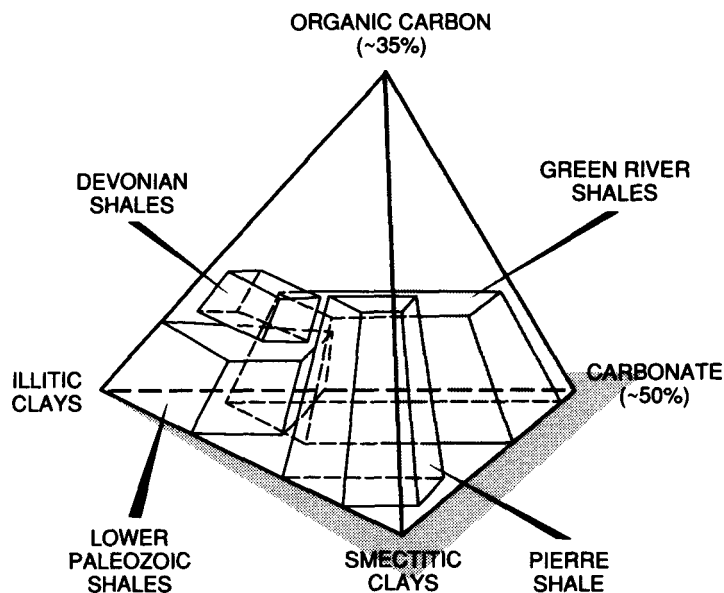


Fig. 27. Generalized representation of end-member shales in the illite-smectite-organic carbon-carbonate tetrahedron.

investigated for repository development. The studies performed under SERP will now be modified to more directly support the new mission of the national program. The information and experience developed through SERP will aid DOE in developing data and models to assess the performance of the Yucca Mountain site.

The Geochemical Modeling Code EQ3NR/EQ6 Is Used to Elucidate Controls on the Composition of Groundwaters in Shales

K. L. Von Damm and A. J. VandenBrook*

The main objective of the Sedimentary Rock Program is to examine sedimentary rocks as potential host rocks for high-level radioactive waste (HLW) repositories. Of the sedimentary rock types, shales have properties that suggest they are the best suited to host an HLW repository. The composition of their groundwaters is important because it will affect the integrity of the waste package as well as the transport of any nuclides that may escape from the package. As part of this activity, a data base of shale groundwater compositions, containing data from 600 locations, was prepared. These results have suggested the importance of halite and carbonates for controlling the groundwater compositions.

To further elucidate the geochemical controls on shale groundwater compositions, modeling with the code EQ3NR/EQ6 was begun. EQ3NR allows the calculation of mineral saturation states and solute speciation for the groundwaters. EQ6 is a reaction path code and, among its many options, allows waters to be mixed and reacted with rocks under varying temperature conditions. EQ6 has been used to model equilibrium reactions occurring with an illitic shale, one of the four end-member shales being examined. An idealized nine-mineral Pumpkin Valley Shale (PVS) has been used as the illitic shale, and the groundwater composition chosen was based on samples obtained from that formation in wells around the Hydrofracture Facility (HF) on the Oak Ridge Reservation. Idealized Knox dolostone compositions (both three- and ten-mineral) and a deep-sampled Knox groundwater composition have also been used in some of the modeling.

The modeled scenarios include the reactions of an HF water with various components under different conditions: (1) with PVS at 13.5°C, (2) with PVS at 250°C, (3) with pyrite replaced by graphite in the nine-mineral PVS assemblage at 13.5°C, (4) with similarly replaced pyrite at 250°C, (5) with a three-mineral Knox, and (6) with a ten-mineral Knox. In addition, the mixing of an HF with Knox water was modeled. The temperatures chosen reflect the sampled temperature of the HF water (13.5°C) and the maximum temperature expected close to a waste package (250°C).

Results suggest that the presence of even a very small amount of a reducing phase, whether pyrite or graphite, is extremely important for controlling the redox state of the water. The elevated temperatures result in minimal changes to the equilibrium mineral assemblage but significantly lower the pH and increase the dissolved sulfide species in the waters, both important parameters in radionuclide transport. Reactions with carbonate-rich rocks are important in buffering the pH and decreasing strontium concentrations in the waters.

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Availability of Aluminum and Iron to Trees Growing in Eastern North America Has Increased in the Past Two to Four Decades

E. A. Bondietti

Because the ratio of Al^{3+} and Fe^{3+} to Ca^{2+} in the soil solution increases with increasing electrolyte concentration, atmospheric deposition of sulfur and nitrogen should increase the relative availability of aluminum and iron to plants in extremely acid soils. Previous research using tree ring chemistry data for the Great Smoky Mountains National Park suggested a linkage between aluminum mobilization, wood aluminum concentrations, radial growth, and regional trends in SO_x emissions. Additional measurements and evaluations (not all discussed here) support those previous conclusions and allow the mobilization model to be extended to iron and to different parts of the eastern United States.

Measurements of cations in red spruce wood from southern Maine and Vermont (Camels Hump Mountain) revealed that the 1950s and early 1960s were a period of abnormal but similar fluctuations in cation availability to trees. At low elevations unusual increases in divalent cation concentrations in wood from 200-year-old trees were followed by rapid declines coincident with large increases in iron and aluminum. Laboratory studies on the wood from the Maine trees revealed that reduced uptake of divalent cations had occurred when the availability of aluminum and iron increased. At higher elevations, however, iron and aluminum concentrations exhibited progressive increases with little or no increase in divalent cation concentrations. This latter cation relationship appears to be more common in conifers sampled in eastern North America. Aluminum- or iron-induced declines in wood calcium storage are found only following a period of enhanced availability of calcium (Fig. 28). The importance of the trends in all of the Maine and Vermont

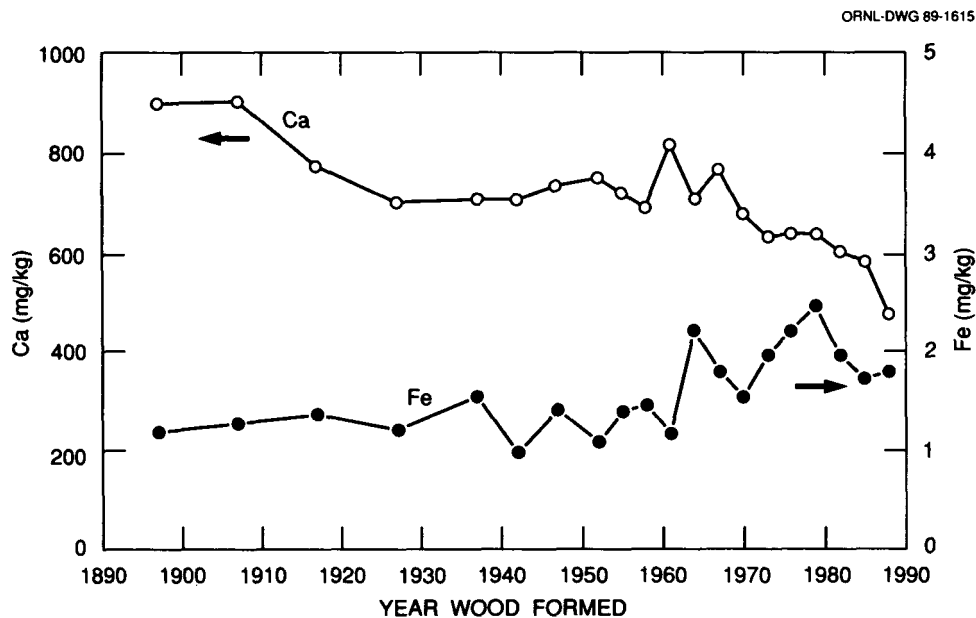


Fig. 28. Concentration trends of calcium and iron in a red spruce from Penobscot National Forest in Maine. Increases in iron (and aluminum) concentrations often coincide with decreases in divalent cation concentrations (Ca^{2+} shown here).

trees is that the timing of the cation perturbations coincides with the maxima of regional sulfur emissions as well as with the onset of widespread radial growth declines and mortality in the red spruce ecosystem.

The widespread increases in aluminum and iron in conifers is undoubtedly related to increasing regional emissions of sulfur and nitrogen. Two distinct perturbations in the calcium nutrition of red spruce that coincide with increases in aluminum and iron availability have now been inferred from tree rings: abrupt declines in calcium:magnesium ratios in wood (previous work) and abrupt declines in calcium storage. These relationships not only reflect an unprecedented disruption of the alkaline earth nutrition of these trees but also illustrate that information on cation availability exists in tree rings.

Water Balance Data for Rogers Quarry Suggest that the Quarry Is a Minor Recharge Source to Local Groundwater

M. A. Bogle and R. R. Turner

Water balance, calculated from measurements or estimates of surface water inflow, surface water outflow, precipitation, evaporation, and change in storage volume, is used to estimate losses to groundwater from ponds, lakes, and reservoirs. The water balance of Rogers Quarry, used as a waste disposal facility for the Oak Ridge Y-12 Plant from ~1962 to the present, is pertinent to future remediation and closure of the quarry because this data can be used, in conjunction with groundwater level data, to determine whether waste contaminants disposed of in the quarry are migrating or have the potential to migrate into the groundwater. If water balance data indicate that the quarry functions like a sealed basin with respect to groundwater, then contaminant migration, except via surface water outflow, is unlikely.

To determine a water budget for Rogers Quarry, we collected and analyzed for the period January 1, 1987, through June 30, 1988, data for five of the six components of the water balance equation (i.e., inflow, outflow, precipitation, evaporation, and change-in-storage data). Collection of data on surface water inflow and outflow for the quarry necessitated the installation of a Palmer-Bowlus flume and a Manning water-level monitoring system at the inflow and a Stevens digital water-level recorder calibrated to the Cipolletti weir at the outflow. The Stevens data were used for calculating daily change in storage as well as the daily flow. Daily precipitation data were obtained by averaging precipitation values for three recording rain gauges in the vicinity of Rogers Quarry. Estimates of daily evaporation for Rogers Quarry are based upon data for a standard class A evaporation pan maintained by The University of Tennessee. Data for these parameters were then entered into a Lotus spreadsheet. From the five measured elements of the water balance equation, the sixth and unmeasured element, daily seepage residual (equivalent to loss to or gain from groundwater), was automatically calculated by the spreadsheet with the water balance equation:

$$\text{seepage residual} = \text{outflow} + \text{evaporation} + \text{change in storage} - \text{inflow} - \text{precipitation} .$$

The spreadsheet was also used to calculate monthly totals for the six elements of the water balance equation.

Analysis of the water balance data for the period January 1987 through June 1988 suggests that Rogers Quarry is relatively tight with respect to exchanges with local groundwater. For the 7-month period with the most reliable hydrologic data (December 1987–June 1988), the quarry-measured inputs and outputs appear to be nearly balanced (i.e., the unmeasured parameter of seepage residual fluctuates closely around zero). The slight negative residual over these 7 months (average cumulative residual = -0.46×10^6 gal/month) suggests that the quarry is a minor recharge source into the shallow groundwater system. However, because the average seepage residual is $<2\%$ of the average monthly inflow or outflow and because uncertainties in inflow and outflow—the two major components of the water balance equation—are at least $\geq 2\%$, the actual seepage residual could be positive. From these preliminary results it appears that contaminant migration from Rogers Quarry into local groundwater may be only a slight concern during future remediations.

Radiotracer (^{203}Hg) Experiments Suggest Low Rates of Methylation of Mercury in East Fork Poplar Creek

R. R. Turner, A. J. VandenBrook,* J. W. Elwood, and I. L. Larsen

Methylmercury (CH_3Hg) is both more toxic and more readily bioaccumulated than inorganic forms of mercury. That inorganic forms of mercury can be methylated by microorganisms in the environment was discovered over 20 years ago and remains central to understanding biotic uptake at sites of inorganic mercury contamination. East Fork Poplar Creek (EFPC) receives releases of inorganic mercury from the Oak Ridge Y-12 Plant, a nuclear weapons production plant in Oak Ridge, Tennessee. Previous studies have demonstrated that total mercury levels in water, sediment, and fish are highest immediately below the plant and that they decrease downstream. The concentration of CH_3Hg in water and the rate of uptake by caged fish are also higher immediately below a 1.2-ha impoundment of EFPC at the plant boundary than above the impoundment.

To identify sites of mercury methylation and the factors affecting it in this aquatic system, we used the radiotracer ^{203}Hg to estimate potential rates of methylation in unfiltered water and in sediment suspensions (1% solids). Samples were spiked with $^{203}\text{Hg}(\text{NO}_3)_2$ and incubated for 2 d at 22°C . The CH_3Hg produced was separated by solvent extraction and counted by gamma spectrometry. Methylation rates are reported here as percentages of spike ^{203}Hg converted to $\text{CH}_3^{203}\text{Hg}$ in 2 d and are thus relative rather than absolute.

The availability of sediment-bound mercury for methylation was investigated by equilibrating sterilized sediment with a ^{203}Hg spike. The added ^{203}Hg partitioned rapidly to the sterile sediment, yielding a distribution coefficient (KD) of 14,000 mL/g after 6 h. After the sterile sediment was mixed (50:50) with nonsterile sediment, only $0.016 \pm 0.004\%$ of the sediment-bound ^{203}Hg was methylated after 2 d, compared with $0.103 \pm 0.010\%$ when the ^{203}Hg spike was not preequilibrated with the sediment. These results suggest that soluble mercury released to EFPC is very rapidly bound to sediment and that sediment-bound mercury is not very available for methylation (Fig. 29). Mercury methylation in water samples without sediment additions has been consistently very low ($<0.02\%$)

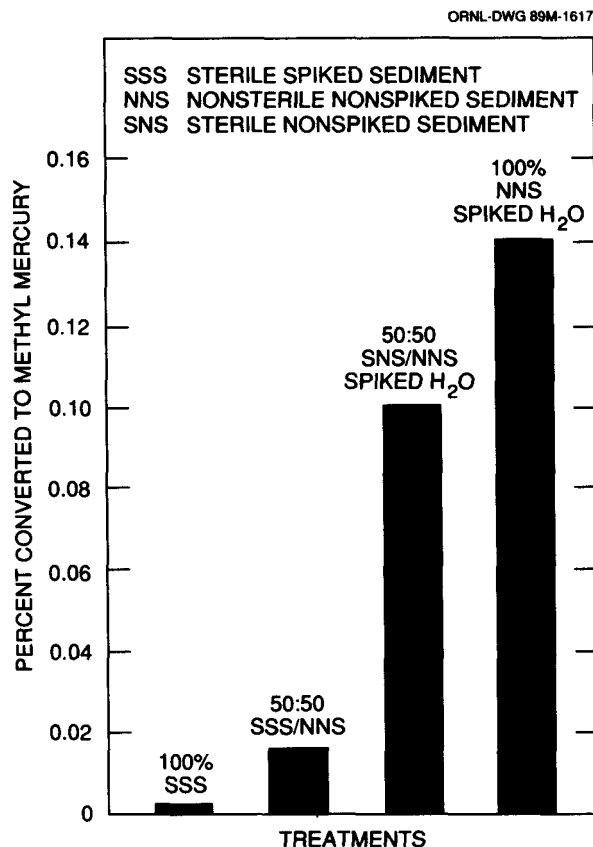


Fig. 29. Comparison of methylation of mercury already bound to sediment (50:50 SSS/NNS and 100% SSS) with methylation of mercury added to sediment suspensions in soluble form (50:50 SNS/NNS and 100% NNS).

or absent. Continuous purging of water samples with nitrogen resulted in a slight increase in methylation in relation to aerated controls; this increase indicates that methylation is enhanced under anaerobic conditions. Collection and speciation of volatile ^{203}Hg during purging revealed that 35–50% of the radioactive spike was released as Hg^0 during the incubation. Volatilization in the sterilized bottles was similar, indicating that conversion of the $^{203}\text{Hg}(\text{NO}_3)_2$ to Hg^0 is not a biotically mediated process. When sediment was present, the volatile ^{203}Hg yield was very low (0.002–0.01%), comparable to the $\text{CH}_3^{203}\text{Hg}$ yield measured by solvent extraction. A disproportionation reaction triggered by the mercuric ion spike and involving reduction of Hg^+ to Hg^0 is suspected.

Overall, the radiotracer results are consistent with other findings for EFPC, including (1) very low concentrations of CH_3Hg in EFPC water and (2) somewhat lower than expected mercury concentrations in EFPC fish despite the relatively high levels in water and sediment. Reported $\text{CH}_3^{203}\text{Hg}$ yields in similar experiments conducted at other sites in the United States and Canada are also generally higher (up to several percent) than yields in EFPC. The high abiotic yield of Hg^0 in water-only experiments is partially an artifact of the experimental design, but it nevertheless demonstrates the ease with which ionic mercury can be reduced to the elemental state and lost from solutions by volatilization.

Leakage of ^{90}Sr from the Impoundment at the Old Hydrofracture Facility Is Verified to Be in the Form of Fractured Flow

C. W. Francis and I. L. Larsen

ORNL has used unlined surface impoundments to collect, treat, and dispose of liquid low-level radioactive wastes. These impoundments represent one of the earliest forms of waste management at ORNL, and some are still in use at certain locations. Construction is under way to convert to more environmentally acceptable methods for the collection, treatment, and disposal of liquid wastes. Over the past few years, considerable effort has been devoted to characterizing the contents of these wastes and to evaluating their impact on groundwater quality. As these impoundments are replaced by new treatment facilities, some form of remedial action or disposal of sediment contained in these impoundments will be required.

To aid in validating the effectiveness of the proposed solidification/fixation of sediment in the impoundment at the Old Hydrofracture Facility (OHF), a ^{85}Sr tracer study was conducted to determine the transport velocity of ^{90}Sr from the impoundment to groundwater. Approximately 13 GBq of ^{85}Sr was added to the 20- by 100-ft impoundment on March 17, 1987. Levels of ^{85}Sr , ^{90}Sr , ^{137}Cs , stable strontium, and other stable elements were monitored in the impoundment water for 1 year. Concentrations of ^{85}Sr in filtered (0.45 μm) pond water rapidly decreased with time (Fig. 30). Approximately 50% of the added ^{85}Sr was lost from the pond water in 10 d, although chemical equilibrium of ^{85}Sr and stable strontium was on the order of 150 to 200 d. A material balance on the quantity of ^{85}Sr added to the impoundment and that measured in pond water and sediment indicated losses of ^{85}Sr in groundwater on the order of 25–38% in 50 d. Monitoring of groundwater showed detectable levels of ^{85}Sr at approximately 50 d and a peak in ^{85}Sr concentration at about 100 d. The transport velocity of ^{85}Sr was calculated to be on the order of

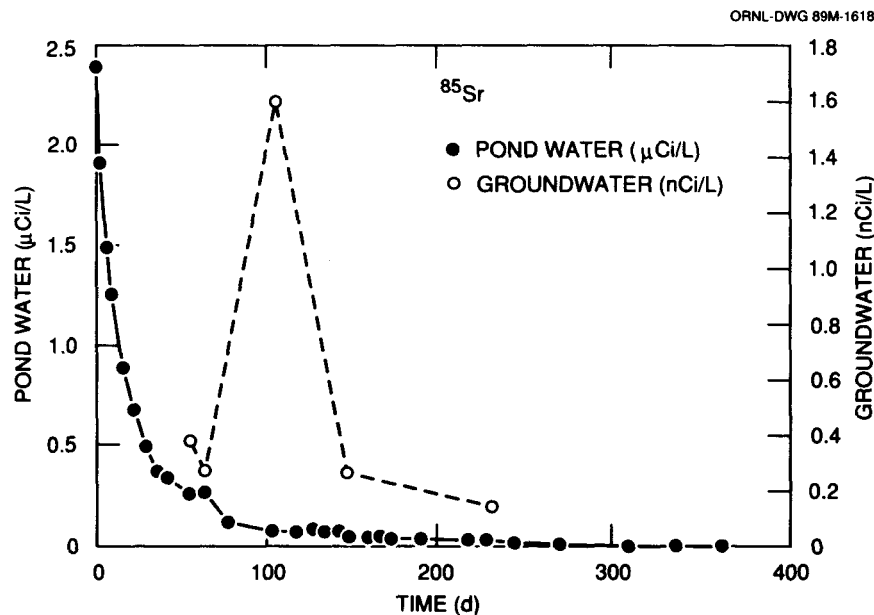


Fig. 30. Strontium-85 transport at the Old Hydrofracture Facility impoundment.

4.6 cm/d. This velocity is generally consistent with values for hydraulic conductivity, effective porosity, and the retardation for strontium in these materials.

These data confirm that movement of ^{90}Sr from the OHF impoundment is not simple seepage through porous media, but rather leakage in the form of flow along fractures in the underlying rock.

Two Types of Fracture Zones Are Identified and Characterized by Borehole Geophysical Techniques in the Waste Disposal Facilities at ORNL

R. B. Dreier and M. B. Leat*

Current conceptual models of groundwater flow in fractured rock suggest that the most significant transport occurs in fracture zones rather than along individual fractures. This finding is of particular concern to waste management investigations because disposal sites are commonly located in rocks of low permeability where contaminant transport is confined to fractures. Hence, in order to understand fluid transport in low-permeability rocks, such as those that underlie the Oak Ridge Reservation (ORR), it is vital that fracture zones be identified and their hydrologic parameters characterized.

The ORR is located in the Appalachian Fold and Thrust Belt and is composed of a series of Paleozoic sedimentary rocks that have been structurally duplicated by thrust faulting. All major fracture zones identified in this study formed in response to this large-scale thrust faulting and are associated with smaller-scale (10- to 100-m) faults.

Borehole geophysical logs were used to investigate the occurrence of fracture zones in Melton Valley, the site of several waste disposal facilities at ORNL. Each suite of geophysical logs included electrical, nuclear, acoustic, temperature, deviation, and caliper logs.

Results of the investigation show evidence of a fracture zone associated with a minor thrust fault within the Maryville Limestone. The fault underlies Solid Waste Storage Area (SWSA) 6 and the Pits and Trenches area. Borehole televiwer (BHTV) logs and logs constructed from neutron porosity/interval transit time crossplots indicate that the fracture zone is approximately 10–15 m thick. The zone can be divided into two smaller zones—a hanging-wall fracture zone and a footwall fracture zone, which are separated by the fault plane (identified by the BHTV log, with supporting evidence from the caliper log) (Fig. 31). The temperature and dual induction logs show distinctly contrasting signatures for the hanging-wall and footwall fracture zones. Thus, at this site the fault plane may be a relatively impermeable boundary that separates the two fracture zones and possibly separates two hydrologic systems.

A fracture zone associated with the WOC Tear Fault represents the other type of fracture zone recognized in this region. One of the Hydraulic Head Measuring Station (HHMS) wells (HHMS 10A) is apparently sited in this near-vertical fracture zone but does not intersect the fault itself. The WOC Fault shows a scissors-like sense of movement, and displacement is minimal (on the order of 5–10 m) at the site of HHMS 10A. Nevertheless, crossplot logs of temperature, dual induction, BHTV, and porosity all suggest the presence of enhanced fracture porosity related to the WOC Tear Fault. Hence, significant fault displacement is not necessary in order to develop a sizeable fracture zone.

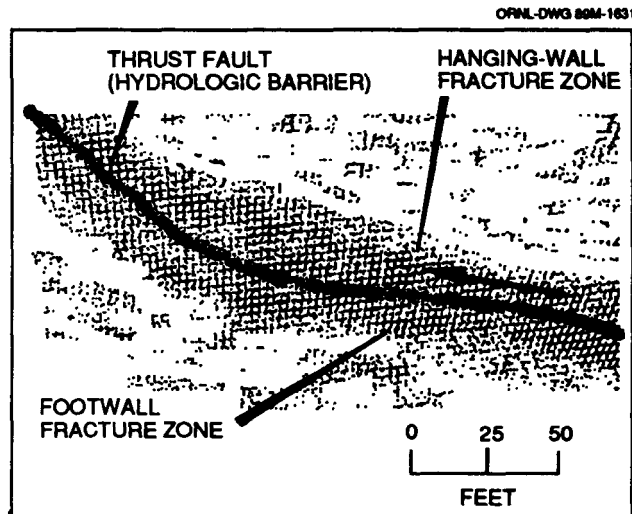


Fig. 31. Conceptual model of thrust fault identified in the Pits and Trenches area and in Solid Waste Storage Area 6.

This research shows that high-quality geophysical logs are very useful in identifying fractures zones that are potentially preferential pathways for groundwater and contaminant transport. Data from such logs will complement and expand on other data used for planning remedial action activities in Melton Valley, particularly well siting and regional hydrologic investigations. In addition, these approaches to characterizing groundwater flow in low-permeability fractured rocks can be used in a variety of geologic settings.

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RISC Computers Provide the Best Performance-to-Price Ratio for Contaminant Transport Simulations

V. S. Tripathi

Computer models of subsurface contaminant transport help in improving our understanding of relevant processes, permit an evaluation of the significance of various competing processes, and help in planning remedial action. However, sophisticated models, when applied to large problems, require tremendous computing resources. Supercomputers such as the Cray X-MP have typically provided the maximum available computer power, but the high cost and the limited availability of the Cray severely limit its use and discourage potential users of contaminant transport models from solving large problems. In addition to high cost, the supercomputer environments at present do not support highly interactive tasks such as development and use of artificial intelligence-based expert systems for use and interpretation of contaminant transport models. Traditionally, faster computers have been developed by designing faster central processing units (CPUs); however, in recent years, the development of multiprocessor computers capable of performing parallel or concurrent computations has been emphasized. While there is considerable ongoing activity in

the design of better hardware and software for parallel computers, optimal tools that can fully automate the utilization of parallel computers do not exist in most cases. Until such tools become efficient and widely available, other alternatives must be explored as well.

More than a decade ago, computer science researchers discovered that computer programs written in high-level languages such as FORTRAN use only a small set of simple machine (CPU) instructions for most operations; many complex instructions available on traditional computer processors are used infrequently. Further research led to a new type of processor architecture—containing fewer instructions, thus resulting in a faster processor—the so-called RISC (Reduced Instruction Set Computer) architecture. The RISC processor simplifies the CPU by devoting hardware resources to the tasks that are most critical to performance, such as mathematical computations and movement of data. The simpler and faster RISC processor is supported by efficient, high-level language compilers that perform the more complex operations absent on the processor.

High-performance RISC machines have recently become available commercially. To investigate the effectiveness of RISC computers in solving contaminant transport problems, we set out to compare such computers with other leading types of machines available for scientific computation. The selected machines included a RISC computer (MIPS) costing \$60–70K, a CRAY X-MP costing several million dollars, a VAX 8600 costing \$500K and up, and a parallel-vector computer employing eight parallel processors (the Alliant FX/8) costing about \$1M. Realistic problems of moderate complexity were chosen for the ORNL-developed contaminant transport model HYDROGEOCHEM. Preliminary model runs demonstrated that the VAX was the slowest performer and provided the lowest performance-to-price ratio. More extensive testing involving a large number of problems showed that the RISC computer consistently outperformed the Alliant FX/8 vector-parallel computer, in addition to outperforming the VAX. Furthermore, the performance of the RISC computer came remarkably close to that of the Cray. For example, a problem involving transport of uranium in a limestone aquifer took 85 min of CPU time on the Alliant FX/8. The same problem took 69 min on the RISC computer and 18 min on the Cray X-MP (Fig. 32). The ranking was confirmed by other test problems. The results clearly demonstrate the effectiveness of the RISC architecture. The variety of benchmarks we employed indicates that RISC computers will be similarly successful in other environmental problems.

The study has demonstrated that RISC computers provide unusually high performance at very low cost. The comparison of a RISC machine with other computers costing 15 to 200 times as much further highlights the cost-effectiveness of RISC computers. In summary, the architecture provides unprecedented performance-to-price advantage and will permit developments (e.g., building contaminant transport expert systems) heretofore unthinkable.

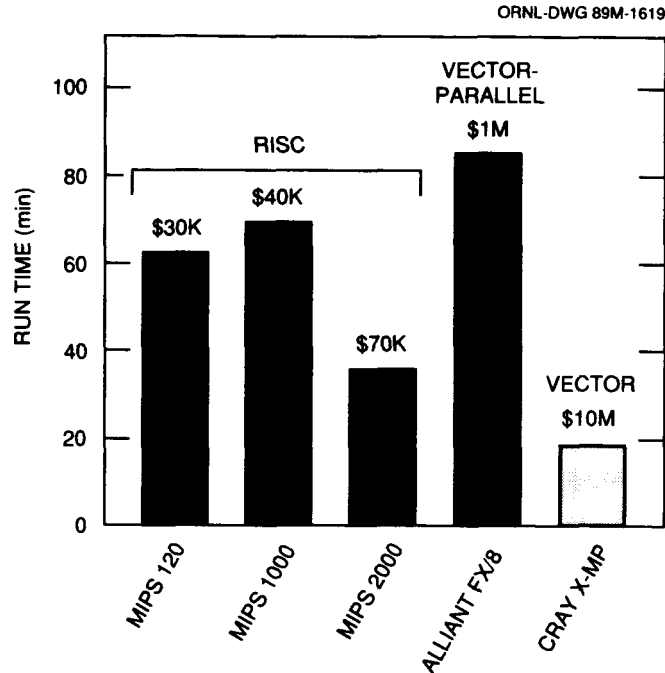


Fig. 32. The run times on three different architectures for a test problem involving transport of uranium and other trace elements in an aquifer. The most expensive computer, the Cray X-MP, is a vector computer; the next most expensive, an Alliant FX/8, is a vector-parallel computer. RISC computers, costing much less, provide excellent performance-to-price ratios, the best of those studied.

A New Tracer Technique Is Used to Study Snowmelt Processes in Alpine Watersheds

C. R. Olsen, D. K. Solomon, and I. L. Larsen

Because many watersheds receive the majority of their total water budget during the winter, deep snowpacks develop. In addition to storing precipitation, snowpacks are important reservoirs for accumulating trace substances removed from the atmosphere through washout or dry deposition. During spring thaw, these substances can be concentrated by sublimation or can be rapidly transported into streams and lakes via snowmelt processes. For instance, snowpack sources can account for as much as 70% of the NO_3^- in North Cascade lakes, and snowmelt inputs can reduce the pH of Sierra Nevada lakes by as much as one unit. Although these examples illustrate the important environmental impact of snowmelt in alpine watersheds, little is known of the interactions between snowmelt and soils on a catchment-wide scale.

To trace snowmelt processes and to quantify the fraction of snowmelt that moves through a watershed without significantly interacting with the soil-bedrock system, we measured the distribution of ^7Be in two snow cores, one soil core, and three stream samples collected from two adjacent watersheds in the Wasatch Mountains, Utah. Beryllium-7 is a chemically reactive radionuclide (53.3-d half-life) produced in the atmosphere and deposited as a constituent of precipitation. The atmospheric flux of ^7Be is consistent

with the snowpack inventory between 35 and 65 mBq/cm². The inventories of ⁷Be in both snow cores were almost identical, and they were similar to that expected from its atmospheric flux even though one of the cores was collected in an open meadow having a snowpack of 73 cm and the other core was collected within a shaded forest area with a snowpack of 115 cm. The ⁷Be concentration profile in these two cores, however, was very different. In the open meadow, the ⁷Be concentration in the top 25 cm was about 3 times higher than the respective concentration in the snow core from the shaded area (Fig. 33).

These results indicate that sublimation can reduce the snowpack and increase the concentration of trace substances in surface snow without affecting the total inventory. These effects of sublimation have important implications concerning the enrichment of exhaust-derived lead or other toxic contaminants in surface snow. After spring thaw, most of the ⁷Be inventory in the snowpack could be accounted for on the soils immediately below. This suggests that snowmelt undergoes significant geochemical interaction with the substrate before moving into surface streams. Stream-water samples collected near the snow-core

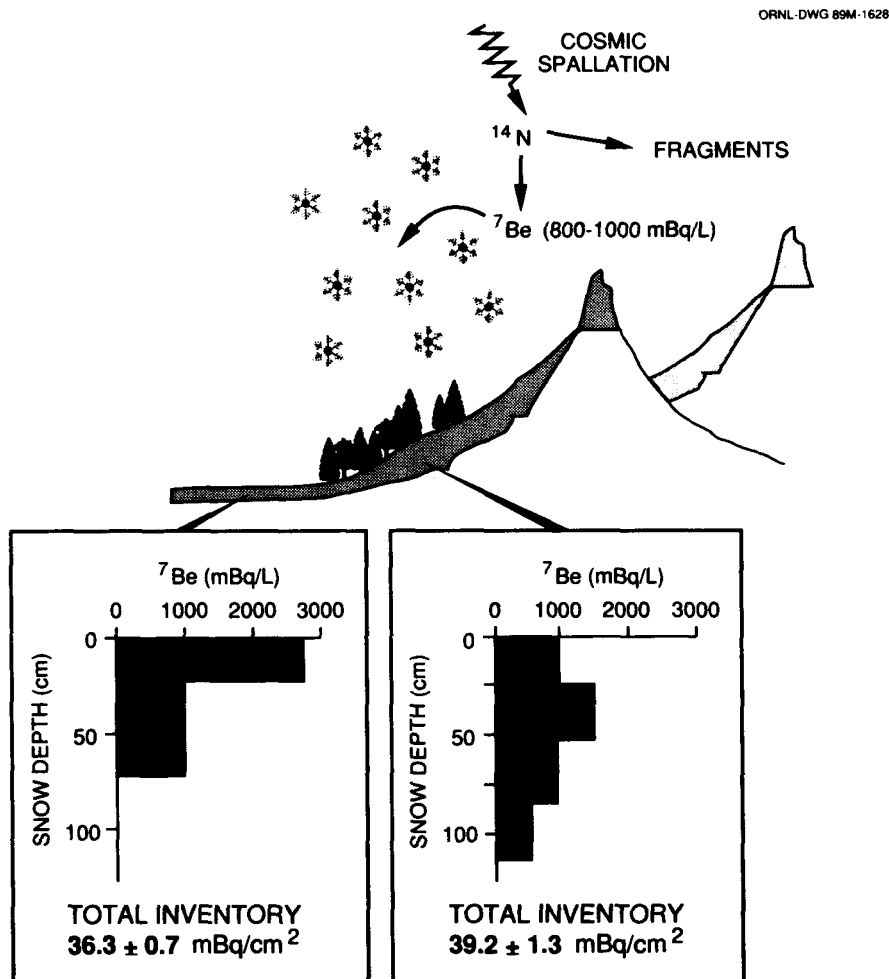


Fig. 33. A schematic illustration of ⁷Be concentrations and inventories in two snow cores collected from an open meadow site and from a forested site within adjacent alpine watersheds of the Wasatch Mountains, Utah.

sites in April indicate that only 1% of the snowmelt enters the stream without interacting with the vegetation-soil-bedrock system. This value increased to about 10% during maximum thaw in May. These results imply that rapid melting increases the mobility of chemically reactive substances in alpine watersheds. Future work will involve measuring other chemical tracers and contaminants within snowpacks and in streams during spring thaw to quantify snowmelt processes on a watershed scale and to document their resulting environmental impacts.

Office of ORNL Is Opened in the Washington, D.C., Area

N. H. Cutshall*

To provide technical assistance and liaison between the DOE Office of Civilian Radioactive Waste Management (OCRWM) and ORNL, an office has been opened in the Washington, D.C., area. This office provides support to DOE in the development of information regarding siting and design considerations for a high-level waste repository. Particular technical disciplines at ORNL that are represented by the office include geology, geochemistry, hydrology, and geologic engineering. Other areas of specialization may be included as requested by DOE.

The Nuclear Waste Policy Act of 1982 (NWPA) specified requirements for DOE in identifying potentially suitable sites for a high-level nuclear waste repository. The NWPA was amended in 1987 to specify that the characteristics of the Yucca Mountain site in Nevada should be evaluated by DOE to determine if the site meets the requirements for a repository. As specified in the amended NWPA, OCRWM is developing and evaluating geologic and engineering information related to (1) attributes of the site itself, (2) repository and waste package design, and (3) other relevant factors that may influence repository performance. These efforts require assistance from DOE contractors in the earth sciences and in other technical specialties.

ORNL staff include technical specialists in virtually all areas relevant to repository siting and characterization, including over 50 geoscientists holding advanced degrees. Additional geoscience capabilities are also available through the private sector in Oak Ridge and at The University of Tennessee. Relevant ongoing programs in geochemistry, structural geology, hydrology, and geophysics include theoretical studies, laboratory analyses, and field evaluations. Technical specialists are also available in many related fields—risk analysis, decision analysis, socioeconomic evaluations, environmental assessment, radioactive material handling and transportation, data management, and systems engineering and integration. However, because these specialists are distributed within a large and complex organizational structure, access to appropriate technical skills requires one not only to determine the needed expertise but also to have detailed knowledge of ORNL and DOE Oak Ridge Operations (DOE-ORO).

Technical issues identified by the OCRWM are reviewed and transmitted through the Washington, D.C., Area Office to Oak Ridge for action. In concert with OCRWM staff and with DOE-ORO, the office is responsible for determining specific technical needs,

identifying resources in the DOE-ORO contractor community, and ensuring communications to provide timely and efficient support. Communication links between the Washington, D.C., Area Office and Oak Ridge are maintained through electronic media and frequent travel.

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Fracture Analysis Is Performed on Cores from the Oak Ridge Y-12 Plant

C. T. Lutz*

The movement of groundwater and contaminants through consolidated sedimentary rocks generally follows fractures. The fracture network present in a body of rock increases porosity and permeability of the strata. Experimental studies and empirical observations of natural fracture systems show that flow tends to be dominant in directions coincident with fracture orientations and is enhanced by high fracture densities. Therefore, a thorough understanding of the fracture network is critical to any study involving either prediction of groundwater flow and contaminant transport or modeling of hydrologic systems. It is essential that fracture sets and their densities be completely characterized. This project is a study of fractures observed in core holes on the site of the Oak Ridge Y-12 Plant, a DOE facility on the Oak Ridge Reservation (ORR). ORR is in the Valley and Ridge Province of the Southern Appalachians, an area characterized by imbricate thrust sheets that contain rocks which are highly fractured. The Y-12 Plant lies within the White Oak Mountain thrust sheet. This study has involved examination of fracturing in the Conasauga Group, a 600-m-thick sequence of limestone and shale. The core holes lie in a strike-perpendicular transect across Bear Creek Valley. The core holes are 178 to 253 m deep.

Five fracture sets occur throughout the cores. One set is parallel to bedding, and the other four are generally perpendicular to bedding. Bedding-parallel fractures are largely release joints or unloading joints. The other four sets are tectonic in origin and are primarily extension joints. Shear fractures are also present but are not as common and are developed only locally (primarily in the lowermost 200 m of the group). Fractures are found at all depths in the cores, although not all sets are present at all horizons. A systematic relationship does not exist between the presence or absence of a particular fracture set and the stratigraphic horizon. Fracture density varies, and the two variables that have the greatest effect on density are lithology and bedding thickness. Density is inversely proportional to bedding thickness. High fracture densities are found in shales and interbedded limestone and shale, whereas limestones exhibit lower densities. All of the fracture sets exhibit mineralization; however, the strike-parallel (N55E) high-angle set is most commonly mineralized. Mineralization is most conspicuous as veins. Veins are generally 1.6 to 3.2 mm wide, up to 15 cm long, and spaced from <1 cm to >3 cm apart. Other deformational features that are observed include bedding slip surfaces (BSS), pressure solution features (PSF), and small-scale folding and faulting (SSFF). It is important to note the presence of these features because they can inhibit flow (PSF) and enhance flow (BSS and SSFF; in some cases PSF).

Although some local variation exists, in general these features are not site specific. All of Bear Creek Valley contains similarly fractured rocks. The features form discontinuities that influence fluid movement; therefore, it is important to identify these features and to know which ones enhance flow and which ones inhibit flow. The architecture created by the inherent stratigraphic variability and the superimposed features is complex; however, the complexity can be unraveled through a systematic analysis of the cores. This study is valuable because it provides a data base that will help clarify how fluid flows in Bear Creek Valley. This data base can be combined with hydrologic data to predict transport directions and to model the hydrologic system, and both of these activities will positively support ongoing studies on how to contain contaminant migration.

*Postdoctoral Fellow, Oak Ridge Associated Universities, Oak Ridge, Tennessee.

Selected Shales Are Characterized Mineralogically in Support of Nuclear Waste Repository Studies

S. Y. Lee, L. K. Hyder, and P. D. Alley*

After critical evaluation of a broad range of issues related to repository performance, shale was identified as a most favorable candidate among selected sedimentary rocks for use as a nuclear waste repository. Favorable geochemical, physical, and hydrological properties of shales were the determining factors in the selection. Because these favorable properties could depend on the mineralogy and micromorphology of the shales, five shales were selected for comprehensive characterization.¹ Baseline characterization is critical to the interpretation of results from studies of radionuclide retardation, groundwater composition, and other geochemical processes.

The Chattanooga Shale has a relatively low surface area (4.6 m²/g) for its moderately high illitic clay (35%), organic matter (11%), and pyrite (6%) contents. The high organic and pyrite contents in this shale are significant characteristics because they may at least partially control groundwater chemistry. The loosely packed Pierre Shale has a high surface area (23 m²/g) as well as a high smectitic clay content (69%). The smectite has an important engineering characteristic for seal and backfill materials. The micropores and fractures observed in the dehydrated state of this shale would be sealed by the swelling of smectitic clays when they are rehydrated. The Green River Formation consists of tightly packed carbonate minerals and has a low surface area (2 m²/g). High-resolution electron microscopy revealed that the carbonate and other minerals are cemented by amorphous silica and carbonates. Such extensive cementation gives physical stability to the rock, and it locks the organic matter in isolated micropores. Both the Nolichucky and the Pumpkin Valley shales had moderate surface areas (13–15 m²/g) and illitic clay contents (30–51%). The presence of micropores with and without carbonate fillings was frequently observed in both shales.

The results confirm that mineralogy and microstructure control many apparent chemical and physical properties of the shales. Because compositional and mineralogical parameters would be of high priority if shales were seriously considered as a repository host rock,

information gained from this activity could be invaluable in helping to narrow the number of potential shale units for further study.

*Miami University, Oxford, Ohio.

1. S. Y. Lee, L. K. Hyder, and P. D. Alley, *Mineralogical Characterization of Selected Shales in Support of Nuclear Waste Repository Studies: Progress Report*, ORNL/TM-10567, Oak Ridge National Laboratory, 1987.

1.6 TECHNICAL AND ADMINISTRATIVE SUPPORT ORGANIZATION

J. L. Trimble

C. H. Abner ¹	P. G. Epperson	C. A. Kappelmann	D. L. Rich ²
R. R. Adams ²	K. N. Gibson	L. W. Littleton	L. E. Roberson ⁵
J. T. Addison ³	N. A. Griffith	G. M. Logsdon ³	M. K. Savage ³
L. M. Apley	A. L. Harkey ³	R. K. McConathy	W. J. Selvidge
A. G. Arp	T. R. Henry ²	A. B. McDaniel	K. T. Strange ⁴
R. E. Booker ²	R. A. Hoffman ⁴	T. C. Minton ¹	T. T. Vann ⁶
S. D. Bridges ¹	J. E. Holbrook ²	S. Y. Porter	
P. V. Carson	L. J. Jennings	A. L. Ragan ³	
D. H. Deaton	D. S. Johnson ⁴	D. D. Rhew	

The Technical and Administrative Support Organization of the Environmental Sciences Division (ESD) provides technical, informational, publications, and operational support for the research and development activities of ESD. During FY 1988, the Technical and Administrative Support functions were challenged to meet the growing needs of the Division, to adapt and upgrade tracking and reporting systems, and to respond to new and increasing requirements. At the end of this reporting period, ESD had a budget of \$40.8 million and 205 employees and had hosted more than 200 guests. As the fourth largest research division at Oak Ridge National Laboratory (ORNL), ESD is fiscally complex: 10 different U.S. Department of Energy sponsors support 64 field work proposals, and 18 other sponsors support 60 interagency agreements.

The technical activities of the Organization primarily support ESD management and include preparing and submitting briefing materials, award fee accomplishments, and components of the institutional plan¹ and the annual report on biomedical and environmental sciences at ORNL.² Technical and Administrative Support staff were actively involved in the preparations for the ESD Annual Information Meeting, held May 24–26, 1988.

Information- and publications-related support is provided to all ESD staff and visitors and includes document preparation (through the Publications Office), editing, graphic arts, and library services. Document preparation and graphic arts support are now based on the use of personal computers (PCs). The Wang word processing system, in use for over a decade, has been nearly phased out and replaced by PCs equipped with WordPerfect software, and the Publications Office equipment is now fully compatible with that of the clerical staff and most of the technical staff. Capabilities in graphic arts have been enhanced by the acquisition of additional PCs and a laser printer for generating

-
1. Plant and Equipment Division, ORNL.
 2. Graphics Division, Martin Marietta Energy Systems, Inc.
 3. Publications Division, Martin Marietta Energy Systems, Inc.
 4. Information Services Division, Martin Marietta Energy Systems, Inc.
 5. Quality Department, ORNL.
 6. Finance and Materials Division, ORNL.

publications-quality black-and-white drawings, graphs, and word slides. Color graphics are available within 24 to 48 h through mainframe computer systems.

The ESD library, a part of the Martin Marietta Energy Systems library collection, is linked electronically to the LION computer network to facilitate access to the entire Energy Systems collection. The ESD library houses 11,654 books, 244 journals, and over 8,000 reports. The library was renovated this year to increase the shelf space, the study area for the users, and the work area for the librarians. Compact shelves were installed on a track system, which increased shelf capacity by 50% and freed essential floor space. In addition, three compact disk ROMs (read-only memories) were acquired: one contains bibliographic information on aquatic science and fisheries, and two contain numeric data on hydrology and climate.

Operational support activities include safety, radiation control, training, quality assurance, waste generation certification, engineering and craft services, and computer operations. The Division received a safety rating of superior for the seventh consecutive year and has never had a recordable injury or illness. Safety activities include quarterly safety meetings for all ESD staff and quarterly safety inspections of all ESD facilities. Safety orientations for new staff have continued, with emphasis on regulations, requirements, and the individual's responsibilities. Training activities and requirements are expanding in response to increasing changes in ORNL procedures and accountability requirements. The Division is now responsible for ensuring that staff receive appropriate training and for keeping formal records. This year staff completed training required for generators of solid low-level waste and training in connection with the Superfund Amendments and Reauthorization Act of 1986 and the Occupational Safety and Health Administration. A full-time quality assurance specialist from the Quality Department is helping ESD staff apply NQA-1 quality requirements to research, development, and assessment activities. A quality assurance plan was prepared for the toxicology laboratory. In addition, ESD is developing an NQA-1 implementation plan that will apply to all Division projects. Waste generation continues to be a concern as the Division identifies and cleans old research sites and facilities. To meet the established waste generation goals, ESD is continuing to minimize the amount of routine waste it generates.

The computing operations within ESD, directed by R. A. McCord with guidance from the ESD Technical Computing Advisory Committee, continue to expand. During FY 1988 several items were added to expand computing capability for administrative and scientific tasks: a high-capacity tape drive, a VAXStation 2000, a MicroVAX 3500, an HP LaserJet 2000 printer, and local area VAX cluster and VAX/VMS services for MS-DOS software. The Wang word processing network and the limited PC network previously used by administrative support and management staff were removed, and initial steps toward installation of a Division-wide DECnet/Ethernet local area network were completed. This network will provide the file- and data base-sharing functions previously provided by the Wang and PC networks.

1. H. Postma, J. R. Merriman, F. R. Mynatt, C. R. Richmond, M. W. Rosenthal, D. B. Trauger, R. S. Wiltshire, A. Zucker, M. L. Sollenberger, T. D. Anderson, J. R. Engel, L. L. Horton, C. A. Johnson, R. E. Pudelek, and J. E. Swift, *Oak Ridge National Laboratory Institutional Plan FY 1988-FY 1993*, ORNL/PPA-87/2, Oak Ridge National Laboratory, 1987.

2. C. R. Richmond and C. A. Johnson, *Biomedical and Environmental Sciences Programs at the Oak Ridge National Laboratory*, Oak Ridge National Laboratory, 1988.

Program Activities

2

2.1 BIOMASS PRODUCTION PROGRAM

J. W. Ranney
J. H. Cushman

J. N. Brantley	W. A. McNabb
D. H. Dawson ¹	R. J. Norby
T. W. Doyle ²	E. G. O'Neill
A. R. Ehrenshaft ³	D. E. Todd, Jr.
P. L. Henry	T. J. Tschaplinski ⁴
D. W. Johnson	A. F. Turhollow ⁵
J. W. Johnston, Jr.	C. R. Wenzel ⁶
P. A. Layton	L. L. Wright
R. J. Luxmoore	

2.1.1 Introduction

The Biomass Production Program (BPP) is a 10-year-old interdisciplinary program of research on plant growth. The BPP includes three divisions at Oak Ridge National Laboratory (ORNL), more than 25 other institutions (most of which are land grant universities), and several consulting scientists across the country. The BPP mission is to improve the productivity and cost efficiency of specialized energy crops destined for conversion to liquid fuel. The Environmental Sciences Division (ESD) manages the BPP for the Biofuels and Municipal Waste Technology Division, a part of the Conservation and Renewables activities of the U.S. Department of Energy (DOE). The BPP has three major components within ORNL: Herbaceous Energy Crops; Short Rotation Woody Crops; and in-house research focused on physiology, nutrient cycling, economics, and data management/synthesis. With the exception of rapeseed for diesel oil production, all energy crops under study are primarily lignocellulosic; that is, they are being developed for organic matter production (cellulose, hemicellulose, lignin, and nonstructural carbohydrates) rather than for oil, special carbohydrates, or protein.

The objective of BPP research has been to improve the productivity, cost efficiency, and energy qualities of dedicated energy crops grown for conversion to liquid and gaseous fuels. Emphasis is now changing from species screening and cultural trials to defining whole-plant physiological bases for genetically and culturally increasing productivity and stress tolerance in model representative species. Results from this research have implica-

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tions for domestically produced liquid fuels, climate change, farm policies, land stabilization, and our understanding of plant growth processes.

BPP research in ESD focuses on physiology and nutrient cycling of plants under various soil nutrient conditions. Objectives of this work are to define aspects of nutrient use efficiency in the context of productivity, nutrient cycling, and nutrient losses through leaching and volatilization. Increasing emphasis is being placed on studies that identify the kind, amount, and distribution of photosynthates above and below ground in response to soil nutrient status and soil moisture status, especially drought stress. Still other studies are defining the potential of old-field successional species for producing biomass under various practices.

Whole-plant physiologically based research is providing valuable information about plant responses to combinations of environmental stresses in the laboratory and field. This coincidentally may help in understanding how climate change may affect plant systems and how plant systems can be used to pull carbon dioxide, the major greenhouse gas, out of the atmosphere. These considerations, along with the potential of plants to displace fossil carbon sources in the production of liquid fuel, have significant implications with regard to the issue of global climate change. Inquiries from interest groups concerned about this topic have dominated information dissemination activities this year. Such groups have included the U.S. Environmental Protection Agency, the U.S. Agency for International Development, and the International Energy Agency. The national data base on lignocellulosic energy crops at ESD is gradually attaining international recognition for its size, its uniqueness in covering almost an entire continent, and its quality and detail.

Because it is the mission of the BPP to produce economically feasible biomass feedstocks for biofuel conversion facilities, several efforts have been under way to identify how biomass can be grown to help the biofuel conversion process. Chemical analyses of biomass samples for new energy crops, studies of their behavior in biofuel conversion processes, and estimations concerning the feasibility of genetically altering biomass qualities are in progress under cooperative agreements with the Solar Energy Research Institute, the Forest Products Laboratory [U.S. Department of Agriculture (USDA), Madison, Wisconsin], the Institute of Paper Chemistry, and Auburn University.

An assessment has also been made on how much biomass could be produced in the United States for conversion to liquid or gaseous fuels. With potential economic feasibility as a major limiting assumption, 5 or more exajoules would be derived from specialized energy crops under research in the BPP. The potential for more energy exists but at costs in excess of \$2.00 per gigajoule, the goal established by DOE. Present estimates of energy crop costs are in the range of \$1.90 to \$3.75 per gigajoule delivered. The economic evaluations conducted on energy crops have been thorough and are being used by several agencies and the participants of the International Energy Agency so that accurate comparisons can be made.

Productivity rates of new energy crops have been phenomenal, attaining in excess of $40 \text{ Mg}\cdot\text{ha}^{-1}\cdot\text{year}^{-1}$ but occurring most often in the 10- to 20-Mg range. With energy benefit:cost ratios of around 12:1, much better than for conventional agricultural crops, it remains a challenge to maintain or increase productivity while improving the energy benefit:cost ratio. Improvements facilitated through biotechnology, genetics, physiology, culture, and handling and storage techniques should provide the necessary gains.

This past year, significant steps have been taken to convince other agencies, the biomass and energy industry, and farmers that biomass crops may indeed hold great

potential for return. Briefings to the USDA Conservation Reserve Program and to DOE's Regional Program for Technology Transfer, as well as contacts with states and resource interest groups, are resulting in the establishment of more plantings of biomass crops. Industrial plantings of rapeseed and American sycamore in the Southeast and hybrid poplars in Oregon and the upper Midwest are increasing in spite of falling oil prices, which might be expected to decrease interest in alternative forms of energy.

2.1.2 Technical Summaries

Evaluating Biotechnology Research Alternatives Provides a Map for Biomass Research Initiatives with Achievable Goals

P. A. Layton, D. D. Ellis,* and B. H. McCown*

The use of biotechnology in agriculture and forestry has only recently begun to be applied to solving problems inherent in growing plants under intensive culture. During the last year, a critical evaluation was made of the status and use of biotechnology in the Biomass Production Program (BPP). The scope was restricted to the problems that occur in the production of the raw material and not in their conversion to fuels. Funding and time limits were considered. The focus was limited to four herbaceous plants and seven woody plants that have been actively investigated by the BPP.

The major problems identified as approachable by biotechnology for the herbaceous plants include weed control during stand establishment and feedstock quality. Because these crops can be improved by classical breeding and be propagated efficiently by seeds, the importance of biotechnology is lessened. However, because little is known about feedstock qualities, their variability, or the potential to change them through biotechnology, it was recommended that they be evaluated in the herbaceous and woody crops. The major problems approachable by biotechnology for woody plants include weed control, cloning, pest control, sexual sterility, and nitrogen nutrition. These plants are not readily improved by using classical breeding methods; therefore, biotechnology has an important place in their utilization. Ongoing research using both somaclonal screening and gene insertion to obtain herbicide resistance (Fig. 34) should be continued to conclusion, including field testing. This research is the preeminent example of the application of biotechnology to woody crops and allows comparison of two biotechnological methods to obtain the same trait.

New research areas were identified: (1) development of in vitro cloning methods for energy crop species, (2) somaclonal variation and/or gene transfer to enhance disease tolerance, (3) inducement or transfer of sexual sterility to poplars to prevent gene migration to native populations, and (4) transfer of genes to black locust to prevent insect damage. At higher funding levels, research on temporal and/or spatial gene promoters is necessary so that transferred genes can operate where and when they are needed. This research does not call for technique development per se but assumes the rapid incorporation of new techniques. The research should be coordinated with that of other agencies to



Fig. 34. Analysis of DNA by gel electrophoresis to determine if gene transfer has been successful.

make the best use of limited available dollars. This program of research establishes the BPP as a world leader in the application of biotechnology to the development of energy crops.

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Successional Vegetation Offers an Economical Alternative for Energy Feedstock Production

J. W. Johnston, Jr.

Successional vegetation offers a low-input, low-risk alternative for the production of lignocellulosic energy feedstock materials. Levels of productivity ranged from 2 Mg/ha with two harvests per year and no fertilizer additions to as much as 7 Mg/ha with a single annual harvest and the addition of either N-P-K fertilizer and lime in an abandoned pasture with low-pH soils or N and P fertilizer in an abandoned soybean field. (Figure 35

shows the high productivity of the test plots at the soybean field.) The yields from this successional vegetation study fall into the upper portion of the productivity range for similarly fertilized perennial forage crops whose potential for energy feedstock production is being tested in the southeastern United States. The chemical composition of successional vegetation offers no known constraints for use as an energy feedstock in any of the conversion processes currently under consideration by DOE, and the structural carbohydrate fraction (up to 70%) is superior to that of many of the energy feedstock candidates currently under consideration.

In addition to the positive production and compositional characteristics of successional vegetation, numerous agronomic and environmental factors make feasible its use as an

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Fig. 35. The productivity of successional vegetation in test plots at an abandoned soybean field in 1987. Given the record-setting drought conditions, biomass production of 7 Mg/ha was exceptional, surpassing the productivity of many drought-hardy perennial forages being tested for energy crop potential under similar conditions in the southeastern United States.

energy feedstock. Successional vegetation automatically invades unmaintained agricultural land. Therefore, there are no establishment costs, and the risk of establishment failure is minimal. Ground cover is rapidly established, reducing the risk of losses in site productivity and environmental degradation that result from soil erosion. All sites suitable for crop production, and many that are not, will support robust successional plant communities capable of producing significant quantities of lignocellulosic feedstock material. The genetic diversity inherent in a multispecies plant community provides a buffering capacity against environmental stresses and biological pests. The loss of one or more species to stresses or pests is likely to be compensated for by other members of the community. In summary, successional vegetation is sufficiently productive and chemically suitable to warrant consideration as a contributing source of lignocellulosic energy feedstock material.

Photosynthetic Rates, Pigment Concentrations, and Nitrate Reductase Activity Are Sensitive Bioindicators of Sycamore Response to Nitrogen Fertilization

T. J. Tschaplinski, R. J. Norby, D. W. Johnson, and D. E. Todd

Maximum efficiency in biomass production in short-rotation intensive culture of woody plants requires optimum nitrogen fertilization, defined as that which maximizes growth and minimizes nitrate leaching to groundwater with minimal effect on the physiological processes that alter a tree's resistance to environmental stress. At ORNL, we are investigating the effects of urea-nitrogen fertilization applied under various timing regimes in plantations of sycamore. Tree growth and physiological parameters were monitored over the growing season to determine which parameters would be the best indicators of the onset of nitrogen deficiency. Physiological parameters included net photosynthetic rate, pigment concentrations, plant water relations, osmotic potentials at full turgor and at turgor loss, and soluble sugar concentrations in leaves and stems. Nitrogen status was assessed by nitrate reductase activity in leaves, and by concentrations of nitrate, soluble protein, total nitrogen, and specific amino acids.

The greatest aboveground biomass accumulation (three times greater than that of unfertilized controls) was obtained with a heavy single addition of nitrogen (450 kg/ha), but nearly as much biomass was obtained when much less nitrogen was added either early in the season (150 kg/ha) or in periodic applications (37.5 kg/ha three times), with the difference lost as a result of leaching. The increased growth resulted from an early-season stimulation of leaf area production and a stimulation of photosynthetic capacity later in the growing season. There was no evidence that fertilization extended the physiologically active season or increased susceptibility to drought or frost. Photosynthetic pigment concentrations, net photosynthetic rate, and nitrate reductase activity in leaves were sensitive indicators of plant response to nitrogen fertilization, but foliar concentrations of nitrate, total nitrogen, soluble carbohydrate, and soluble protein were poor indicators. Amino acid concentrations were indicative of nitrogen deficiency, but the response was somewhat delayed, limiting their use as sensitive indicators. If nitrogen greatly stimulates photosynthesis and growth in sycamore, it remains to be determined how the increased assimilation of nitrogen and carbon is accomplished without an accumulation of metabolites. Future

work will focus on the turnover of key metabolites (e.g., glutamate, glutamine, glucose, fructose, sucrose, and starch) under the different fertilization regimes.

These initial results suggest that some nitrogen fertilization strategies for increasing growth may not result in optimum ecosystem retention of nitrogen and minimize nitrate contamination of groundwater. Carefully timed (dependent on bioindicators) applications of low levels of nitrogen fertilizer can optimize growth with fewer environmental consequences.

Research of the Energy Poplar Consortium Is Given Direction

L. L. Wright

The Short Rotation Woody Crops Program (SRWCP) of DOE has been a major supporter of poplar research in the United States since 1978. To date the program has spent about \$4 million on poplar research. The SRWCP expects to spend \$1 to \$1.5 million per year (about 60% of its research) distributed among five to seven subcontractors over the next few years. The goal is to improve the genetics and cultural management of poplars for use as energy crops as quickly and cost effectively as possible. Coordination and focusing of the ongoing and planned research were necessary to ensure achievement of the SRWCP's goals.

SRWCP staff took the initiative to form a consortium of SRWCP-funded poplar researchers in the United States and to engage their participation in developing a comprehensive plan for coordinated and focused research on poplars. The consortium approach was expected to capitalize on the interdisciplinary synergism that results from bringing investigators in specialized fields together to work on a common goal. A preliminary integrated research plan was prepared, distributed to key poplar researchers in the United States, and then revised following a workshop of about 20 of these scientists.

The resulting research plan of the Energy Poplar Consortium documents general goals, a conceptual framework, anticipated participants, specific milestones with a timetable, and the required coordination effort of SRWCP staff. The conceptual framework of the plan assumes that an "ideal," economically viable, operational wood energy production system will be developed only if the biological components of the system are optimized in an integrated fashion. Recommendations in the plan include (1) the support of at least two or optimally three centers for poplar breeding research in the United States, (2) the incorporation of research on whole-tree physiology into genetic and cultural evaluations, (3) the utilization of biotechnological advances to enhance ongoing breeding programs, (4) the development of growth and energy models with predictive capability that can factor in climatic and cultural variables, (5) the establishment of field trials of sufficient size to serve as technology transfer tools for demonstrating the effectiveness of short-rotation intensive culture (SRIC) in producing energy wood, and (6) the development of links between plant research and conversion research to facilitate the ultimate DOE goal of improving a complete liquid biofuel pathway. One of the major decisions made by the consortium was to make disease resistance a primary selection criteria in all breeding programs. Another decision was to place high priority on the evaluation of the energy qualities of SRIC wood.

The Energy Poplar Consortium has the potential of becoming a major force in shaping the direction of poplar research in all of North America. This plan can serve as a basis for decisions about funding poplar research within DOE's SRWCP. Several non-SRWCP scientists (including Canadians) have requested the opportunity to participate in the consortium, and consortium workshops and communications could informally serve to coordinate SRWCP work with that of other major poplar research programs.

Economic Energy Potential of Biomass Is Significantly Improved with New Biomass Energy Crops

J. W. Ranney and A. F. Turhollow*

The U.S. energy potential from biomass converted to a liquid fuel remains poorly defined but is of increasing interest because such a fuel would displace fossil fuels and their CO₂ emissions. The poor definition of this potential comes from an inexact awareness of (1) land use and environmental issues, (2) energy costs and logistics from the viewpoint of utilities and refineries, (3) the economic accessibility of huge biomass inventories, (4) international economic competitiveness, and (5) new technological developments. Given the environmental ultimatum for CO₂ cleanup, the practical necessity for liquid fuel, and the need for domestic fuel security in a competitive international market, biomass energy may emerge as a very important component of our energy supply.

An assessment was conducted that recognized these problems and constraints in determining U.S. biomass energy potential. The assessment included all renewable (nonfossil) biomass sources under practical assumptions about the economy, land availability, productivity, and conversion efficiency, and included new energy crops. A potential of no more than 31.8 EJ/year of gross energy content was estimated at a cost of about \$2/GJ. This converted to a net energy contribution of about 14.6 EJ/year as liquid fuel and an additional 2.2 EJ produced as electricity and chemicals. A 50% efficiency for biofuel conversion was assumed for most technologies. It was also assumed that most of the waste products from conversion could be used to fuel the conversion processes or to produce by-products. Greater conversion efficiency would be at the expense of energy self-sufficiency and the generation of by-products.

Of the gross 31.8-EJ energy potential, 8.5 EJ is lost before the biomass enters the conversion process. An additional 7.2 EJ is lost in conversion, and 1.5 EJ of external energy is brought in to fuel selected steps in the biofuel pathway. Energy crops that are entirely new should account for 37% (11.7 EJ) of the expected biomass available in the future, with only 12% (1.4 EJ) being lost to production activities. These new energy crops will play a key role in logistical considerations of biomass supply and assurance for conversion facilities. In the determination of biomass energy priorities, the productivity rates and production efficiency of the new crops are as important as the improvement of efficiency in biofuel conversion.

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2.2 CARBON DIOXIDE INFORMATION ANALYSIS AND RESEARCH PROGRAM

M. P. Farrell

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2.2.1 Introduction

As part of the Environmental Sciences Division (ESD) at Oak Ridge National Laboratory (ORNL), the Carbon Dioxide Information Analysis and Research Program (CDIARP) is operated for the U.S. Department of Energy (DOE) Carbon Dioxide Research Division, Office of Basic Energy Sciences. CDIARP consists of three components: (1) the Carbon Dioxide Information Analysis Center, (2) Resource Analysis, and (3) the Global Carbon Cycle Research Program.

2.2.1.1 Carbon Dioxide Information Analysis Center

The objective of the Carbon Dioxide Information Analysis Center (CDIAC) is to compile, evaluate, and distribute CO₂-related information in support of the DOE Carbon Dioxide Research Division (CDRD). To accomplish this objective, CDIAC identifies researchers' needs for data and computer hardware, software, and languages; it obtains, evaluates, and ensures the quality of information; and it works with other national and international data centers as well as with individual researchers to promote and facilitate the exchange of data.

CDIAC has two types of functions: (1) analyzing data and other types of information and (2) distributing CO₂-related information. In fulfilling the first function, CDIAC evaluates and ensures the accuracy of many types of information, including numeric data and computer models. CDIAC also engages in studies such as estimating the effects that a rise in sea level will have on coastal resources and evaluating the use of sound to analyze multivariate data.

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In fulfilling its second function, CDIAC serves as the CDRD information distribution center. In 1988 CDIAC received 3069 requests for different types of information. In response to many of these requests, 4258 reports and 522 numeric data packages and computer model packages were distributed. In addition, 22 searches of the CDIAC Bibliographic Information System (a computerized bibliography on CO₂) were performed, requiring the evaluation of 2788 references. As an additional service for CDRD, CDIAC maintains a directory that lists ~4000 researchers and policy makers from 149 countries.

Many CDIAC activities continue from year to year—for example, evaluating and packaging numeric data and computer models, expanding the Bibliographic Information System, and examining the effects on resources as changes occur in the concentrations of atmospheric CO₂. CDIAC also works on special projects for CDRD. (A special project is one for which CDIAC helps develop the groundwork.) One project that began in 1985 and continued through 1988 was a collaborative research project with the People's Republic of China and DOE. CDIAC developed and implemented a computer system for facilitating the exchange of >64 million data elements and provided continuing technical personnel support for the research. During 1988, CDIAC staff continued to provide technical support by updating and testing the computer systems.

Data and information analyses

CDIAC increased its numeric data packages (NDPs) to 32 by assembling 9 NDPs during FY 1988. (In addition, 4 of those 32 packages have been revised.) The NDP documentation consists of an abstract, a data listing (either in tabular form or on microfiche), a FORTRAN data retrieval program, graphical displays of the data, and pertinent literature. CDIAC distributes the NDP-associated data files on magnetic tape or, when feasible, on floppy disk.

The nine NDPs include A Global Planktonic Foraminifers Data Base for Evaluation of the Stability of Low-Latitude Sea Surface Temperatures (NDP-024); Monthly Mean Pressure Reconstructions for Europe (1780–1980) and North America (1858–1980) (NDP-025); Climatological Data for Clouds over the Globe from Surface Observations (NDP-026); GEOSECS Atlantic, Pacific, Indian, and Mediterranean Radiocarbon Data (NDP-27); Carbonate Chemistry of the Weddell Sea (NDP-028); Carbonate Chemistry of the North Pacific Ocean (NDP-029); Estimates of CO₂ Emissions from Fossil Fuel Burning and Cement Manufacturing Using the United Nations Energy Statistics and the U.S. Bureau of Mines Cement Manufacturing Data (NDP-030); Average Total Snowfall Data for Selected U.S. Stations (NDP-031); and Antarctic Surface Temperature and Pressure Data (NDP-032).

CDIAC did not assemble any computer model packages (CMPs) during FY 1988 but still offers a mainframe version and a personal computer version of the IEA/ORAU (Institute for Energy Analysis/Oak Ridge Associated Universities) Long-Term Global Energy CO₂ Model. Other packaging activities during FY 1988 included notifying all previous recipients of the availability of updated packages and sending lists of the requesters of each NDP to the original contributor(s) of the data. In addition, an automated tape-generating system to fill requests for NDP magnetic tapes was used during FY 1988. Another FY 1988 activity closely associated with packaging was the development of a computerized data inventory system for all data bases currently archived at CDIAC.

Information distribution

Bibliographic Information System. The CDIAC Bibliographic Information System (BIS) contains 9677 references, an increase from 9100 at the end of FY 1986. Citations are entered into BIS according to the following CDRD program area classifications: climate, carbon cycle, vegetation response, and resource analysis. CDIAC is working with the DOE Office of Scientific and Technical Information to merge BIS into the DOE Energy Data Base.

During FY 1988, CDIAC also published and distributed C. A. S. Hall's bibliography entitled *Tropical Rain Forests and the Global Carbon Cycle*. This bibliography, which is a compendium of nearly 2000 entries, is Volume I of a two-part series. Volume II will be *An Ecological and Land-Use Bibliography on South and Southeast Asia*, by J. F. Richards.

Communications. CDIAC publishes a semiannual newsletter, *CDIAC Communications*, which is distributed to all persons listed in the CDIAC directory. (The number of persons listed in the directory increased from 3372 to 4094 by the end of FY 1988.) *CDIAC Communications* informs CO₂ researchers and policy makers of current research, recent policy decisions, CDIAC services, and new CO₂-related publications and meetings.

Networking. One of the CDIAC objectives is to work with data centers, universities, and individual researchers to promote and facilitate the exchange of data. During FY 1988, CDIAC staff engaged in several activities toward this end, including both organizing and attending symposia and workshops and working with researchers to obtain and distribute important CO₂ data sets.

2.2.1.2 Resource Analysis

Changes in climate and vegetation caused by increasing concentrations of atmospheric CO₂ may have significant consequences for human health and welfare. Many important resources, such as agriculture, forests, fisheries, human populations, and water resources, could be affected by the interactive impacts of changing atmospheric CO₂ and climate. Some of these resources will be affected primarily by climate; for others, the direct effect of CO₂ may be significant. Additionally, coastal resources may be sensitive to rising sea level (caused by global warming) and related factors, such as changes in tidal regime. Effects on resources such as these could have important implications for industrial productivity, land use, and energy use. The Resource Analysis Group within CDIARP is charged with managing and carrying out the appropriate research and analytical tasks to address these issues.

The objective of the Resource Analysis Group is to participate in integrated quantitative analyses of the effects of CO₂-climate changes on key resources on a regional basis, analyzing the pros and cons of various adaptive or corrective measures. The effects of both CO₂ and climate will be considered, and important connections between key resources will be accounted for.

To fulfill these objectives, the following types of questions must be answered: What are the most important resource areas and resource issues for analysis? What are the most important interresource connections? What are the best definitions of regions to be used in these analyses? What analytical approaches are best for these analyses? How satisfactory is our understanding of the response of resources both to CO₂-climate change and to other

important factors, such as technology or government/economic actions, and what additional models need to be developed? How much of the required data base is available, and what additional data need to be developed for the analyses?

2.2.1.3 Global Carbon Cycle Research Program

The main objective of the Global Carbon Cycle Research Program is to develop a scientific basis for predicting changes in concentrations of atmospheric CO₂ in response to continued releases of CO₂ by fossil fuel combustion.

Measurements of atmospheric CO₂ levels since 1958 at the Mauna Loa Observatory have shown a recent increase, which could have significant repercussions on climate and plant development and could have many secondary impacts. Scientists are characterizing the patterns and processes of the global carbon cycle to predict future increases in atmospheric CO₂ and the potential impacts of fossil fuel burning. The DOE Carbon Dioxide Research Program requires this information to formulate energy policies related to fossil fuel use.

During the past decade, major progress has been made in measuring and understanding the global carbon cycle and in developing methods for projecting future changes in atmospheric CO₂. Significant steps have been achieved in estimating the sizes of the carbon reservoirs, examining the components of the ocean carbon cycle, estimating the fluxes between the terrestrial biosphere and the atmosphere, and integrating components of the carbon cycle into global models. Nevertheless, uncertainties in quantitative estimates and in the current understanding of major carbon cycle processes are large enough that there is little confidence in projections of future levels of atmospheric CO₂.

The approach of the Global Carbon Cycle Research Program is to organize data collection and analyses as well as modeling studies around three questions that provide a framework within which assumptions can be tested and uncertainties reduced:

1. What are the ramifications of assuming that disturbances from fossil fuel burning dominate the carbon cycle processes that regulate atmospheric concentrations of CO₂?
2. Will the assumption that carbon cycle processes remain unaltered by future levels of atmospheric CO₂ cause significant errors in projections of atmospheric CO₂?
3. What additional knowledge of carbon cycle processes is needed to accurately estimate future concentrations of atmospheric CO₂?

The priority of research over the next decade is to emphasize the first two questions, although future findings may require reevaluation of the importance of particular research studies. Answering the first question is critical because current knowledge is insufficient to corroborate or negate the possibility that uncertainties of ocean- and land-use dynamics are as important as fossil fuel burning in explaining the observed increases in atmospheric CO₂ levels. The second question is important because CO₂ projections that are made without considering altered feedbacks or their potential for changing carbon cycle processes would be inaccurate.

Major program accomplishments during 1988 include (1) implementing a multi-organization research program that will evaluate the contribution of land-use changes to atmospheric CO₂ concentrations, which are currently estimated at 0.4 to 2.9 Pg of carbon

per year; (2) conducting a workshop to estimate the potential flux of CO₂ and methane from northern ecosystems; (3) establishing the first of two centers for studying ocean carbon dynamics through the use of three-dimensional ocean models; (4) estimating seasonal latitudinal CO₂ fluxes for the oceans, which indicate the oceans may be capable of taking up 50% of anthropogenic CO₂; and (5) evaluating how forest ecosystems reduce atmospheric CO₂ concentrations.

Summaries of specific research sponsored by CDIARP follow.

2.2.2 Technical Summaries

Global Reforestation Could Play a Significant Role in Addressing the CO₂ Problem

G. Marland

It may become necessary to limit the increase in atmospheric CO₂ in order to prevent adverse effects on the global climate. Limiting CO₂ must ultimately require decreased reliance on fossil fuels. Because fossil fuels play a major role in the global economy, we must determine if there is some short-term way to limit increases in atmospheric CO₂ while providing time for the global energy system to be diverted from its addiction to fossil fuels.

One short-term approach would be to stimulate the growth of forests so that enough carbon would be taken up in woody matter to counter the discharge of CO₂ from fossil fuel burning. Although it is more likely that forestry will be only one component of a host of schemes implemented to control the CO₂ increase, this study explores the magnitude of the effort required for using trees to take up an amount of carbon equal to the current annual discharge from fossil fuel burning. How much would we have to increase the area and/or net annual growth rate (mean annual increment) of global forests in order to remove an additional 5 billion tons (net mass) of carbon per year from the atmosphere?

Although it is physically possible to plant large areas of new plantation and/or to stimulate tree growth through advanced silvicultural techniques, conflicts in land use and resource allocation are quickly encountered in efforts of sufficient magnitude. We also confront the reality that, although net decreases in forest area may have ceased in many temperate regions, the earth is still experiencing significant deforestation in the tropics. The scale of the effort required is approximately equal to doubling the net annual yield of all of the world's closed forests or planting new fast-growing forests over an area equivalent to the total area of global forest clearing to date.

Although it is impractical to expect to solve the CO₂ problem through forestry alone, it is clear that global reforestation could play a significant role in the process of limiting atmospheric CO₂ increases.

Simulations Delineate the Potential Response of Pacific Northwest Forests to Increasing Temperatures

V. H. Dale

The potential for climate change in the near future mandates a need to understand the range of responses of forests to predicted climatic conditions. Increases in atmospheric CO₂ have been measured since 1958; a possible consequence of these increases is a 1.5–4.2°C rise in the global average temperature. Understanding how forests respond to changes in temperature is critical to predicting the global impacts of increased CO₂ because forests cover more than one-third of the globe and store more than 80% of the terrestrial organic carbon. Predicting the effects of changes in climate can best be achieved on a biome-by-biome basis because each area is likely to experience unique climate changes and because the species composing each biome will have distinct limitations to temperature and moisture conditions.

The Pacific Northwest was targeted for this study because of the high productivity and the high biomass concentrations of the forests. Long-term records of stand structure and climate as well as simulations of forest development under different scenarios were combined to assess the future impacts of potential temperature changes in the Pacific Northwest.

The predicted rapid climatic change would expose the Pacific Northwest forests to temperatures that are very different from those experienced recently and could alter the patterns of forest development directly, by changing species composition, or indirectly, through its effects on disturbances exogenous to the forest ecosystem (e.g., bark beetle outbreaks). Significant changes in September temperatures in northwestern Oregon have been revealed by analyses of the last 100 years of climate data. Measures of stand development obtained over the past seven decades are typical of stands dominated by Douglas-fir: stem density declines, leaf area stabilizes, aboveground biomass increases, and shifts in size distribution occur. The observed structural changes are consistent, however, with patterns of natural succession and are not necessarily due to changes in temperature. Using different climate scenarios, a model of forest development predicted changes in species composition, leaf area, and stem density in response to climate changes. Changes in species composition might require alterations in current management practices. Total aboveground biomass was not sensitive to the simulated temperature alterations. Biomass stability suggests that the Pacific Northwest forest would continue to store large amounts of carbon in the living trees. Therefore, the predicted climate change would not alter the role of the Pacific Northwest forests as a major storage location of terrestrial carbon.

A Warmer Climate Will Alter the Role of Peatlands, Tundra, and Boreal Ecosystems in the Global Carbon Cycle

W. M. Post

Anticipated climatic change caused by increased levels of atmospheric CO₂ may have dramatic impacts on the source-sink relationships of peat and other pools of “subfossil” organic matter (i.e., bogs, tundra, and forests of the boreal zone) and may alter current

methods of projecting future levels of atmospheric CO₂. Currently, these ecosystems are a net sink of atmospheric CO₂. Drainage and climatic change may be altering this former sink of organic humus into a source of CO₂.

Leading North American researchers assembled at a workshop to estimate the net flux of carbon cycle gases between ecosystems and the atmosphere in the Northern Hemisphere. These estimates were based on the projected climate that would result from atmospheric CO₂ concentrations approaching 580 ppmv.

At the workshop, tundra and boreal working groups were formed to provide draft calculations of net biosphere-atmosphere fluxes of CO₂ and methane. For the purposes of calculation, a conservative estimate of 5°C average annual temperature increase was assumed for these latitudes. The important influence of hydrological factors on the anaerobic conditions favorable to peat formation and the uncertainty in projected changes in precipitation necessitated parallel computation for two climate regimes—warmer climate with unchanged hydrology (warm-wet) and warmer climate with water tables lowered by 10 cm (warm-dry). The potential contribution of increased fire frequency in these ecosystems was computed as an additional CO₂ release. The effect of fires on methane production could also be large, but too much uncertainty exists for an estimate to be included.

The estimates of increased rates of CO₂ and methane evolution from northern ecosystems are quite large. The total increase in CO₂ emission could be 3 Pg of carbon per year under a warmer-wetter climate or 5 Pg of carbon per year under a warmer-dryer climate. (The 1987 CO₂ emission from burning fossil fuels was 5.5 Pg of carbon.) Increases in methane emissions may be 0.3 Pg of carbon per year under either climate. These calculations are supported by the observation that the predicted rise in global methane release is similar to the observed rise in methane at the end of the last glacial period, which had comparable changes in climatic regimes. A workshop report is in preparation, outlining the methods and assumptions that produced these calculations and discussing the uncertainties involved. This report will also outline short- and long-term research tasks that will be needed to reduce these uncertainties.

Ocean Ventilation Rates Changed over the Last 7000 Years Based on ¹⁴C Variations in the Atmosphere and Oceans

T.-H. Peng

Published ¹⁴C data for atmospheric CO₂ indicate a net decrease of 100 per mil over the last 7000 years. The decrease has generally been interpreted as a consequence of changing rates of atmospheric ¹⁴C production that result from changes in the magnetic field of the earth. However, changes in the ocean ventilation rate could be another possible cause.

The past rate of ocean ventilation can be derived from the ¹⁴C record preserved in planktonic and benthic foraminifera in deep sea sediments, if one assumes that the ¹⁴C:C ratio in these foraminifera shells represents the past ¹⁴C:C ratio of the total dissolved carbon in the surface water and the deep water, respectively. Results of radiocarbon dating using accelerator mass spectrometry¹ on handpicked planktonic and benthic foraminifera in deep sea sediments from the South China Sea show that the age differences between

planktonic (*G. sacculifer*) and benthic foraminifera increase from 1350 years about 7000 years ago to 1590 years at present.

An 11-box geochemical model of global ocean circulation is used for studying changes in ocean ventilation rates. Both tree ring-determined atmospheric ^{14}C values and ^{14}C age differences in foraminifera are used as constraints to place limits on the patterns of change in the rates of ocean ventilation and the rates of atmospheric ^{14}C production. Calculations with the model indicate (1) that ^{14}C production rates in the atmosphere may have decreased by as much as 30% between 7000 and 3000 years ago and may have increased again by ~15% in the past 2000 years and (2) that the global rate of ocean ventilation may not have been at steady state over the last 7000 years but, instead, may have slowed by as much as 35%. These conclusions are tentative because of the sparseness of the data base on ^{14}C age differences for planktonic and benthic foraminifera and because of uncertainty concerning whether the ^{14}C contents of foraminifera accurately represent those of seawater.

1. M. Andree, H. Oeschger, W. Broecker, N. Beavan, M. Klas, A. Mix, G. Bonani, H. J. Hofmann, M. Suter, W. Woelfli, and T.-H. Peng, "Limits on the Ventilation Rate for the Deep Ocean over the Last 12,000 Years," *Climate Dyn.* 1, 53-62 (1986).

Oceanic Uptake of CO_2 in the Atlantic Is Modeled

B. Moore* and B. Bolin†

At present, our ability to interpret the carbon cycle and thus predict future concentrations of CO_2 in the atmosphere is hampered by unresolved balances in the carbon budget. The complexity of the oceanic carbon cycle suggests that more-detailed and more-realistic models are needed to determine more precisely the oceans' uptake capabilities, not to mention their important role in the climate system. Thus, researchers at the University of New Hampshire and the University of Stockholm have constructed a higher-resolution box model to analyze oceanic uptake of CO_2 . The model is calibrated by using diverse chemical tracer data, together with dynamical constraints. In this initial study, the analysis has been restricted to the Atlantic Ocean because of its important role in the carbon cycle.

To define the model, the Atlantic basin is divided geographically into 12 regions and vertically into 8 layers, based on qualitative knowledge about the key features of the circulation in the Atlantic. Based on ocean survey, values are assigned in each of the "boxes" for the approximate concentrations of several chemical tracers: dissolved inorganic carbon (DIC), ^{14}C , oxygen, phosphorus, alkalinity, and salinity. In addition, the water motions (advections) are constrained to be quasigeostrophic (the condition on relative water velocities imposed by the turning of the earth). From these tracer profiles and the geostrophic condition, the following sets of model parameters are determined: organic and inorganic production or dissolution in each of the boxes, the advective fluxes of water between adjacent boxes, and the rates of turbulent exchange between adjacent boxes. All the tracers are assumed to be in steady state (the DIC and ^{14}C data are first adjusted to reflect pre-industrial conditions), and a constrained inverse technique is used to deduce the values of the model parameters that most nearly reproduce all the tracer fields and satisfy the geostrophic constraints.

To test the plausibility of the deduced parameters, the transient response of the model is first tested with bomb ^{14}C data from nuclear testing during 1957–1963. It is assumed that water motions and biological processes remain unchanged, and the model is integrated in time from 1950 to 1980, with a pulse of ^{14}C prescribed for the atmosphere according to the bomb data. The resulting distribution of ^{14}C in the surface boxes is then compared with known data from other sources.

Although the computed uptake of ^{14}C differs from observations by varying amounts in different regions, the overall observed uptake is only $\sim 10\%$ larger than the one computed. In particular, the agreement between the observed changes and the computed changes in the surface of Region 4 is excellent. In contrast, the greater uptake in the western basin than in the eastern is considerably more pronounced in the reference solution than that observed. In spite of discrepancies between observed and computed changes, however, the overall fields show similarities that justify a preliminary analysis of the CO_2 uptake.

The model was subjected to an atmospheric CO_2 perturbation from 1760 to 1983 that reflects the actual record as deduced from ice core data.¹ The penetration of CO_2 into the ocean was then examined. Figure 36 shows the vertical distribution of the uptake in a series of profiles for the northern regions of the model. Rapid penetration down to the bottom occurs in Region 2, whereas it does not reach the bottom in Region 3 because of upwelling from the deepest layer of the eastern basin.² Also, the vertical distributions in Regions 2, 4, and 6 show clearly the gradual invasion of carbon from the north due to the advective flow, while turbulent penetration from above is considerably less significant.

Because the model includes the Atlantic basin only, no firm conclusions regarding the global carbon cycle are possible. However, model computations make more plausible the view that the world's oceans are probably not the only significant sink for man's emission of CO_2 . Further synthesis of tracer-based and dynamically based models holds the key to reliably describing the cycling of carbon in the sea in the years ahead.

*Institute for the Study of Earth, Oceans, and Space, University of New Hampshire, Durham, New Hampshire.

†Arrhenius Laboratory, University of Stockholm, Sweden.

1. U. Siegenthaler and H. Oeschger, "Biospheric Emissions of CO_2 During the Past 200 Years Reconstructed by Deconvolution of Ice Core Data," *Tellus* **39B**, 140–154 (1987).

2. R. Schlitzer, "Renewal Rates of East Atlantic Deep Water Estimated by Inversion of ^{14}C Data," *J. Geophys. Res.* **92**, 2953–2969 (1987).

increased availability of high-speed "super" computers has made it practical to base a model of the biota-driven oceanic chemistry on an oceanic GCM. The current generation of oceanic GCMs, however, are relatively primitive. They attempt only to model the very large scale oceanic circulation: western boundary currents, central gyres, deep-water formation in the North Atlantic and Antarctic oceans, and equatorial upwelling.

Personnel at the Scripps Institution of Oceanography, in collaboration with the Max-Planck Institut für Meteorologie in Hamburg, Federal Republic of Germany, have developed a model of the natural oceanic carbon cycle, using the final circulation field of oceanic GCM.^{1,2} The 72-by-72 grid is coarse, ~555 km between points at the equator. Ten calculational levels are arranged vertically, spaced closer together through the thermocline than in deeper water, so that the ocean is represented by 27,443 boxes. A one-box atmosphere exchanges CO₂ with each surface ocean box. The chemical species modeled include total CO₂, alkalinity, dissolved oxygen, nutrient (either phosphate or nitrate), and carbon isotopes. The partial pressure of CO₂ (pCO₂) at the ocean surface is calculated from total CO₂ and alkalinity concentrations in the surface boxes, with equilibrium constants evaluated at the local temperature.

Ocean chemistry is driven by a model of new production, which is represented by the product of an incident light irradiance factor (varying with latitude) and a Michaelis-Menton kinetic factor dependent on nutrient concentration. In the simplest version of the biota model, the new production is specified to dissolve and remineralize in boxes directly below where it is formed, but other schemes involving advection of particulate and dissolved organic matter are being explored. Chemical concentrations are set to average values, and the advective-diffusive equation is integrated forward for 2400 years, after which the concentrations have adjusted close to steady-state values.

When model results are compared with GEOSECS observations for the Western Pacific Section, an obvious discrepancy appears: the depth for the $-120 \Delta^{14}\text{C}$ contour in the high southern latitudes is too large. The circulation model includes a convective adjustment that contributes strongly to deep-water formation, and it appears that there is too much of this deep-water formation in the Antarctic region in relation to the North Atlantic. The distribution of phosphate in the GEOSECS Western Pacific Section also shows the effect of penetration of water from the south with low concentrations. Getting the deep-water formation and circulation right is difficult in GCMs because deep-water formation tends to be episodic and below grid scale.

A comparison of near-surface contours indicates that model surface values of phosphate are about twice as large as those observed. The likely cause of these high nutrient values is too much numerical diffusivity through the thermocline region. Numerical diffusivity, caused by finite box size, is unavoidable, but its effect can be reduced by employing more calculational levels.

Model pCO₂ of the ocean surface waters is in reasonably good agreement with observations: both are dominated by the Pacific equatorial peak. The agreement partly results from forcing circulation model surface temperatures to observed values as a boundary condition.

Contrary to hopes, a circulation model (which is relatively disaggregated) does not take up anthropogenic CO₂ more readily than the simpler box models, such as the box-diffusion model. With input from the standard fossil fuel production data, the recent

ocean-borne fraction in the model is 0.32–0.29, depending on the wind, temperature, and salinity forcing of the GCM. Because the observed airborne fraction (based on fossil fuel input) is about 0.57, the land biota would have to be a small net sink for fossil fuel CO₂ (~0.5 Gt/year, by difference). Because land clearing continues to deplete this sink, the most likely way to increase the sink is through CO₂ fertilization of the land biota.

*Scripps Institution of Oceanography, University of California, LaJolla.

1. E. Maier-Reimer and K. Hasselmann, "Transport and Storage of CO₂ in the Ocean—A Inorganic Ocean-Circulation Carbon Cycle Model," *Climate Dyn.* 2, 63–90 (1987).

2. R. Bacastow and E. Maier-Reimer, "Circulation Model of the Oceanic Carbon Cycle," submitted to *Climate Dynamics* (1988).

Preliminary Development of a Global Coastal Hazards Data Base Is Completed

V. M. Gornitz* and P. Kanciruk

If the predicted rise of sea level caused by greenhouse warming of the climate does indeed occur, low-lying areas could be imperiled. Resources at risk include human populations, coastal structures (including cities and ports), and wetlands. At present, it is not possible to consistently predict which parts of the world's shorelines are at greatest risk from a rise in sea level. High-risk areas are characterized by one or more of the following conditions: (1) low coastal relief, (2) erodible substrate (e.g., sand and unconsolidated sediment), (3) subsidence, (4) extensive shoreline retreat, (5) high wave/tide energies, and (6) storm frequency. In order to define such high-risk areas, a global coastal hazards data base is under development. This data base will provide information on at least eight variables related to the coastal zone: (1) elevation (relief), (2) bedrock geology (lithology), (3) geomorphology (coastal landforms), (4) vertical movements (relative sea-level changes), (5) horizontal shoreline movements (erosion or accretion), (6) tidal ranges, (7) wave heights, and (8) storm frequency.

Preliminary work included a pilot study to examine the feasibility and utility of developing a complete global data base. The first step was to make a detailed global assessment of the spatial coverage of both quantitative and qualitative coastal data, sources of information, and their degree of accessibility. Of the eight variables listed above, quantitative data currently exist globally with fairly continuous coverage for elevation and tidal ranges. Coverage for sea-level data is more widely scattered. Coastal geomorphology is being interpreted directly from 1:250,000 topographic maps. Geology maps are generally available at 1:250–1:500,000 scales for developed countries and at smaller scales for developing countries. Quantitative data for shoreline displacement exist for the United States and several other countries.

Compilation of data for the eight coastal variables has been completed for the contiguous portions of the United States. Annotated, coded, documented maps for geology and geomorphology, plus electronic data files for the other variables, were incorporated into the ESD ARC/INFO Geographic Information System (GIS). Existing coastal geologic and geomorphologic classification schemes were especially modified for this project. Use of a GIS ensures maximum flexibility in combining spatial data in complex ways in order to create a uniform coastal hazards data base.

Preliminary development began on an index to identify coastal segments sensitive to a projected rise in sea level. Each variable is classified according to relative risk factor, and the risk factors are combined into an overall index. This data base will assist in the identification of those coastal areas that will face an increased threat of erosion and inundation. It will be relevant to regional and global planners and will provide important input for data bases on socioeconomic risk.

*Lamont-Doherty Geological Observatory, Columbia University, New York.

Interactions Between CO₂ and Climate Have Unknown Consequences for Agriculture

D. S. Shriner and R. M. Cushman

Changes in climate and vegetation caused by increasing concentrations of atmospheric CO₂ may have significant consequences for human welfare by affecting agriculture, forests, fisheries, and water resources. Perhaps more importantly, multiple-resource interactions will result in a complex set of issues about water quantity, water quality, and land use.

The objectives of this study were to use the existing literature base to make a priority list of resource issues to be considered in an integrated assessment and to begin to identify important linkages between the major resource areas. In the process, a number of issues and research needs became evident in the context of other major regional and global issues. Although agricultural resource issues are better understood than issues about forests or other unmanaged terrestrial ecosystems, major uncertainties remain because of three important factors: (1) multiple stress interactions; (2) within-species variation in agricultural crop response, especially for regionally important specialty crops; and (3) interresource competition for land use and water resources.

Multiple stress interactions. Physiological response research should strive to understand the potential for multiple stress interactions not only with water, temperature, and nutrients but also with insects and disease. How CO₂ and climate change interact with major air pollutants affecting agricultural production (e.g., O₃, SO₂, NO_x, and acidic deposition) should also be investigated.

Within-species variation in response. Information on the differential response of crop varieties and species to climatic change is needed. Currently, adequate detail is available for only a limited number of species. A large number of regionally important specialty crops that are likely to be affected by shifting climate zone margins are apparently being discounted because, on the basis of national crop statistics, either their areal extent or their dollar value is low. However, these species may be of major economic significance in a particular region and should be studied.

Moreover, research is needed about fruit and nut trees and other crops that can be affected over the course of their life span by climate change. In addition, the infrastructure within the nation's crop-breeding programs must be studied. Although major national crops such as corn, soybeans, and small grains are serviced by equally large breeding programs, major programs do not exist for many regionally important crops.

Thus, turnaround times for new varieties may be lengthy, and adjustments in insect- and disease-resistance breeding programs to accommodate response to climate change may result in lengthier turnarounds.

Statistical/regression models for analyzing growth and yield changes due to climate change have a significant shortcoming: varieties are changed frequently enough that those used to develop the historic baseline may not have the growth and yield characteristics of varieties currently grown or likely to be grown in the future.

Interresource linkages. Water resource issues and land use can be expected to drive the major interactions between resource types. Interresource issues include relationships between agricultural cover and the timing and quality of water yield, water requirements for agriculture, competition between forest and agricultural land uses, and elimination of certain types of habitat.

A comprehensive strategy for the development of adaptive or corrective measures to respond to the effects that climate change has on natural resources may require some significant adjustments at the regional scale of agricultural production.

Carbon Dioxide Information Analysis Center Provides Numeric Data and Computer Model Packages

T. A. Boden

The Carbon Dioxide Information Analysis Center (CDIAC) makes CO₂-related data bases and computer models available to international researchers and policymakers. These numeric data packages (NDPs) and computer model packages (CMPs) consist of written documentation and magnetic tapes. The documentation consists of an abstract, a data or source code listing (either in tabular form or on microfiche), a FORTRAN data retrieval program, graphical displays of the data or model output, and reprints of pertinent literature.

Since FY 1985, we have assembled 32 NDPs and 2 CMPs.* Four NDPs have been updated to incorporate more recent data. To date, we have filled 684 requests from 34 countries for 1770 copies of these packages. In filling these requests, >500 magnetic tapes have been generated and distributed.

During FY 1988, nine new NDPs were compiled. (Each year we attempt to assemble a minimum of eight.) One of the new NDPs provides a subset of the United Nations Energy Data Base, cement production data from the U.S. Bureau of Mines, and CO₂ emission estimates calculated by energy analyst Gregg Marland (ESD). This package provides detailed documentation of the data and procedures used to estimate the CO₂ releases to the atmosphere that result from fossil fuel consumption and cement production.

A second NDP documents a set of long-term mean monthly totals of snowfall (including ice pellets) for 216 stations across the conterminous portions of the United States. The data were extracted from a larger data set compiled by the National Climatic Data Center and include only stations having at least 1 month during the period of record with a mean snowfall greater than a trace and having at least a 10-year data record. This package supplements the snow cover data generally used in climatological studies and can be used in general circulation modeling.

The remaining seven NDPs document a variety of data sets including cloud data, oceanographic carbonate chemistry and radiocarbon data, reconstructed pressure data, and surface temperature data. This diversity reflects both the broad scope of research supported by DOE's Carbon Dioxide Research Division and the complexity of CO₂ and climate issues.

*Complete listings of the NDPs and CMPs compiled by CDIAC are provided in two publications available from CDIAC: *Publications and Other Documents* and *CDIAC Communications* (CDIAC's biannual newsletter).

Lists

3

3.1 AWARDS AND HONORS

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

M. A. BOGLE

Special Recognition Award, Savings Bond Campaign, 1988, Martin Marietta Energy Systems, Inc.

S. W. CHRISTENSEN

PIP President's Luncheon, 1988, Martin Marietta Energy Systems, Inc.

D. E. FOWLER

Technical Communication Award, 1988, East Tennessee Chapter of the Society for Technical Communication

S. B. GARLAND II

Registered Professional Engineer, 1988, Tennessee State Board of Architectural and Engineering Examiners

G. K. JACOBS

One of Ten Best Papers, 1988, U.S. Department of Energy Model Conference

J. D. JOSLIN, JR.

Outstanding Paper Award, 1988, Soil Science Society of America

J. M. KELLY

Gold Honor Award, 1988, Tennessee Valley Authority

R. J. LUXMOORE

Fellow, 1988, Soil Science Society of America

S. B. McLAUGHLIN

Technical Achievement Award, 1988, Martin Marietta Energy Systems, Inc.

C. R. OLSEN

Research Highlighted, 1988, *Science News*

W. M. POST III and L. K. MANN

Best Poster Award, 1987, Soil Science Society of America

J. W. RANNEY

Award of Leadership in Short-Rotation Forestry, 1988, University of Washington and Washington State University

B. V. SHELTON

Administrative Achievement Award, 1988, Environmental Sciences Division

C. F. SIGMON

**Certified Hazardous Materials Manager, 1987, Institute of Materials Management;
Certified Asbestos Abatement Supervisor, 1987, University of Alabama**

G. L. SIMMONS

Award for Excellence in Poster Presentation, 1987, Soil Science Society of America

E. D. SMITH

**Award for Distinguished Service to the East Tennessee Chapter, 1988, Association for
Women in Science**

G. W. SUTER II

Scientific Achievement Award, 1988, Environmental Sciences Division

T. TAMURA

Fellow, 1988, American Institute of Chemists

D. E. TODD

Technical Achievement Award, 1988, Environmental Sciences Division

L. L. WRIGHT

**Award for Distinguished Service to the East Tennessee Chapter, 1988, Association for
Women in Science**

G. T. YEH

PIP President's Luncheon, 1988, Martin Marietta Energy Systems, Inc.

3.2 SIGNIFICANT ACCOMPLISHMENTS

J. L. Trimble

During the year ESD reported numerous technical accomplishments in all areas of the division's multidisciplinary activities. The most significant accomplishments are listed here.

- Over 550 acres of short-rotation plantations were established on three regions, thereby tripling the acreage available for such studies. Cooperating industries shared 30–100% of the costs. These plantings are providing standardized data on the costs, risks, and returns of operational-scale wood energy crops.
- The Herbaceous Energy Crops Program concluded a 4-year project at Lawrence Berkeley Laboratory on energy and hydrocarbons from plants. The final report describes the biochemistry of triterpenoid biosynthesis in *Euphorbia lathyris* and identifies the enzyme that catalyzes the rate-limiting step.
- ESD researchers showed that natural organic colloidal particles in soils and groundwater can sorb hydrophobic organic contaminants (i.e., polychlorinated biphenyls) and enhance their mobility in subsurface systems. These results are improving our understanding and enhancing our ability to model the belowground transport of organic colloids.
- Research results showed that soluble mercury released in East Fork Poplar Creek is rapidly bound to sediment and is not readily available for methylation. These results are environmentally significant because methylated mercury is the most biologically active form.
- ESD completed a validation of EPA regional soil survey data for the Direct/Delayed Response Project in the northeastern and the southern Blue Ridge Province. These data will be used to predict long-term acidification of streams and lakes in these regions. This is a major accomplishment toward completion of the 1990 National Acid Precipitation Assessment Program (NAPAP) assessment of aquatic effects from acidic precipitation.
- ESD collaborated with Columbia University in the development of a global data base on coastal hazards. The data base will help identify coastal areas susceptible to rises in sea level.
- ESD researchers collaborated with engineers and chemists at the Oak Ridge Y-12 Plant to develop wastewater treatment procedures that yield effluents of the highest biological quality. These procedures are now being used in the treatment of nitrate-contaminated wastewater at the Y-12 Plant West End Treatment Facility.
- ESD successfully applied an image analysis system, equipped with superior television sensors, to the resolution of 1-year intervals in tree-ring chronologies. This system reduces the data acquisition phase of tree-ring analyses by greater than a factor of 30 and significantly improves the accuracy and precision of the ring measurements.

- The Oak Ridge Environmental Survey Program, in support of the Assistant Secretary for Environment, Safety, and Health, completed on schedule the sampling and analysis of Argonne National Laboratory, the fifth site sampled by ORNL. The program has now completed sampling at half of the currently scheduled sites.
- Research showed that nutrient input and the number of trophic levels in a food web can significantly influence the resilience of the food web to external perturbations. A manuscript documenting this research will be published in *American Naturalist*.
- Research results from the DOE Carbon Dioxide Program, managed by ESD, indicated that climate change could trigger releases of CO₂ from peatlands that are as large as the current anthropogenic releases of CO₂.
- ESD hosted the first DOE High School Honors Program in environmental sciences. Fifty-seven outstanding students representing each state, the District of Columbia, Puerto Rico, and five foreign countries worked with scientists on environmental research problems.
- New theoretical methods that include both the frequency and the intensity of a disturbance (e.g., fire and pests) were developed by ESD scientists to predict with simple models the effects of disturbances at the landscape level.
- A new method, based on ⁷Be:²¹⁰Pb ratios, was developed and used for quantifying sediment dynamics in coastal systems. Use of this method in the Savannah River estuary showed that 85% of the suspended matter is dynamically resuspended sediment. This methodology will be applied to other aquatic systems (i.e., Watts Bar Reservoir and Pearl Harbor) to distinguish materials resuspended from sediments from those produced in situ or added directly to the systems.
- The feasibility of bioremediation of trichloroethylene (TCE) by methanotrophic bacteria was demonstrated in a bench-scale reactor. This is the first successful demonstration of TCE degradation to use groundwater. A field demonstration at the Bendix plant in Kansas City is proposed for FY 1989.
- A toxicology study showed that the ORNL sewage treatment facility could safely use lower concentrations of chlorine during processing, thereby saving about \$800,000 to replace the chlorine treatment unit. Use of less chlorine is environmentally advantageous and will help ORNL avoid National Pollutant Discharge Elimination System permit violations for toxicity and chlorine.

3.3 CONFERENCES ORGANIZED OR CHAIRED

J. L. Trimble

During the past year, ESD staff members actively participated in numerous conferences. Listed below are conferences organized or chaired by members of the Division.

Methods for Evaluating Reliability of Environmental Radiological Models, Athens, Greece, October 1987. Chairman and organizer: F. O. Hoffman.

National Meeting of the American Fisheries Society, Winston-Salem, North Carolina, October 1987. Chairman and organizer: S. M. Adams.

International Biospheric Model Validation Study, Grand Canyon National Park, Arizona, November–December 1987. Chairman and organizer: F. O. Hoffman.

Workshop on Turbine-Induced Fish Mortality, Federal Energy Regulatory Commission, Charleston, West Virginia, December 1987. Chairman and organizer: C. C. Coutant.

1987 Integrated Forest Study Program Review, Electric Power Research Institute, Pinehurst, North Carolina, February 1988. Chairman and organizer: E. A. Bondietti.

Symposium on Prospects for Mitigating Climatic Warming by Carbon Dioxide Control, Boston, Massachusetts, February 1988. Organizer: G. Marland.

Eighth ORNL Life Sciences Symposium, Bioindicators: Exposure and Effects, Knoxville, Tennessee, March 1988. Chairman: C. W. Gehrs.

Environmental Auditing Workshop, U.S. Air Force Space Command, Oak Ridge, Tennessee, March 1988. Organizer: L. L. Sigal.

Geoscience Aspects of Hazardous and Radioactive Waste, Columbia, South Carolina, March 1988. Chairman and organizer: S. H. Stow.

Third Annual Landscape Ecology Symposium, Albuquerque, New Mexico, March 1988. Chairperson and organizer: M. G. Turner.

Forest Growth: Process Modelling of Responses to Environmental Stress, Gulf Shores, Alabama, April 1988. Organizer: D. W. Johnson.

International Biospheric Model Validation Study, Budapest, Hungary, April 1988. Chairman: F. O. Hoffman.

U.S.–Japan Joint Seminar in the Environmental Sciences, National Science Foundation, Honolulu, Hawaii, April 1988. Chairman and organizer: D. L. DeAngelis.

Coordinated Research Program on Model Validations in the Urban, Terrestrial, and Aquatic Environments—Multiple Pathways Scenario, International Atomic Energy Agency, Vienna, Austria, May 1988. Chairman: F. O. Hoffman.

Role of Northern Ecosystems in the Global Carbon Cycle, Oak Ridge, Tennessee, May 1988. Chairman and organizer: W. M. Post III.

Evolution and Maintenance of Biota Diversity in Tropical Ecosystems, Organization for Tropical Studies, La Selva, Costa Rica, June 1988. Organizer: M. A. Huston.

First Tennessee Hydrology Symposium, Nashville, Tennessee, June 1988. Cochairman and coorganizer: D. D. Huff.

Winter Flounder Research Workshop, Electric Power Research Institute, Narragansett, Rhode Island, June 1988. Chairman and organizer: L. W. Barnhouse.

Annual Subcontractors Workshop, Herbaceous Energy Crops Program, Auburn, Alabama, July 1988. Chairperson and organizer: J. H. Cushman.

International/DOE Workshop on Short-Rotation Forestry, Tacoma, Washington, August 1988. Chairman and organizer: J. W. Ranney.

Biogeochemistry of the Greenhouse Effect, Los Angeles, California, September 1988. Organizer: M. P. Farrell.

Chemical Modeling in Aqueous Systems II, American Chemical Society, Los Angeles, California, September 1988. Chairman and organizer: V. S. Tripathi.

International Symposium on Forest Tree Physiology, Nancy, France, September 1988. Chairman: R. J. Luxmoore.

Problems of Ecophysiology in Coniferous Forest Species, Tallinn, Estonia, U.S.S.R., September 1988. Organizer: R. J. Luxmoore.

Second U.S.-U.S.S.R. Symposium on Air Pollution Effects on Forests, Gatlinburg, Tennessee, September 1988. Organizer: D. S. Shriner.

Symposium on Biological Markers of Environmental Contaminants, Los Angeles, California, September 1988. Chairman and organizer: L. R. Shugart.

Workshop on Aerosol Interactions with Natural Surfaces, Lund, Sweden, September 1988. Cochairman: S. E. Lindberg.

3.4 RESEARCH AND DEVELOPMENT SUBCONTRACTS AND INTERAGENCY AGREEMENTS

A. B. McDaniel

Presented here are the institutions and organizations 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.

Adaptive Environmental Assessments

Technical support for assessment of effects of acidic deposition on Canada's aquatic resources (R. B. Cook)

Advanced Sciences Group

Technical support for student training in health and safety (R. J. Selfridge)

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

Validate the use of biomarkers in animals as indicators of exposure to contaminants (J. F. McCarthy)

Technical support in processing field data for stream discharge and groundwater levels for Bear Creek Watershed (R. B. Clapp)

Amana Society, Inc.

Establishment and maintenance of silver maple monoculture viability trials (L. L. Wright)

Analysas Corporation

Support in locating and classifying streams potentially at greater risk of acidification (M. J. Sale)

Assistance in Walker Branch Watershed Research Program for DOE (S. M. Bartell)

Assistance in development of computerized information system for National Acid Precipitation Program (R. S. Turner)

Support to DOE's Environmental Survey (P. Kanciruk)

Technical support in development, implementation, and analysis of models pertaining to several areas of research (S. M. Bartell)

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

Applied Biomathematics, Inc.

Statistical analysis of surface water, chemistry survey data bases (D. S. Shriner)

Argonne National Laboratory

Organics lab analytical services for Environmental Survey samples taken at the INEL and METC (R. B. Fitts)

ASL and Associates

Statistical analysis of atmospheric deposition data (D. S. Shriner)

Auburn University

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

Critical review and summary of efforts to alter compositions of plants (J. H. Cushman)

Automated Sciences Group, Inc.

Technical support in the analysis of the effects of air pollution on forest ecosystems (D. S. Shriner)

Technical support for SWSA-6 disposal demonstrations (S. B. Garland)

Support to the Sedimentary Rock Program (S. H. Stow)

Technical support to the DOE Environmental Compliance Program (F. E. Sharples)

Support in describing level of development of tree response to competition in even-aged monoculture plantations (L. L. Wright)

Technical assistance in the study of the relationships between nutrient cycling and ecosystem stability (P. J. Mulholland)

Technical support characterizing plant physiological processes (G. E. Taylor)

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

Preparation of Clinch River Resource Facility Investigation Workplan and supporting documents (B. L. Kimmel)

QA support for the Waste Management Research and Development Programs (S. H. Stow)

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

Geophysical mapping (S. H. Stow)

Manipulation of aquatic organisms in local streams (H. L. Boston)

Battelle Pacific Northwest Laboratories

Determination of feedstock composition and structure: Effects of biomass conversion processes (J. H. Cushman)

Research and development in application of in situ vitrification technology for low-level wastes (B. P. Spalding)

Analytical services on environmental survey samples (R. B. Fitts)

Berkeley Hydrotechnique, Inc.

Support for ORNL's Sedimentary Rock Program (S. H. Stow)

Bern, University of

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

Bioenergy Development Corporation

Eucalyptus plantations for energy production in Hawaii (J. W. Ranney)

California, University of

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

Assist in the biomass research project on hydrocarbons and energy from plants (J. W. Johnston)

Support in storage and transfer of organic matter in terrestrial ecosystems, litter, and soil (W. M. Post)

Regional analysis of sedimentary rock resources and acidic deposition impacts (D. S. Shriner)

Monitor atmospheric CO₂ levels (M. P. Farrell)

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

Calvin College

Development of water table mapping capability applied to waste disposal sites at ORNL (R. B. Clapp)

Clemson University

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

Colgate University

Research on weathering characteristics of soil minerals at sites associated with EPRI Integrated Forest Study (D. W. Johnson)

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

Screening and selection of herbaceous species for biomass production in the midwest lake states (J. H. Cushman)

Duke University

Field nutrient cycling research at the loblolly pine plantation in Duke Forest (S. E. Lindberg)

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

East Carolina University

Placement and maintenance of wells for sampling peat drainage waters (J. F. McCarthy)

EG&G

Support of environmental survey on-site field sampling at INEL (R. B. Fitts)

Emory University

Integrated forest study of effects of atmospheric deposition (S. E. Lindberg)

Energy/Development International

Species screening and genetic selection at sites in Arizona, New Mexico, and Texas (L. L. Wright)

Enreco, Inc.

Technical assessment of stabilizing sediment in Old Hydrofracture Facility impoundment (C. W. Francis)

Environmental Consulting Engineers

SWSA-6 contaminant pathways analysis study and hydrologic modeling (S. B. Garland)

Fisk University

Support of DOE's Short Rotation Woody Crops Program (J. W. Ranney)

Florida, University of

Effect of sea level rise on coastline (R. M. Cushman)

Eucalyptus for biomass production in Florida (part of DOE's Short Rotation Woody Crops Program) (L. L. Wright)

Geophyta

Selection of lignocellulosic species for energy crops (J. H. Cushman)

Georgia, University of

Development of winter rapeseed production practices for the southeastern United States (J. H. Cushman)

Optimizing energy yields in black locust through genetic selection (P. A. Layton)

Perform specialized studies on incorporation of sulfur into soil organic matter (D. W. Johnson)

Support in optimum nitrogen nutrition in short-rotation sycamore plantations (R. J. Luxmoore)

Chemical analysis of plant, soil, and solution samples for the project Elevated CO₂ Effects on Terrestrial Ecosystems (R. J. Norby)

Support of integrated forest study of atmospheric deposition (D. W. Johnson)

Hudson River Foundation

Measuring changes in the forests of the Amazon basin (M. P. Farrell)

Idaho, University of

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

IIT Research Institute

Support of report on CO₂ climate problems (M. P. Farrell)

Illinois, University of

Graduate student support (C. W. Gehrs)

Support in development, evaluation, and application of analytical methods to isolate and characterize forms of soluble organic phosphorus (J. W. Elwood)

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

Indiana University

Provide high-quality student interns who are well suited to ESD programs (C. T. Hunsaker)

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)

Institute of Paper Chemistry

Critical review and summary of efforts to alter the composition of plants (P. A. Layton)

Iowa State University

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

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

IT Corporation

Support in preparing reviews of specific hazardous and radioactive waste action (R. M. Reed)

JAYCOR

Provide analysis and technical assistance for Herbaceous Energy Crops Program (J. H. Cushman)

Kansas State University

Determination of the best species and management techniques for short-rotation production of fuel wood in the Great Plains (P. A. Layton)

Kelso-Regan Associates

Development and construction of devices for exclusion of ambient rain and/or gaseous pollutants from trees (J. W. Johnston)

Kentucky, University of

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

Conduct field study on biomass production by fescue and switch grass alone and in mixed swards with legumes (J. H. Cushman)

Knoxville College

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

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

Lamont-Doherty Geological Observatory, Columbia University

Comparison of prebomb and postbomb radiocarbon in soils and soil fractions (M. P. Farrell)

Assessment of carbon dioxide sinks and sources in oceanic areas (M. P. Farrell)

Assemble and evaluate oceanographic data in support of ocean model development (M. P. Farrell)

Research designed to identify and quantify principal sources and sinks of atmospheric CO₂ on a global scale (M. P. Farrell)

Lee-Wan and Associates, Inc.

Technical support in environmental survey (R. B. Fitts)

Develop management system for DOE-HQ Office of Environmental Guidance (F. E. Sharples)

Louisiana State University

Study of characterization of clay mineralogy (S. H. Stow)

Louisville, University of

Effects of nutrient constraint on ecosystem structure, nutrient recycling mechanisms, and stability in lotic ecosystems (P. J. Mulholland)

Miami, University of

Collect radiocarbon data from the Indian Ocean (M. P. Farrell)

Miami University, Oxford, Ohio

Internship program (M. P. Farrell)

Michigan State University

Tree species and management strategies for biomass production in the Great Lakes states (P. A. Layton)

Michigan, University of

Integrated forest study of effects of atmospheric deposition (S. E. Lindberg)

Minnesota, University of

Use of wetlands for production of woody plants for fuels and petrochemical substitutes (J. W. Johnston)

Mississippi Agricultural and Forestry Experiment Station

Technical support in early selection criteria and clonal propagation systems (P. A. Layton)

National Aeronautics and Space Administration

Computer support to run models of the atmosphere (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)

Provide model of the global cycles of carbon, nitrogen, and phosphorus (W. R. Emanuel)

New Mexico, University of

Provide support for a postdoctoral student to test theoretical predictions made by staff of Environmental Sciences Division (R. V. O'Neill)

New York Botanical Gardens

Atmospheric deposition and canopy interactions studies (S. E. Lindberg)

New York, State University of

Atmospheric deposition research at Whiteface Mountain (S. E. Lindberg)

Exchanges of carbon between the atmosphere and terrestrial ecosystems as a result of land-use change (M. P. Farrell)

North Carolina Agricultural and Technical State University

Development of trade-off analysis methods for application to river basin level development of hydroelectric resources and their associated environmental impacts (M. J. Sale)

North Carolina State University

Species selection and silvicultural substeps for producing fuels from woody biomass in the southeastern United States (L. L. Wright)

Monoculture viability trials of woody crops for energy production (L. L. Wright)

North Dakota State University

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

Northern States Power Company

Multiacre monoculture viability trial (L. L. Wright)

Norwegian Forest Research Institute

Integrated forest studies on atmospheric deposition (D. W. Johnson)

Nova Scotia, University of

Lipid biochemistry of fish from East Fork Poplar Creek (S. M. Adams)

Oak Ridge Research Institute

Technical support in the conduct of aquatic bioassays (A. J. Stewart)

Oklahoma State University

Evaluate *Populus* selection for fuel wood (P. A. Layton)

Oregon State University

Continued collection of oceanic carbonate data to verify ocean penetration of anthropogenic CO₂ (M. P. Farrell)

Support for production and publication of North Atlantic Treaty Organization Advanced Research Workshop on climate-ocean interaction (M. P. Farrell)

Oregon, University of

Support in study of prehistoric climate determined from modern pollen-climate relationships and fossil pollen records (W. R. Emanuel)

Pennsylvania State University

Net energy and economic analysis for producing *Populus* hybrid under four management strategies (P. A. Layton)

Pennsylvania, University of

Nutrient cycling research at White Face Mountain (D. W. Johnson)

Phyton Technologies

Research on trace element toxicity to red spruce (S. B. McLaughlin)

Princeton University

Development of a three-dimensional model for predicting the distribution of dissolved carbon species in the oceans (M. P. Farrell)

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)

Radiological Assessments Corporation

Research on effects of radionuclides and hazardous chemicals (C. F. Baes)

ReSpec Inc.

Decision analysis support for repository site selection (S. H. Stow)

Rhode Island, University of

Validate method of determining age and growth role of larval winter flounder from otolith analysis (L. W. Barnthouse)

Roane State Community College

Student support for field work (N. T. Edwards)

Science & Technology

Organization and management of four regulatory training workshops (F. E. Sharples)

Science Applications International Corporation

Support services in the analysis of acidic deposition (D. S. Shriner)

Development, implementation, and analysis of models used to forecast the fate and effects of chemical contaminants in aquatic systems (S. M. Bartell)

Support for development, testing, and application of terrestrial ecosystem models (W. R. Emanuel)

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)

Programming and technical support for development, implementation, and analysis of uncertainties of models used to forecast future rates of fossil fuel combustion (M. J. Sale)

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)

Provide research and data analysis support to the National Acid Precitation Assessment Program (D. S. Shriner)

Support services for the Woody Biomass Program at ORNL (J. W. Ranney)

Identification and evaluation of legal-regulatory aspects of remedial action activities at ORNL (L. D. Voorhees)

Sirrine Environmental Consultants

Comprehensive technical assessment of stabilizing sediment in Old Hydrofracture Facility (C. W. Francis)

Southern Illinois University

Genetic biomass and growth analysis of clonal silver maple in several locations (P. A. Layton)

Tennessee Technological University

Investigations in the transportation and fate of contaminants (B. L. Kimmel)

Microconsumers in experimental stream channels (J. W. Elwood)

Modeling contaminant transport and fate (M. J. Sale)

Support on NSF-sponsored study on nutrient cycling and ecosystems stability (P. J. Mulholland)

Tennessee, The University of

Short-term and exploratory programmatic needs in areas where staff capability and/or funding uncertainty preclude ORNL staff commitments (S. E. Herbes)

Staff members of the Department of Civil Engineering are to provide assistance in waste-management-related programs (S. H. Stow)

Provide technical assistance in conducting DOE-sponsored limnological research on watershed-reservoir interactions (B. L. Kimmel)

A cooperative venture between ORNL's ESD and The University of Tennessee Graduate Program in Geological Sciences (S. H. Stow)

Field collection of data and sediments from lakes and ponds in Tennessee adjacent to Kentucky (D. C. West)

Support in ESD biomass project on optimum nutrition (R. J. Luxmoore)

Life Sciences Distinguished Scientist, David White (D. E. Reichle)

Life Sciences Distinguished Scientist, Robert Hatcher (D. E. Reichle)

Support for ESD subsurface transport project (R. J. Luxmoore)

Investigation of soil characteristics of Bear Creek Valley (S. Y. Lee)

Integrated forest study on effects of atmospheric deposition—Tasks A1 and A3 (S. E. Lindberg)

Pollutant stress effects on the growth and nutrition of woody plants (R. J. Luxmoore)

Study on use of biological markers as indicators of environmental pollutants (J. F. McCarthy)

Biological monitoring (A. J. Stewart)

East Fork Poplar Creek, White Oak Creek, and Bear Creek monitoring (M. G. Ryon)

Study role of natural organic macromolecules on the subsurface transport of organic contaminants (J. F. McCarthy)

Research assistance in field monitoring and laboratory studies of the accumulation of contaminants in fish and aquatic invertebrates (G. R. Southworth)

Perform specified hydrologic support for waste management and research tasks (D. D. Huff)

Scientific support in geohydrologic characterization at ORNL (D. D. Huff)

Modeling watershed response for 1990 Aquatic Effects Research Program support (R. S. Turner)

Support in identifying and propagation of rare and endangered plant species (P. D. Parr)

Performance of light stable isotope ratio analysis on gaseous samples to determine spatial and temporal variability in biogeochemical cycling in watersheds (P. J. Mulholland)

Geophysical research associated with waste burial grounds in Melton Valley (S. H. Stow)

Support to the Sedimentary Rock Program at ORNL (S. H. Stow)

Tennessee Valley Authority

Analysis of macrobenthos samples from the Bear Creek watershed (J. M. Loar)

Biomass harvesting and field handling (J. W. Ranney)

Geophysical data acquisition and reduction services (S. H. Stow)

Mercury and PCB uptake by ash (C. W. Gehrs)

ORNL spill forecasting (M. J. Sale)

Assessment of nonwoody resources in the southeastern United States (J. H. Cushman)

Tetra Tech, Inc.

Development of conceptual model to evaluate forest nutrient cycling data from the integrated forest study (D. W. Johnson)

Texas A&I University

Extending systems analysis in ecology (R. I. Van Hook)

Texas A&M Research Foundation

Supportive research for development of plant tissue culture techniques (J. W. Johnston)

Texas Tech University

Development of solid phase standards for laser fluorescence analysis of organic-rich shales (G. K. Jacobs)

Tuskegee Institute

Strengthen programs in biomass and carbon dioxide research at Tuskegee Institute and Environmental Sciences Division at ORNL (J. H. Cushman)

Uppsala, University of

Forest dynamics of southern Fennoscandia from simulation models, pollen-climate relationships (W. R. Emanuel)

U.S. Department of Agriculture

Establishment of biomass energy farms (J. W. Ranney)

Eucalyptus plantations for energy production in Hawaii (J. W. Ranney)

Research on atmospheric deposition (D. W. Johnson)

Identify risks of cultural treatments, coppice productivity, and improved productivity for energy through genetic research and selection (J. W. Ranney)

Increasing the biomass production of alder plantations in the Pacific Northwest (J. W. Ranney)

U.S. Department of the Interior

Collect surface water discharge data (D. D. Huff)

Geological survey (D. D. Huff)

Effects of atmospheric deposition on canopy and soil processes (S. E. Lindberg)

ORNL access to water quality and quantity data (S. G. Hildebrand)

U.S. Department of the Navy

Symposium on clay microstructure (S. H. Stow)

U.S. Environmental Protection Agency

Continued access to the Environmental Protection Agency's STORET/BIOSTORET data base (C. T. Hunsaker)

U.S. Geological Survey

Geologic and hydrologic characterization of the Oak Ridge Reservation (S. H. Stow)

Utah, University of

Support for investigation of bedload transport of contaminated gravel in White Oak Creek drainage (D. D. Huff)

Vanderbilt University

Experimental field studies on Walker Branch Watershed (J. W. Elwood)

Virginia Polytechnic Institute

Conduct research on the selection of lignocellulosic species for energy crops (J. H. Cushman)

Washington, University of

Preparation and nursery establishment for study of varying physiological processes in Biomass Program (P. A. Layton)

Effects of acid rain on forest nutrient status (D. W. Johnson)

Evaluation and genetic improvement of black cottonwood for short-rotation coppice culture (L. L. Wright)

3.5 TECHNOLOGY TRANSFER

V. S. Tripathi

3.5.1 Direct Transfer

Some of the technologies developed in the Environmental Sciences Division in the course of its activities have been transferred directly to other users:

- **T. A. Boden** transferred the IEA/ORAU Long-Term Global Energy-CO₂ model to the National Energy Software Center.
- **I. L. Larsen** helped the Water Quality and Watershed Research Laboratory of the U.S. Department of Agriculture develop analysis capabilities for ²¹⁰Pb.
- **M. L. Tharp** transferred the FORECE model to the National Energy Software Center.
- **G. T. Yeh** and **D. K. Solomon** provided water quality and contaminant transport modeling capabilities to Taipower, Taiwan.

3.5.2 Indirect Transfer

The work of the Environmental Sciences Division results in technical reports and in papers published in scientific journals. Many of these publications are widely read, and the information reported is used by others. This, in effect, is indirect transfer of technology. Following is a list of the publications that have elicited the greatest response from the scientific and industrial community during this reporting period. The list is arranged in decreasing order of requests for reprints. At least 40 reprints have been requested for each of the titles on this list, and several hundred copies of the first title have been distributed.

D. L. DeAngelis and J. C. Waterhouse. Equilibrium and nonequilibrium concepts in ecological models. *Ecol. Monogr.* 57(1):1-21 (1987).

M. A. Huston and T. M. Smith. Plant succession: Life history and competition. *Am. Nat.* 130(2):168-198 (1987).

R. B. Cook, C. A. Kelley, D. W. Schindler, and M. A. Turner. Mechanisms of hydrogen ion neutralization in an experimentally acidified lake. *Limnol. Oceanogr.* 31:134-148 (1986).

R. B. Cook, C. A. Kelley, J. C. Kingston, and R. G. Kreis. Chemical limnology of soft water lakes in the Upper Midwest. *Biogeochemistry* 4:97-117 (1987).

C. C. Coutant. Thermal preference: When does an asset become a liability? *Environ. Biol. Fish.* 18(3):161-172 (1987).

V. Dale and R. H. Gardner. Assessing regional impacts of growth declines using a forest succession model. *J. Environ. Manage.* 24:83-93 (1987).

- A. J. Stewart. Responses of stream algae to grazing minnows and nutrients: A field test for interactions. *Oecologia* (Berlin) 72:1-7 (1987).
- J. W. Johnston, D. S. Shriner, and C. K. Kinnerley. The combined effects of simulated acid rain and ozone on injury, chlorophyll, and growth of radish. *Environ. Exp. Bot.* 26:107-113 (1986).
- J. W. Johnston, D. S. Shriner, and C. H. Abner. Design and performance of an exposure system for measuring the response of crops to acid rain and gaseous pollutants in the field. *J. Air Pollut. Control Assoc.* 36:894-899 (1986).
- D. L. DeAngelis and M. A. Huston. Effects of growth rates in models of size distribution formation in plants and animals. *Ecol. Modell.* 36:119-137 (1987).
- J. W. Ranney, L. L. Wright, and P. A. Layton. Hardwood energy crops: The technology of intensive culture. *J. For.* 85(9):17-28 (1987).
- M. A. Huston and D. L. DeAngelis. Size bimodality in monospecific populations: A critical review of potential mechanisms. *Am. Nat.* 129(5):678-707 (1987).
- V. S. Tripathi. An algorithm and a FORTRAN biogram (CHEMEQUIL-2) for calculation of complex equilibria. *Talanta* 33:1015-1020 (1986).
- B. K. Takemoto, D. S. Shriner, and J. W. Johnston. Physiological responses of soybean (*Glycine max* L. Merr.) to simulated acid rain and ambient ozone in the field. *Water Air Soil Pollut.* 33:373-384 (1987).
- V. Dale and T. W. Doyle. The role of stand history in assessing forest impacts. *Environ. Manage.* 11(3):351-357 (1987).
- J. W. Johnston and D. S. Shriner. Yield response of Davis soybeans to simulated acid rain and gaseous pollutants in the field. *New Phytol.* 103:695-707 (1986).
- L. L. Sigal and J. W. Johnston, Jr. Effects of simulated acidic rain on one species each of *Pseudoparmelia*, *Usnea*, and *Umbilicaria*. *Water Air Soil Pollut.* 27:315-322 (1986).
- A. V. Palumbo, P. J. Mulholland, and J. W. Elwood. Response of microbial communities on leaf material to low pH and aluminum accumulation. *Can. J. Fish. Aquat. Sci.* 44:1064-1070 (1987).
- L. L. Sigal and J. W. Johnston, Jr. Effects of acidic rain and ozone on nitrogen fixation and photosynthesis in the lichen *Lobaria pulmonaria* (L.) Hoffm. *Environ. Exp. Bot.* 26:59-64 (1986).
- R. J. Norby, E. G. O'Neill, and R. J. Luxmoore. Effects of atmospheric CO₂ enrichment on the growth and mineral nutrition of *Quercus alba* seedlings in nutrient-poor soil. *Plant Physiol.* 82:83-89 (1986).
- R. S. Turner, R. J. Olson, and C. C. Brandt. Areas having soil characteristics that may indicate sensitivity to acidic deposition under alternative forest damage hypothesis. ORNL/TM-9917. Oak Ridge National Laboratory, 1986.

- G. F. Cada, J. M. Loar, and D. K. Cox. Food and feeding preferences of rainbow and brown trout in southern Appalachian streams. *Am. Midl. Nat.* 117:374–385 (1987).
- B. D. Jimenez, C. P. Cirno, and J. F. McCarthy. Effects of feeding and temperature on uptake, elimination, and metabolism of benzo[*a*]pyrene in the bluegill sunfish (*Lepomis macrochirus*). *Aquat. Toxicol.* 10:41–57 (1987).
- A. V. Palumbo, P. J. Mulholland, and J. W. Elwood. Simultaneous measurement of periphyton production, chlorophyll, and ATP using DMSO extraction. *Limnol. Oceanogr.* 32:464–471 (1987).
- A. V. Palumbo, M. A. Bogle, R. R. Turner, J. W. Elwood, and P. J. Mulholland. Bacterial communities in acidic and circumneutral streams. *Appl. Environ. Microbiol.* 58:337–344 (1987).
- L. Shugart, J. McCarthy, B. Jimenez, and J. Daniels. Analysis of adduct formation in the bluegill sunfish (*Lepomis macrochirus*) between benzo[*a*]pyrene and DNA of the liver and hemoglobin of the erythrocyte. *Aquat. Toxicol.* 9:319–325 (1987).
- G. T. Yeh. An orthogonal-upstream finite element approach to modeling aquifer contaminant transport. *Water Resour. Res.* 22(6):952–964 (1986).
- F. E. Sharples. Regulation of products from biotechnology. *Science* 235:1329–1332 (1987).
- R. L. A. Franklin, R. H. Gardner, V. H. Dale, and P. S. White. PLOTSAM: A simulation of systematic and random sampling. ORNL/TM-10670. Oak Ridge National Laboratory, 1988.
- L. R. Shugart. Quantitation of chemically induced damage to DNA of aquatic organisms by alkaline unwinding assay. *Aquat. Toxicol.* 13:43–52 (1988).

3.6 EDUCATION PROGRAMS

ESD traditionally maintains strong relationships with universities and other research institutions, and through these interactions we are able to augment staff capabilities in key scientific areas. Universities also provide valuable assistance by supplying summer staff and interns for short-term positions and by assisting us in our search for high-quality people to fill permanent staffing needs. In recent years ESD has become increasingly involved in providing educational opportunities for precollege students and for teachers as part of the nationally recognized need to enhance science education.

Our 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 the Division's programmatic objectives.

3.6.1 Undergraduate Education Program

C. T. Hunsaker

Several ORNL and Oak Ridge Associated Universities (ORAU) programs for undergraduate student participation in ESD research and assessment projects provide a continuing opportunity for interaction between students and staff. Highly qualified undergraduates are selected from colleges and universities throughout the United States (see table). Students are assigned to individual ESD advisors, who guide them through a summer- or semester-long experiment or project associated with one of the ESD programs. Each student is required to document the results in a report and present a seminar to the ESD staff. These experiences in research participation are designed to expose the student to the research process in a large laboratory. The greatest benefits to the students are frequently an expanded outlook on career opportunities in research and an understanding of practical approaches to research problems. The total number of students participating in ESD's Undergraduate Education Program increased from 27 in FY 1987 to 41 in FY 1988.

3.6.2 Graduate Education Program

S. E. Herbes

ESD provides the opportunity for graduate and postdoctoral research consistent with the mission of ORNL. During this reporting period, a total of 46 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 12 other universities, largely through the ORNL Summer Research Internship Program. In addition, 13 postdoctoral interns, 1 Hollaender Fellow, and 1 Wigner Fellow pursued research studies as part of Divisional 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

**Universities and high schools represented by guests in residence at the Environmental Sciences Division
during the period October 1, 1987, through September 30, 1988**

Institution	Students			Postdoctoral appointees	Faculty		Program ^a
	High school	Under- graduate	Graduate		High school	College/ university	
Albion College		1					GLCA/ACM
Auburn University		1				1	FRP, SSP
Austin-East High School (Tennessee)					1		STRIVE
Baylor University			1				SRI
Bearden High School (Tennessee)					1		GG
Blackburn College		1					ORSERS
California State University—Los Angeles		1					ORSERS
Centenary College		2					SCUU
Clemson University				1			P RTP
Clinton High School (Tennessee)					1		STRIVE
College of Wooster		1					GLCA/ACM
Cornell University		2					SRP, ORSERS
Denison University		1	1				GLCA/ACM, SRI
DePauw University		1					GLCA/ACM
Duke University		1					SRP
Earlham College		1					GLCA/ACM
Eastern New Mexico University		1					ORSERS
Heritage High School (Georgia)					1		GG
Illinois State University		1					PIP
Indiana State University			1				GSRP
Indiana University			3				Subcontract
Iowa State University		1					SRP
Jamestown School (Rhode Island)					1		REST
Jefferson Junior High School (Tennessee)					1		STRIVE
Knoxville College		3					SSP, SASP
Lakeshore Middle School (Florida)					1		STRIVE
Lawrence University		1					GLCA/ACM
Louisiana State University			2				GSRP, SRI
McGill University (Canada)				1			P RTP
Michigan State University		1					ORSERS
Millsaps College		4					SRP, SCUU
Minot State University		1					SRP
Murray State University			1				SRI
North Carolina State University				1			P RTP
Oak Ridge High School (Tennessee)	1				4		HSHSP, GG, HST
Oregon State University				1			P RTP
Robertsville Junior High School (Tennessee)					1		STRIVE
Selma University						1	FRP
South Dakota School of Mines and Technology		1					ORSERS
Southern University			1				GSRP
State Technical Institute (Knoxville, Tennessee)		1					TIP
Swarthmore College		1					SRI
Tuskegee University						1	OHER FRP
Universidad Metropolitana (Puerto Rico)						1	FRP
University of Arkansas			1				PIP
University of California—Davis				1			P RTP
University of California—Los Angeles			1				Subcontract
University of Delaware				1			P RTP
University of Hawaii—Hilo		1					ORSERS
University of Michigan		1					ORSERS
University of Minnesota				2			P RTP
University of Oklahoma				1			P RTP
University of Puerto Rico—San Juan		5					ORSERS, SRP

**Universities and high schools represented by guests in residence at the Environmental Sciences Division
during the period October 1, 1987, through September 30, 1988 (continued)**

Institution	Students			Postdoctoral appointees	Faculty		Program ^a
	High school	Under- graduate	Graduate		High school	College/ university	
University of Puerto Rico—Mayaguez			1				GSRP
University of Tennessee			31	2			Subcontract, ^b P RTP
University of the South		1					SCUU
University of Toronto				1			P RTP
University of Washington				1			P RTP
U.S. Naval Academy			1				SARA
Vanderbilt University			1				Subcontract
Virginia Polytechnic Institute and State University					1		FSP
Wake Forest University		1					SRI
Western Carolina University		2					ORSERS
Westmont College		1					ORSERS
Total	1	41	46	13	12	5	

^aFRP = Faculty Research Participation Program; FSP = Faculty Sabbatical Program; GG = Greenhouse Gases and Global Climate Change Project; GLCA/ACM = Great Lakes Colleges Association/Associated Colleges of the Midwest Science Semester Program; GSRP = Graduate Student Research Participation Program; HSHSP = High School Honors Study Program; HST = High School Teacher Employment; OHER FRP = DOE/OHER-Sponsored Faculty Appointment for Minority Institution; ORSERS = Oak Ridge Science and Engineering Semester Program; PIP = Professional Internship Program; P RTP = Postgraduate Research Training Program; REST = Research Experience for Science Teachers; SARA = Service Academy Research Association Program; SASP = Summer Administrative Support Program; SCUU = Southern Colleges and Universities Union; SRI = Summer Research Internship Program; SRP = Summer Research Participation Program; SSP = Special Summer Program for Undergraduate Students at Minority Institutions; STRIVE = Science Teachers Research Involvement for Vital Education Program; subcontract = subcontract from ESD to university; TIP = Technology Internship Program.

^bBreakdown by program/department: 1, biomedical science; 16, ecology; 1, environmental engineering; 6, environmental toxicology; 1, fisheries science; 4, geology; 1, microbiology; 1, plant physiology.

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 the Office of University and Educational Programs. 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 (Sect. 3.4).

3.6.3 Faculty Program

S. E. Herbes

ESD provides opportunities for professional educators to participate in collaborative research with Division staff. During this reporting period, five university faculty participated as ORAU Faculty Research Participants in summer or sabbatical research at ESD through the ORAU Faculty Summer Research Participation Program. In addition, many faculty members visited ESD for workshops, seminars, or subcontract consultations.

3.6.4 High School Science Teachers Education Program

S. E. Herbes

Several programs have been instituted by ORNL during the past several years to encourage and strengthen science education on the secondary school level by providing opportunities for teachers and students to participate directly in ORNL research projects. During summer 1988, five high school teachers from Tennessee, Georgia, and Texas worked for 8 weeks in ESD through the STRIVE (Science Teachers Research Involvement for Vital Education) Program. Through the Greenhouse Gases and Global Climate Change project, funded through DOE's Office of Carbon Dioxide Research, four other teachers from the Southeast participated in projects dealing with issues related to effects of carbon dioxide accumulation. Several area teachers were employed through the ORNL High School Teacher Employment program, while another participated through the Research Experience for Science Teachers Program. In addition, through the ORNL Special Honors Study Program for High School Students, an area high school senior performed studies at ESD to analyze the effects of nutrients on periphyton communities in artificial streams.

3.6.5 Ecological and Physical Sciences Study Center

P. D. Parr, K. M. Blair, and L. C. Cain

The Ecological and Physical Sciences Study Center is a precollege science education program initiated in 1984 as the Ecological Study Center. The program has grown considerably over the last 5 years, from 125 students in the 1984 pilot program to over 4000 students and teachers representing 7 East Tennessee counties during the 1988 school year.

The primary purpose of the Center is to enhance environmental and science education for precollege-age students (kindergarten through high school). Half-day field activity units on the Oak Ridge National Environmental Research Park emphasize a "hands-on" approach to learning about ecological relationships and physical science concepts. Additional objectives 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.

In 1987 the Office of University and Educational Programs began funding a major portion of the program. Program management is provided by the Oak Ridge National Environmental Research Park.

3.6.6 DOE High School Honors Workshop in Environmental Sciences

G. H. Marland and R. M. Cushman

A significant addition to the ESD education program in 1988 was the DOE High School Honors Workshop in Environmental Sciences. The workshop complemented several others sponsored by DOE at different national laboratories and was both the first offered in environmental sciences and the first to be held at ORNL. For 2 weeks in July, ESD

hosted 57 high school honors students selected on the basis of exceptional scientific ability. The students represented each of the 50 states, the District of Columbia, Puerto Rico, and 5 foreign countries. The purpose of the workshop was to teach through first-hand experience what environmental science research really is and how this research might become part of the academic or career plans of the participants. Most of the students left with plans that focused on environmental science issues.

Following initial welcoming activities, including a dinner hosted by University of Tennessee President Lamar Alexander, the students were divided into groups of 3 or 4 to participate in 1 of 17 ongoing Divisional research activities. Examples of projects included measurement of ^{137}Cs in lake sediments, evaluation of the effect of stream pollution on algal growth, measurement of evapotranspiration, and assessment of the effects of ozone on loblolly pines. The students also collectively examined three broader environmental problems: the prospects for global climate change, the disposal of low-level radioactive waste, and the impact of industrial pollutants on a stream. On these latter three issues, the students invoked the results of their research projects, participated in a mock public hearing, and confronted the challenge of decision making in a pluralistic society.

The 2-week workshop was also filled with tours, demonstrations, and speakers; the students frequently complained that there were "not enough hours in the day" for them to learn as much as they wanted about the environmental sciences. A typical written evaluation suggests that the program filled most of its objectives: "The staff was great . . . Overall, I learned a tremendous amount about science, met some great people, and had a lot of fun."

Participating ESD staff included 17 principal investigators who took students into their research groups for 2 weeks, plus an estimated 120 others who aided with projects, led field trips, lectured, and provided secretarial and administrative assistance. Personnel from other ORNL divisions, such as Energy Division, from TVA, and from The University of Tennessee also enthusiastically contributed their time and talents.

3.7 AFFIRMATIVE ACTION

V. R. Tolbert and A. U. Sheard

ESD firmly supports the Affirmative Action Program at ORNL and has made a concerted effort 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 handicapped. During FY 1988, ESD continued to support affirmative action principles in four main areas: promotions, hiring and staffing, career development, and education programs. ESD has also continued to build on the groundwork laid in the past to further develop minority recruiting. The following summarizes ESD progress in affirmative action during this reporting period.

- ESD made a significant commitment to develop closer relationships with minority educational institutions (MEIs). These relationships will allow identification of and development of potential minority employees as well as offer opportunities for subcontract interactions and development of MEI capabilities. Representatives from eight MEIs attended the ESD Annual Information Meeting and held discussions with staff members. Staff from ESD have held discussions with representatives of at least five other MEIs. Several of these interactions have led to identification of opportunities for project collaboration.
- Female professional staff members are actively involved as officers and members of the local chapter of the Association for Women in Science. One staff member is secretary for the national organization.
- The Oak Ridge National Environmental Research Park program continues to encourage interest in science in young children by providing hands-on experience. Two female professional staff taught stream ecology classes for children this summer.
- ESD is continuing to develop a mentoring program.
- The Division as a whole contributed to affirmative action through hiring and staffing on all levels—including managerial, professional, technical, and clerical—as well as through subcontractual arrangements.
 - A female technician in the Environmental Toxicology Section was promoted to research associate.
 - A female was hired as a Research Associate I in the Environmental Toxicology Section.
 - ESD has a number of ongoing subcontracts with MEIs and with minority businesses.
- ESD has also furthered affirmative action objectives by extending opportunities for professional development and skills training to its employees.
 - Female professional staff members attended a variety of national and international conferences and workshops, hosted foreign visitors, and participated in training opportunities as either leaders or participants.

- A female group leader in the Environmental Analyses Section attended the United Nations Environmental Programme meeting held in Paris and the First International Conference on the Release of Genetically Engineered Microorganisms held in Wales for the United Nations Environmental Programme.
- With an eye to the future, ESD has taken steps to include women and minorities in the wide variety of training programs and education programs that are open to visiting students, faculty, and scientists.
 - ESD hosted the 2-week DOE High School Honors Workshop in Environmental Sciences that enabled outstanding high school students from each of the 50 states and from several foreign countries to learn about science and to participate in hands-on research efforts.
 - Staff of the Environmental Toxicology Section supervised the research and training of two minority faculty from Selma University and the University of Puerto Rico.
 - Of a total of 19 students funded for the summer through the ORNL Office of University Relations, 5 minority students and 12 female students worked in ESD.
 - One minority female undergraduate working in ESD during the summer was the recipient of the Blacks in Government/Federally Employed Women (BIG/FEW) scholarship award based on scholastic achievement.
 - Three of the four teachers working in ESD this summer as part of the Science Teachers Research Involvement for Vital Education Program were female.
 - Three of five faculty members working in ESD for the summer were minorities from MEIs.

3.8 SEMINAR PROGRAM

V. H. Dale

During the past year, the ESD Seminar Committee offered a diverse program of guest lecturers (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.

T. Rosswall, Royal Swedish Academy of Sciences, Stockholm, Sweden: "The International Geosphere-Biosphere Program: A Study of Global Change," October 22, 1987.

J. C. Westall, Department of Chemistry, Oregon State University, Corvallis: "Adsorption of Ionic Organic Compounds in the Environment: Hydrophobic or Electrostatic," January 28, 1988.

J. F. Franklin, College of Forest Resources, University of Washington, Seattle: "Patch Dynamics as Affected by Timber Harvest in the Western United States," March 24, 1988.

T. Takahashi, Geochemistry Division, Lamont-Doherty Geological Observatory, Palisades, New York: "In Search of Direct Evidence for Fossil Fuel CO₂ Uptake by the Oceans," April 12, 1988.

D. Elmore, Nuclear Structure Laboratory, University of Rochester, Rochester, New York: "Application of Accelerator Mass Spectrometry to the Geological and Environmental Sciences," April 1988.

W. Schlesinger, Department of Botany, Duke University, Durham, North Carolina: "Processes Maintaining Forest Vegetation in a Desert Ecosystem," May 3, 1988.

M. E. Mitchell, Martin Marietta Energy Systems, Environmental and Safety Activities Organization, Oak Ridge, Tennessee: "Environmental Activities in Martin Marietta Energy Systems," June 15, 1988.

P. Opdam, Research Institute for Nature Management, The Netherlands: "Fragmentation in the Dutch Agricultural Landscapes: A Problem of Ecological Research," September 22, 1988.

C. Walters, University of British Columbia, Vancouver, British Columbia, Canada: "Managing Renewable Resources Using Very Large Scale Experiments," September 29, 1988.

3.9 VISITORS HOSTED

C. F. Baes III

During FY 1988 a total of 1513 persons visited the ESD facilities as part of tour groups (see table below). This number represents an increase of 325 over that of the previous year.

Tour groups hosted from October 1, 1987, to September 30, 1988

Institution ^a	Date	Number in tour	ESD host(s)
Physics and biology students, Lenoir City High School	10/1/87	20	R. J. Norby, A. J. Stewart, M. B. Adams
Cast of "Up with People"	10/7/87	40	C. J. Ford, M. B. Adams
National Association of Accountants	10/9/87	40	J. W. Ranney
New employee orientation	10/23/87	40	S. M. Adams
Students of National Environmental Health Association, Eastern Kentucky University	10/30/87	12	J. W. Ranney, C. J. Ford
GLCA Science Semester students	11/2/87	18	C. J. Ford
High school students participating in National Chemistry Day	11/6/87	20	R. J. Norby, B. L. Kimmel, P. A. Layton
GLCA Science Semester students	11/10/87	11	R. J. Norby
New employee orientation	11/16/87	25	A. J. Stewart
Environmental health problems class, East Tennessee State University	11/24/87	10	B. P. Spalding
Eighth and ninth graders, Powell Middle School	11/25/87	20	A. J. Stewart
Physics majors, Western Kentucky University	11/30/87	10	C. P. Anderson
DOE new employee orientation	12/2/87	40	B. L. Kimmel
Yancy County Middle School teachers	12/11/87	8	A. J. Stewart
Nursing and biology students, ORAU/Dabney Lancaster College	12/15/87	17	C. J. Ford, T. J. Blasing
Oak Ridge Science and Engineering Research and Southern College/University Union Semesters	1/11/88	40	A. J. Stewart
Seventh and eighth graders, Anderson County Gifted Resource Center	1/20/88	15	M. B. Adams, C. J. Ford, P. A. Layton
ORAU/Minimester Course participants	1/20/88	20	B. L. Kimmel
ORAU/Minimester Course participants	1/21/88	20	S. M. Adams
Honors physics and chemistry students, Bearden High School	1/26/88	70	L. A. Kszos, R. J. Norby, T. Tschaplinski, A. J. Stewart
New employee orientation	2/8/88	25	C. J. Ford
Honors/gifted course in future problem solving, Doyle Middle School	2/11/88	18	D. S. Shriner
Oak Ridge Girl Scout troop	2/16/88	15	S. M. Adams
1988 Junior Science and Humanities Symposium	3/4/88	20	J. W. Johnston, C. J. Ford, C. P. Anderson
DOE new employee orientation	3/8/88	40	S. M. Adams
Radiochemistry majors, ORAU/Indiana University of Pennsylvania	3/11/88	10	F. O. Hoffman
American Field Service students, Clinton High School	3/18/88	50	
New employee orientation	3/24/88	25	S. M. Adams
Chemistry and biology majors, High Point College	3/24/88	11	J. W. Johnston
Business Services Department personnel, Finance and Materials Division	4/19/88	20	A. J. Stewart

Tour groups hosted from October 1, 1987, to September 30, 1988 (continued)

Institution ^a	Date	Number in tour	ESD host(s)
Ecology students, Tennessee Wesleyan College	4/27/88	11	G. J. Haynes, M. B. Adams
Sisters of Loretto	4/28/88	3	P. A. Layton, B. L. Kimmel
Science Club, Northwest High School	5/6/88	58	L. A. Kszos
Participants, 39th International Science and Engineering Fair	5/10/88	40	C. J. Ford, N. T. Edwards, C. F. Baes III
Participants, 39th International Science and Engineering Fair	5/13/88	40	C. J. Ford, N. T. Edwards, C. F. Baes III
Science students, Robertsville Junior High School	5/20/88	25	S. M. Adams, H. L. Boston
National Association for Foreign Student Advisors, The University of Tennessee	5/25/88	10	L. L. Wright, C. J. Ford
Environmental problems class, Middle Tennessee State University	5/26/88	13	R. J. Norby, H. L. Boston, J. W. Johnston
Biology class, Carroll College	5/27/88	6	J. W. Johnston, C. J. Ford, R. J. Norby, N. T. Edwards, C. F. Baes III
Science majors, ORAU Science Minimester	5/31/88	25	L. A. Kszos
Science majors, ORAU Science Minimester	6/1/88	25	S. M. Adams
Science majors, ORAU/HBCU	6/3/88	15	A. J. Stewart
Attendees, course on management of natural resources, Executive Seminar Center	6/8/88	40	A. O. Steinman
Science majors, ORAU/Chipola College	6/13/88	19	L. A. Kszos
ORNL summer employees	6/16/88	20	H. L. Boston
NCO Academy, Air National Guard	6/22/88	95	A. J. Stewart, J. W. Ranney, P. A. Layton
DOE new employee orientation	6/23/88	40	H. L. Boston
Arnold Roane, Director of Administration, Martin Marietta Denver Aerospace	6/27/88	1	A. J. Stewart
Gifted female high school students, Career Awareness Program	6/27/88	21	J. W. Ranney
Chemistry majors, The University of Tennessee Summer Research Program	7/7/88	15	G. J. Haynes
ORAU summer research participants	7/19/88	10	A. O. Steinman
Gifted high school science students, Southwest Virginia Community College Governor's School	7/26/88	15	C. J. Ford
Valley Alliance for Minority Achievement High School Science and Engineering Workshop	8/1/88	20	C. J. Ford
NCO Academy, Air National Guard	8/10/88	87	J. H. Cushman, H. L. Boston
New employee orientation	8/15/88	25	S. M. Adams
DOE interns briefing	8/23/88	4	B. L. Kimmel
GLCA participants	8/29/88	20	G. J. Haynes
New employee orientation	8/31/88	25	C. J. Ford
ORAU and ORNL Science Semester students	9/6/88	32	S. M. Adams
Business Services Department personnel, Finance and Materials Division	9/13/88	20	G. J. Haynes
Douglas Ditto, Deputy Consul General and Senior Trade Commissioner Canadian Consulate	9/14/88	3	R. I. Van Hook
Total		1513	

^aDOE = U.S. Department of Energy; GLCA = Great Lakes Colleges Association; HBCU = historically black colleges and universities; NCO = noncombat officers; ORAU = Oak Ridge Associated Universities; ORNL = Oak Ridge National Laboratory.

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3.11 PRESENTATIONS

Adams, M. B., N. T. Edwards, J. M. Kelly, and G. E. Taylor, Jr.

"Growth of Loblolly Pine Seedlings in Response to Two Years of Ambient, Subambient, or Elevated Ozone Exposure," Fourth Annual Gatlinburg Acid Rain Conference, Gatlinburg, Tennessee, October 1987.

"Response of Five Loblolly Pine Families in Two Years of Ambient, Subambient or Elevated Ozone Levels," Seventh North American Forest Soils Meeting, Vancouver, British Columbia, Canada, July 1988.

Adams, M. B., and S. B. McLaughlin

"Effects of Ozone and Acidic Precipitation on Loblolly Pine Root Growth," Annual Meetings of the American Society of Agronomy, the Crop Science Society of America, and the Soil Science Society of America, Atlanta, Georgia, November 1987.

Adams, S. M.

"Status and Use of Bioindicators for Evaluating the Effects of Chronic Stress on Fish," 117th Annual Meeting of the American Fisheries Society, Winston-Salem, North Carolina, October 1987.

"Trophic Dynamic Relationships of Fish Communities in Southeastern Reservoir Ecosystems," invited seminar, Virginia Polytechnic Institute and State University, Blacksburg, April 1988.

"Bioindicators as Useful Environmental Monitoring Tools," invited seminar, Tennessee Technological University, Cookeville, May 1988.

Adams, S. M., M. G. Ryon, and J. G. Smith

"Importance of Multiple Reference Sites for Evaluating the Significance of Environmental Stress to Fish Populations," Annual Meeting of the American Fisheries Society, Toronto, Ontario, Canada, September 1988.

Auerbach, S. I.

"Importance of Establishing Long-Term Environmental Research," Science, Universities and Government, Chicago, Illinois, December 1987.

"Monitoring the Environment in the 21st Century," Second U.S.-U.S.S.R. Symposium, Gatlinburg, Tennessee, September 1988.

Baes, C. F., III, and G. Marland

"How Clean Is Clean: A Review of Superfund Cleanups," Oak Ridge Model Conference, Oak Ridge, Tennessee, October 1987.

"The SARA Mandate, the CERCLA Remedial Action Process, and a Review of Superfund Cleanups," Spectrum '88 International Topical Meeting on Nuclear and Hazardous Waste Management, Pasco, Washington, September 1988.

Baker, J. P., S. W. Christensen, C. S. Creager, and W. Warren-Hicks

"Regional Effects of Acidification on Fish Populations in the Adirondack Region of New York," invited paper, Final Regional Case Studies Project Meeting, EPA, Boulder, Colorado, June 1988.

Barnthouse, L. W., J. E. Breck, C. W. Christensen, D. L. DeAngelis, K. A. Rose, A. S. Trebitz, and W. Van Winkle

"An Individual-Based Approach to Fish Population Models," Annual Meeting of the American Fisheries Society, Toronto, Ontario, Canada, September 1988.

Barnthouse, L. W., G. W. Suter II, and A. G. Rosen

"Assessing Risks of Toxic Contaminants to Explained Fish Populations," Eighth Annual Meeting of the Society for Environmental Toxicology and Chemistry, Pensacola, Florida, November 1987.

Barnthouse, L. W., G. W. Suter II, A. G. Rosen, and D. S. Vanshaw

"Fish Population Models in Regulatory Risk Assessment," International Society for Ecological Modeling, Davis, California, August 1988.

Bartell, S. M., and A. L. Brenkert

"Spatial-Temporal Modeling of Nitrogen Dynamics in the Walker Branch Watershed," Third Annual Landscape Ecology Symposium, Albuquerque, New Mexico, March 1988.

Bates, L. D., and J. R. Trabalka

"Program Overview: Remedial Actions at Oak Ridge National Laboratory," Summer National Meeting of the American Institute of Chemical Engineers, Denver, Colorado, August 1988.

Blaylock, B. G., and F. O. Hoffman

"Research Issues in Radioecology as a Result of the Chernobyl Accident," Electric Power Research Institute, Palo Alto, California, August 1988.

Bondietti, E. A.

"Soil Acidification Trends in the Great Smoky Mountains," Fourth Annual Acid Rain Symposium, Gatlinburg, Tennessee, October 1987.

Bondiatti, E. A., C. F. Baes III, and S. B. McLaughlin

"Potential of Trees to Record Aluminum Mobilization and Changes in Alkaline Earth Availability," National Research Council Workshop on Markers of Air Pollution Effects on Trees, Little Switzerland, North Carolina, April 1988.

"Tree Rings, Soil Chemistry, and Forest Decline," ESD Annual Information Meeting, Oak Ridge, Tennessee, May 1988.

Borders, D. M., D. W. Hyndman, and D. D. Huff

"Forecasting Contaminant Concentrations: Spills in the White Oak Creek Basin," Oak Ridge Model Conference, Oak Ridge, Tennessee, October 1987.

Brenkert, A. L., R. H. Gardner, S. M. Bartell, and F. O. Hoffman

"Uncertainties Associated with Estimates of Radium Accumulation in Lake Sediments and Biota," Workshop on Methods for Assessing the Reliability of Environmental Transfer Models Predictions, Athens, Greece, October 1987.

Cada, G. F.

"The Value of Reference Sites for Assessing Disturbance and Recovery of Impacted Headwater Streams," Annual Conference of the National Association of Environmental Professionals, Orlando, Florida, April 1988.

Cada, G. F., and C. T. Hunsaker

"Assessment of Cumulative Impacts for Hydropower Development," Annual Conference of the National Association of Environmental Professionals, Orlando, Florida, April 1988.

Christensen, S. W.

"Young-of-the-Year Growth and Survival Modules," invited paper, Electric Power Research Institute, Project on Compensatory Mechanisms in Fish Populations, Review of the COMPMECH Modeling Framework, Houston, Texas, February 1988.

"The LAF Framework for Predicting Acidification Effects on Fish," invited paper, U.S. Environmental Protection Agency, Planning Workshop for the 1990 Final Report for the Aquatic Effects Research Program—Biology, Herndon, Virginia, April 1988.

"Regional Models for Predicting Effects of Acidification on Fish," invited paper, U.S. Environmental Protection Agency, Planning Workshop for the 1990 Final Report for the Aquatic Effects Research Program—Biology, Herndon, Virginia, April 1988.

"Reintroduction to the LAF Framework and Overview of Task I Activities," invited paper, Electric Power Research Institute, Lake Acidification and Fisheries Project Advisory Committee Meeting, Laramie, Wyoming, July 1988.

"Application of the LAF Framework to Brook Trout," invited paper, Electric Power Research Institute, Lake Acidification and Fisheries Project Advisory Committee Meeting, Laramie, Wyoming, July 1988.

"The Aquatic Effects Research Program: Results Relating to Economic Impacts of Acidification on Fish Populations," invited paper, Planning Workshop for the Economic Analysis of the Aquatic Effects of Acidification for the NAPAP 1990 Assessment, Seattle, Washington, September 1988.

"Comparing the Significance of Stress on Different Life-Stages of Fish: A Reproductive Potential Approach," invited paper, Research Session, Third Biennial National Workshop on Micro-Computer Applications in Fish and Wildlife Programs, Stateline, Nevada, September 1988.

Christensen, S. W., J. E. Breck, W. Van Winkle, J. P. Baker, and D. R. Mount

"Acidification Effects on Fish Populations: Regional Predictions Using a Modeling Framework," invited paper, Eighth Annual Meeting of the Society of Environmental Toxicology and Chemistry, Pensacola, Florida, November 1987.

Cook, R. B.

"Mechanisms Controlling Sulfur Accumulation in Lake Sediments," International Conference on Trace Metals in Lakes, Hamilton, Ontario, Canada, August 1988.

Cook, R. B., M. A. Bogle, R. S. Turner, and J. W. Elwood

"The Isotope Content of Sulfur in Watersheds in the Great Smoky Mountains National Park," Fourth Annual Gatlinburg Acid Rain Conference, Gatlinburg, Tennessee, October 1987.

Cook, R. B., J. M. Eilers, and H. I. Jager

"Acid Deposition and Lakewater Chemistry in the Upper Midwest," American Society of Limnology and Oceanography, Boulder, Colorado, June 1988.

Coutant, C. C.

"Microchemical Analysis of Fish Hard Parts for Reconstructing Habitat Use: Practice and Promise," International Symposium and Educational Workshop in Fish-Marking Techniques, Seattle, Washington, June-July 1988.

"Temperature-Oxygen Habitat for Fish in a Changing Climate," Annual Meeting of the American Fisheries Society, Toronto, Ontario, Canada, September 1988.

"A Holistic View of Striped Bass Habitat Suitability in Chesapeake Bay: Insights on a Population Decline," Annual Meeting of the American Fisheries Society, Toronto, Ontario, Canada, September 1988.

Dale, V. H.

"Determinants of Ecological Pattern," ORAU Traveling Lecture, Tennessee Technological University, Cookeville, March 1988.

"Sampling Spatially Distributed Ecological Information," Third Annual Landscape Ecology Symposium, Albuquerque, New Mexico, March 1988.

"Effects of Climate Change on Stand Development in the Pacific Northwest," Annual Meeting of the Ecological Society of America, Davis, California, August 1988.

"Biogeochemistry of CO₂ and the Greenhouse Effect," Meeting of the American Chemical Society, Los Angeles, California, September 1988.

Davis, E. C.

"Groundwater Contamination and Control at a Low-Level Radioactive Waste Site," American Society of Civil Engineers Spring Convention, Nashville, Tennessee, May 1988.

DeAngelis, D. L.

"Ecological Processes Governing Ecosystem Function," Workshop on Biological Response to Environmental Change, Woods Hole, Massachusetts, October 1987.

"Some Stability Relations in Nutrient-Limited Systems," Joint U.S.-Japan Seminar on the Environmental Sciences, Honolulu, Hawaii, April 1988.

"Individual-Based Models in Fisheries Research," invited paper, Southern California Edison Company, Los Angeles, California, July 1988.

DeAngelis, D. L., and R. M. Cushman

"The Potential Application of Models in Forecasting the Effects of Climate Changes on Fisheries," Annual Meeting of the American Fisheries Society, Toronto, Ontario, Canada, September 1988.

Doyle, T. W.

"An Evaluation of Competition Models for Investigating Tree and Stand Growth Processes," Forest Growth Modeling Conference, Gulf Shores, Alabama, April 1988.

Dreier, R. B., and M. B. Leat

"Fracture Zone Identification in the Appalachian Fold and Thrust Belt Determined from Geophysical Logs," International Conference on Fluid Flow in Fractured Rocks, Atlanta, Georgia, May 1988.

Eddlemon, G. K.

"Hazardous Materials Management," Annual Meeting of the U.S. Navy Inactive Fleet Site Directors, Pearl Harbor, Hawaii, March 1988.

Eddlemon, G. K., and L. L. Sigal

"Auditing Hazardous Waste Management at DOD Facilities: Lessons Learned and Recommendations," Annual Conference of the National Association of Environmental Professionals, Orlando, Florida, April 1988.

Edwards, N. T., M. B. Adams, and G. E. Taylor, Jr.

"Effects of Ozone, Acid Precipitation, and Soil Magnesium on Growth and Leaf Pigments in Loblolly Pine (*Pinus taeda* L.)," 39th Annual Meeting of the American Institute of Biological Sciences, Davis, California, August 1988.

Elwood, J. W.

"Watershed Research and Walker Branch Watershed," Walker Branch Watershed Project Briefing, DOE Headquarters, Washington, D.C., June 1988.

Elwood, J. W., D. W. Johnson, R. J. Luxmoore, P. J. Mulholland, C. T. Garten, Jr., S. M. Bartell, and W. Van Winkle

"Walker Branch: An Integrated Study of C, N, and P Cycling and Transport in a Forested Watershed," ESD Annual Information Meeting, Oak Ridge, Tennessee, May 1988.

Elwood, J. W., M. J. Sale, H. I. Jager, and P. R. Kaufmann

"Variation in the Acid-Basic Chemistry Among Streams in the Southern Blue Ridge Province," Annual Meeting of the American Society of Limnology and Oceanography, Boulder, Colorado, June 1988.

Eng, W., A. V. Palumbo, and C. D. Little

"Kinetics of Trichloroethylene Degradation by a Methane Utilizing Bacterium Under Oxygen Limiting Conditions," 88th Annual Meeting of the American Society for Microbiology, Miami, Florida, May 1988.

Francis, C. W.

"Laboratory and Field Leaching Studies for Deposition of Solid Wastes in the Environment," Institut für Chemische Technologie der Nuklearen Entsorgung, Kernforschungsanlage (KFA) Jülich Research Centre, Jülich, Federal Republic of Germany, March 1988.

"Leaching Characteristics of Thermal Process Residues," Treatment and Disposal of Thermal Process Residues, New York, New York, September 1988.

Friend, A. L., and T. M. Hinckley

"Carbon-14 Allocation and Growth in Douglas-Fir Seedlings Under Nitrogen Stress," Annual Meeting of the Ecological Society of America, Davis, California, August 1988.

Gardner, R. H.

"Uncertainty Analysis," invited paper, BIOMOVs Workshop on Biospheric Model Validation, Grand Canyon, Arizona, November 1988.

Gardner, R. H., and V. H. Dale

"Error Propagation and Uncertainty in Process Modeling," Forest Growth: Process Modeling of Responses to Environmental Stress, Gulf Shores, Alabama, April 1988.

Gardner, R. H., B. T. Milne, V. H. Dale, R. V. O'Neill, and M. G. Turner

"Percolation Theoretic Methods for Estimating Landscape Viscosity," Third Annual Landscape Ecology Symposium, Albuquerque, New Mexico, March 1988.

Garten, C. T., Jr.

"Isotope Studies to Determine Dry Deposition of Sulfate to Deciduous and Coniferous Trees," NAPAP Atmospheric Chemistry (Task II) Review, Knoxville, Tennessee, March 1988.

Garten, C. T., Jr., E. A. Bondiotti, and R. D. Lomax

"Contribution of Foliar Leaching and Dry Deposition to Sulfate in Net Throughfall Below Deciduous Trees," Fourth Annual Gatlinburg Acid Rain Conference, Gatlinburg, Tennessee, October 1987.

Graham, R. L., C. T. Hunsaker, L. W. Barnthouse, S. M. Bartell, R. H. Gardner, R. V. O'Neill, and G. W. Suter II

"Environmental Risk Assessment at the Landscape and Regional Scale," Third Annual Landscape Ecology Symposium, Albuquerque, New Mexico, March 1988.

Graham, R. L., L. R. Iverson, and E. A. Cook

"Stand Structure and Growth in the Great Smoky Mountains, Tennessee: Whittaker's Stands Revisited," National Park Service, Gatlinburg, Tennessee, May 1988.

"Long-Term Records of Stand Structure and Function in the Great Smoky Mountains, Tennessee," Annual Meeting of the Ecological Society of America, Davis, California, August 1988.

Gregory, S. M., and D. K. Solomon

"Lateral Transport Above the Water Table During Storms," Tennessee Hydrology Symposium, Nashville, Tennessee, June 1988.

Grigal, D. F., and R. S. Turner

"Evaluating Impacts of Pollutants for the Atmosphere," International Interaction Workshop on Soil Resources: Their Inventory, Analysis, and Interpretation for Use in the 1990s, Minneapolis, Minnesota, March 1988.

Haase, C. S., K. Von Damm, and S. H. Stow

"Studies to Determine the Fate of Radioactive Wastes Disposed of by Underground Injection at ORNL," Waste Management '88, Tucson, Arizona, March 1988.

Hanson, P. J., and S. B. McLaughlin, Jr.

"Growth, Photosynthesis, and Chlorophyll Concentrations of Red Spruce Seedlings Treated with Fog Containing H₂O₂," Annual Meeting of the American Society of Plant Physiologists, Reno, Nevada, July 1988.

Hanson, P. J., S. B. McLaughlin, Jr., M. B. Adams, N. T. Edwards, P. A. Layton, R. J. Norby, and E. G. O'Neill

"Comparative Sensitivity, Mechanisms, and Whole Plant Physiological Implications of Responses of Loblolly Pine Genotypes to Ozone and Acid Deposition," Fourth Annual Gatlinburg Acid Rain Conference, Gatlinburg, Tennessee, October 1987.

Hanson, P. J., and G. E. Taylor, Jr.

"Modeling Pollutant Gas Uptake by Leaves: An Approach Based on Physicochemical Properties," Forest Growth: Process Modeling of Responses to Environmental Stress, Gulf Shores, Alabama, April 1988.

Haynes, G. J., A. J. Stewart, and B. C. Harvey

"Sex and *Ceriodaphnia*: Gender-Dependent Problems in Toxicity Tests with *C. dubia*," North American Benthological Society, Tuscaloosa, Alabama, May 1988.

Hildebrand, S. G., and G. F. Cada

"Case Studies Defining Environmental Issues for Nonfederal Hydroelectric Development in the United States," UNESCO Staff, Paris, France, May 1988.

Hill, D. L., T. L. Donaldson, T. J. Phelps, D. C. White, G. W. Strandberg, and A. V. Palumbo

"Bioremediation of Polychlorinated Biphenyls: Degradation Capabilities in Field Lysimeters," Tenth Symposium on Biotechnology for Fuels and Chemicals, Gatlinburg, Tennessee, May 1988.

Hoeksema, R. J., and R. B. Clapp

"Cokriging Model of Water Table Evaluation," Fall Meeting of the American Geophysical Union, San Francisco, California, December 1987.

Hoffman, F. O.

"Interception and Retention of ^{131}I by Pasture Vegetation," National Cancer Institute Task Group on Exposure of American People to Iodine-131 from NTS Fallout, Oak Ridge, Tennessee, January 1988.

"The Evaluation of Models Used for Environmental Radiological Assessments," Colorado State University, Fort Collins, February 1988.

"Review of Procedures and Implications of Uncertainty Analyses," Uncertainty Analysis Workshop, Fort Collins, Colorado, February 1988.

"Modelling Approaches for Estimating Derived Intervention Levels in Food," Scientific Seminar on Foodstuff Intervention Levels Following a Nuclear Accident, Commission of the European Communities, Luxembourg, Belgium, March 1988.

Hoffman, F. O., and M. L. Frank

"Throughfall Experiments on Pasture Vegetation," Atmospheric Turbulence and Diffusion Laboratory Seminar, Oak Ridge, Tennessee, February 1988.

Hoffman, F. O., and E. Hofer

"An Overview of the IAEA Safety Series on Procedures for Evaluating the Reliability of Predictions Made by Environmental Transfer Models," Workshop on Methods for Assessing the Reliability of Environmental Transfer Model Predictions, Athens, Greece, October 1987.

Huff, D. D.

"Transport Processes and Waste Management," Nuclear and Chemical Waste Program Seminar Series, Oak Ridge, Tennessee, February 1988.

Huff, D. D., G. K. Moore, R. H. Ketelle, and L. D. Hyde

"The ORNL Ground-Water Monitoring Program," Oak Ridge Model Conference, Oak Ridge, Tennessee, October 1987.

Hunsaker, C. T.

"Water Resources and Climate Change: What Do We Know?" Fall Meeting of the American Geophysical Union, San Francisco, California, December 1987.

"Environmental Assessment for Large-Scale Disturbances: Acid Rain, Climate Change, and Energy Development," Seminar Series, University of Georgia, Athens, February 1988; Oak Ridge Science Semester Seminar Series, Oak Ridge, Tennessee, April 1988.

Hunsaker, C. T., R. L. Graham, L. W. Barnhouse, S. M. Bartell, R. H. Gardner,
R. V. O'Neill, and G. W. Suter II

"The Big Picture—Regional Risk Assessment," Annual Conference of the Association
of Environmental Professionals, Orlando, Florida, April 1988.

Huston, M. A.

"The Physiological Basis of Ecosystem Patterns," Institute for Ecosystem Studies,
Cary Arboretum, Millbrook, New York, May 1988.

"Synthesis and Integration—Walker Branch Watershed," DOE-OHER, Germantown,
Maryland, June 1988.

Iverson, L. R., E. A. Cook, and R. L. Graham

"Applications of Remote Sensing to Forested Ecosystems," Annual Meeting of the
Ecological Society of America, Davis, California, August 1988.

Jacobs, G. K.

"In Situ Vitrification: Man-Made Magmas for Waste Stabilization," Geology Depart-
ment Seminar, University of Vermont, Burlington, March 1988.

"Laboratory Tests in Support of Waste Management: Can Both Scientific and Regula-
tory Needs Be Served?" Meeting of the Southeast Section of the Geological Society
of America, Columbia, South Carolina, April 1988.

Jacobs, G. K., and B. P. Spalding

"Geochemical Aspects of In Situ Vitrification," Nuclear and Chemical Waste
Management Seminar Series, Oak Ridge National Laboratory, Oak Ridge, Tennes-
see, May 1988.

Jacobs, G. K., B. P. Spalding, J. G. Carter, and S. S. Koegler

"In Situ Vitrification Demonstration for the Stabilization of Buried Waters at the
Oak Ridge National Laboratory," Oak Ridge Model Conference, Oak Ridge, Tennes-
see, October 1987.

Jardine, P. M., J. F. McCarthy, and N. L. Weber

"Chemical and Hydrologic Factors Controlling the Transport of Organic Colloids in
Soil," Mobility of Colloidal Particles in Subsurface, Manteo, North Carolina, October
1988.

Jardine, P. M., G. V. Wilson, and R. J. Luxmoore

"Modeling the Transport of Inorganic Ions Through Undisturbed Soil Columns from
Two Contrasting Watersheds," Annual Meeting of the American Society of Agron-
omy, Atlanta, Georgia, November 1987.

"Modeling Solute Transport Through Undisturbed Soil Columns and an Isolated Pedon in the Field," Soil Physics Workshop, Blacksburg, Virginia, March 1988.

Jardine, P. M., G. V. Wilson, R. J. Luxmoore, and R. J. Jones

"Modeling Solute Transport Through Undisturbed Soil Columns and an Isolated Pedon in the Field," Validation of Flow and Transport Models, Ruidoso, New Mexico, May 1988.

Jimenez, B. D., A. Oikari, S. M. Adams, B. D. Esau, T. Petamen, and C. M. Morrissey

"Laboratory and Field Studies on Monooxygenase Activity in Sunfish *Lepomis* sp.," Annual Meeting of the American Chemical Society, Los Angeles, California, September 1988.

Johnson, D. W., R. B. Harrison, D. E. Todd, Jr., and D. S. Silsbee

"Nutrient Status of Red Spruce Forests Near Clingman's Dome, Great Smoky Mountains National Park," Fourth Annual Gatlinburg Acid Rain Conference, Gatlinburg, Tennessee, October 1987.

Johnson, D. W., R. J. Olson, L. K. Mann, and D. E. Todd, Jr.

"Twenty-Year Changes in Biomass and Nutrient Distribution in Forests of Walker Branch Watershed, Tennessee," Seventh North American Forest Soils Conference, Vancouver, British Columbia, Canada, July 1988.

Johnson, D. W., and D. E. Todd, Jr.

"Soil Available N Dynamics Following Melamine Vs. Urea Fertilization in a Loblolly Pine Plantation," Annual Meeting of the American Society of Agronomy, Atlanta, Georgia, November 1987.

Johnson, D. W., H. Van Miegroet, and W. T. Swank

"Markers of Air Pollution in Forests: Nutrient Cycling," National Research Council Workshop on Markers of Air Pollution Effects in Forests, Little Switzerland, North Carolina, April 1988.

Joslin, J. D.

"Predicting the Response of Red Spruce Seedlings to Soil Al," Annual Meeting of the American Society of Agronomy, Atlanta, Georgia, November 1987.

Kelly, J. M., J. D. Joslin, F. C. Thornton, M. Schaedle, and D. Raynal

"A Comparison of the Response of Red Spruce to Al in Soil and in Solution Culture," Annual Meeting of the American Society of Agronomy, Atlanta, Georgia, November 1987.

Kimmel, B. L.

"Ecological Basis for Lake and Reservoir Management Guidance Manual," North American Lake Management Society Workshop, Orlando, Florida, November 1987.

King, A. W.

"Transmutations and Functional Representation at the Landscape Level," Third Annual Landscape Ecology Symposium, Albuquerque, New Mexico, March 1988.

"Linking Mechanistic Models of Tree Physiology with Models of Forest Stand Dynamics: Problems of Temporal Scale," Conference on Forest Growth: Process Modeling of Responses to Environmental Stress, Gulf Shores, Alabama, April 1988.

"Predicting Seasonal Carbon Dioxide Dynamics of the Terrestrial Biosphere Using Ecosystem Models," Annual Meeting of the Ecological Society of America, Davis, California, August 1988.

King, A. W., and R. V. O'Neill

"Biogeochemistry of CO₂ in Carbon Cycle Models: Interactions of C, N, and P in the Biosphere," Annual Meeting of the American Chemical Society, Los Angeles, California, September 1988.

Kszos, L. A., and A. J. Stewart

"Toxicity Patterns in Streams at the Oak Ridge National Laboratory," 36th Annual Meeting of the North American Benthological Society, Tuscaloosa, Alabama, May 1988.

Lambert, R. E., J. T. Ammons, D. A. Lietzke, and S. Y. Lee

"Landform and Soil Development on the Pumpkin Valley Shale of East Tennessee," Annual Meeting of the American Society of Agronomy, Atlanta, Georgia, November 1987.

Layton, P. A.

"Biotechnology of Poplars in the U.S.A.," IEA/BA Task II Biotechnology Development Conference, Bristol, England, September 1988.

Lee, S. Y., L. K. Hyder, and P. D. Allen

"Mineralogical Characterization of Selected Shales for Evaluation of a High-Level Nuclear Waste Repository," 24th Annual Meeting of the Clay Minerals Society, Socorro, New Mexico, October 1987.

Lee, S. Y., D. H. Phillips, D. A. Lietzke, and J. T. Ammons

"Microscopic Study of Iron and Manganese Oxide Distribution in Soils from East Tennessee," International Working Meeting on Soil Micromorphology, San Antonio, Texas, July 1988.

Lerniszki, P. J., R. D. Hatcher, C. T. Lutz, L. E. Toran, and R. B. Dreier

"Fluid Movement in Sedimentary Rock Systems," First Tennessee Hydrology Symposium, Nashville, Tennessee, June 1988.

Lindberg, S. E.

"Field Measurements of the Atmospheric Deposition and Plant Uptake of Airborne Nitrogen in the Integrated Forest Study," invited paper, Swedish Environmental Research Institute, Göteborg, Sweden, September 1988.

"Understanding Aerosol Dry Deposition Processes in Forests from the Analysis of Throughfall," invited keynote paper, Workshop on Aerosol Interactions with Natural Surfaces, Nordic Aerosol Association Joint Meeting with the German Society for Aerosol Research, Lund, Sweden, September 1988.

"Can Total Atmospheric Deposition of Sulfur Be Estimated from Analysis of Throughfall: Results of Integrated Forest Study Measurements and ³⁵S Experiments," invited paper, Meteorological Institute of the Stockholm University, Stockholm, Sweden, September 1988.

"Dry Deposition of Trace Metals Associated with Coarse Aerosols," invited paper, NATO Advanced Workshop on Atmospheric Trace Metals, Oslo, Norway, September 1988.

"Deposition and Canopy Scavenging of Aerosols," invited paper, Illinois Institute of Technology, Chicago, April 1988.

"Aerosol Dry Deposition Estimates from a Throughfall Model," European Aerosol Conference, Lund, Sweden, August 1988.

"Precipitation Chemistry and Scavenging Ratios at High- and Low-Elevation Sites," MAP3S/RAINE Review and Workshop, Washington, D.C., January 1988.

"Overview of Results of Surface Analysis Approaches to Dry Deposition Parameterization for the NAPAP," NAPAP Peer Review, Knoxville, Tennessee, March 1988.

"Deposition of Pb to a High-Elevation Forest," National Atmospheric Deposition Program Annual Meeting, Minneapolis, Minnesota, October 1987.

Little, C. D., A. V. Palumbo, and S. E. Herbes

"Trichloroethylene Degradation by Methane-Oxidizing Groundwater Bacteria," Eighth Annual Meeting of the Society for Environmental Toxicology and Chemistry, Pensacola, Florida, November 1987.

Lutz, C. T.

"The Gap Between Total Strain and Total Strain in Carbon in Forward Thrust Shoots: An Example from the South Appalachians," Meeting of the Geological Society of America, Phoenix, Arizona, October 1987.

Mann, L. K., and D. W. Johnson

"Postharvest Effects of Whole-Tree and Stem-Only Clearcutting," International Energy Agency Forest Productivity Workshop, Seattle, Washington, August 1988.

Mann, L. K., and W. M. Post

"Soil Carbon Storage in Cultivated Soil: Paired Plots and Regional Data," Annual Meeting of the Soil Science Society of America, Atlanta, Georgia, November 1987.

McCarthy, J. F.

"Biomarkers of Environmental Contamination," Lawrence Livermore National Laboratory, Livermore, California, April 1988; California State University, Long Beach, September 1988; Annual Meeting of the American Chemical Society, Los Angeles, California, September 1988.

"Colloidal Organic Matter Enhances the Subsurface Transport of Hydrophobic Organic Contaminants," Battelle Pacific Northwest Laboratory, Richland, Washington, April 1988.

McCarthy, J. F., D. N. Jacobson, B. D. Jimenez, and L. R. Shugart

"Pre-Exposure to 3-Methylcholanthrene Increases Benzo(a)pyrene Adducts on DNA of Fish," Eighth Annual Meeting of the Society of Environmental Toxicology and Chemistry, Pensacola, Florida, November 1987.

McCarthy, J. F., L. R. Shugart, and B. D. Jimenez

"Biological Markers in Animal Sentinels," Eighth Life Symposium on Bioindicators: Exposure and Effects, Knoxville, Tennessee, March 1988.

McLaughlin, S. B.

"Interactive Effects of Natural and Anthropogenic Factors on the Growth and Physiology of Red Spruce," Symposium on the Effects of Atmospheric Pollutants on Spruce Fir Forests in the Federal Republic of Germany and the Eastern United States, Burlington, Vermont, October 1987.

"The Use of Branch Level Measurements in Evaluating Whole Plant Responses to Air Pollutants," EPA Workshop on Response of Trees to Air Pollutants: The Role of Branch Chambers, Boulder, Colorado, November 1987.

"Carbon Allocation Processes as Indicators of Air Pollution Effects on Forests," National Research Council Symposium: Biomarkers of Air Pollutant Effects on Forests, Little Switzerland, North Carolina, April 1988.

"Comparative Sensitivity, Mechanisms, and Whole Plant Physiological Implications of Response of Loblolly Pine Genotypes to Ozone and Acid Deposition," NAPAP Annual Program Review, Corpus Christi, Texas, April 1988.

"Effects of Air Pollution on Southern Commercial Forests: An Overview," Sixth World Congress of Plant Pathology, Kyoto, Japan, August 1988.

"Interactive Effects of Natural and Anthropogenic Factors on the Growth and Physiology of Red Spruce," NAPAP Annual Program Review, Corpus Christi, Texas, April 1988; Sixth World Congress of Plant Pathology, Kyoto, Japan, August 1988.

Moore, G. K.

"Analysis of Hydraulic Conductivities in Fractured Rocks near Oak Ridge, Tennessee," International Conference on Fluid Flow in Fractured Rocks, Atlanta, Georgia, May 1988.

"Uses of Probability Graphs for the Characterization of Fractured-Rock Aquifers near Oak Ridge, Tennessee," First Tennessee Hydrology Symposium, Nashville, Tennessee, June 1988.

Mulholland, P. J.

"Nutrient Flux in Walker Branch Watershed," Walker Branch Watershed Briefing, Germantown, Maryland, June 1988.

Mulholland, P. J., M. A. Huston, and J. W. Elwood

"Regulation of Hydrologic Nutrient Input and Uptake in a First-Order Woodland Stream," Annual Meeting of the American Society of Limnology and Oceanography, Boulder, Colorado, June 1988.

Norby, R. J.

"Physiological Aspects of Optimum Nitrogen Nutrition in Short Rotation Sycamore," Department of Forestry Seminar, University of Illinois, Urbana, October 1987.

"Foliar Nitrate Reductase: A Marker for Assimilation of Atmospheric Nitrogen Oxides," National Research Council Workshop on Markers of Air Pollution Effects in Forests, Little Switzerland, North Carolina, April 1988.

"Responses of Forest Trees to Carbon Dioxide Enrichment of the Atmosphere: Physiological Studies to Address Ecological Questions," Seminar Series on Environmental Change, Oregon State University, Corvallis, April 1988.

"Direct Responses of Forest Trees to Increasing Atmospheric Carbon Dioxide," Second U.S.-U.S.S.R. Symposium, Air Pollution Effects on Vegetation, Gatlinburg, Tennessee, September 1988.

Norby, R. J., and E. G. O'Neill

"Comparative Responses of Tulip-Poplar and White Oak Seedlings to CO₂ Enrichment of the Atmosphere," Annual Meeting of the American Society of Plant Physiologists, Reno, Nevada, July 1988.

Olsen, C. R.

"Beryllium-7: New Tracer Applications in Aquatic and Terrestrial Systems," invited paper, R. V. Goldschmidt Conference, Baltimore, Maryland, May 1988.

"Radionuclide Tracers of River-Ocean Exchange," Meeting of the American Geophysical Union, Baltimore, Maryland, May 1988.

"Radionuclide-Particle Associations in Estuarine Environments," invited paper, Meeting of the American Geophysical Union, Baltimore, Maryland, May 1988.

Olson, R. J., R. A. McCord, K. C. Dearstone, and S. P. Timmins

"Regional Environmental Studies Using National Data Bases and GIS," Environmental Systems Research Institute User Conference, Palm Springs, California, April 1988.

O'Neill, E. G., and R. J. Norby

"Differential Responses of Ecto- and Endomycorrhizae to Elevated Atmospheric CO₂," Annual Meeting of the Ecological Society of America, Davis, California, August 1988.

O'Neill, R. V., and T. F. H. Allen

"On Choosing What To Predict," Annual Meeting of the Ecological Society of America, Davis, California, August 1988.

Peng, T.-H.

"Ocean Carbon Cycle Model Based on the Distribution of Bomb-Produced Radiocarbon in the Ocean," invited paper, The University of Tennessee, Knoxville, October 1987; Marine Science Institute, University of Connecticut, Avery Point, Groton, November 1987.

"Changes in Ocean Ventilation Rates Over the Last 7000 Years Based on ^{14}C Variations in the Atmosphere and Oceans," 13th International Radiocarbon Conference, Dubrovnik, Yugoslavia, June 1988.

Phillips, D. H., J. T. Ammons, D. A. Lietzke, and S. Y. Lee

"Relationship Between Soil Formation and Topography on the Maryville Formation of East Tennessee," Annual Meeting of the American Society of Agronomy, Atlanta, Georgia, November 1987.

Post, W. M.

"Chemistry of Organic Carbon in Soil with Relationship to the Global Carbon Cycle," Annual Meeting of the American Chemical Society, Los Angeles, California, September 1988.

Post, W. M., and L. K. Mann

"Soil Carbon and Nitrogen Changes Resulting from Cultivation," Annual Meeting of the Soil Science Society of America, Atlanta, Georgia, November 1987.

"Changes in Soil Organic Matter Resulting from Cultivation. II. Influence of Nitrogen Content," Annual Meeting of the Soil Science Society of America, Atlanta, Georgia, November 1987.

Railsback, S.

"Dissolved Oxygen Strategies for Hydropower Licensing," National Hydropower Association, Washington, D.C., April 1988.

Sale, M. J.

"The Role of Modeling in Emergency Response," Oak Ridge Model Conference, Oak Ridge, Tennessee, October 1987.

"Trout-Habitat Relationships in the Southern Blue Ridge Streams," Instream Flow Workshop for Fish Biologists, Cookeville, Tennessee, October 1987.

Schaefer, D. A., S. E. Lindberg, and D. R. Nicolai

"Ionic Exchange Rates as Determined by Foliar Surface Rinsing," Annual Meeting of the Ecological Society of America, Davis, California, August 1988.

Schaefer, D. A., S. E. Lindberg, J. G. Owens, and D. Silsbee

"Wet and Dry Deposition to a High-Elevation Spruce-Fir Forest in the Great Smoky Mountains National Park," Fourth Gatlinburg Acid Rain Conference, Gatlinburg, Tennessee, October 1987.

Sharples, F. E.

"Environmental Applications of Biotechnology: Controlling or Cooperating with Nature?" Science, Technology and Human Values Series, Princeton University, Princeton, New Jersey, December 1987.

"Guidelines for Field Testing and Environmental Applications of Genetically Altered Organisms," Third Meeting of the United Nations Industrial Development Organization/World Health Organization/United Nations Environment Program Working Group on Biotechnology Safety, Paris, France, December 1987.

"History of Hazardous Waste Regulations and Introduction to Terminology," 33rd Annual Meeting of the Health Physics Society, Boston, Massachusetts, July 1988.

Shugart, L. R.

"Hemoglobin Modification as a Biological Marker of Exposure to Environmental Pollutants," Tennessee Blood Club Seminar, Paris Landing State Park, Tennessee, October 1987.

"Use of Biological Markers to Detect Environmental Contaminants," Biochemistry Department Seminar, West Virginia University, Morgantown, October 1987.

"Detection and Quantitation of Benzo(a)pyrene Adducts in Brain Tissue of Stranded Beluga Whales from the St. Lawrence Estuary," Seventh Biennial Conference on Biology of Marine Mammals, Miami, Florida, December 1987.

"Effect of Genotoxic Chemicals on DNA Integrity in Aquatic Organisms," ORAU Traveling Lecture, Jackson State University, Jackson, Mississippi, December 1987; Millsaps College, Jackson, Mississippi, December 1987.

"Effect of Genotoxic Agents on DNA of Aquatic Organisms," Pharmacology Department Seminar, Duke University, Durham, North Carolina, May 1988.

"Biological Monitoring: Application and Interpretation," Eighth Annual Meeting of the Southeast Regional Chapter of the Society of Toxicology, The University of Tennessee, Knoxville, June 1988.

Shugart, L. R., J. F. McCarthy, and B. D. Jimenez

"DNA Integrity of Bluegill Sunfish Exposed to Benzo(a)pyrene," Eighth Annual Meeting of the Society of Environmental Toxicology and Chemistry, Pensacola, Florida, November 1987.

Sigal, L. L.

"A New Approach to Air Pollution Effects: Loblolly Pine Protoplasts and Flow Cytometry," International Conference on Assessment of Crop Loss from Air Pollutants, Raleigh, North Carolina, October 1987.

Sigal, L. L., and J. W. Webb

"The Programmatic Environmental Impact Statement: Its Purpose and Use," Annual Conference of the National Association of Environmental Professionals, Orlando, Florida, April 1988.

Sigmon, C. F., and F. E. Sharples

"Hazardous Waste Regulatory Update," Spectrum '88, Pasco, Washington, September 1988.

"Overview of Hazardous Waste Law: The Resource Conservation and Recovery Act (RCRA) and the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)," Management of Hazardous Waste: A Regulatory Training Course, Augusta, Georgia, September 1988.

"Overview of Hazardous Waste Law: RCRA and CERCLA," Management of Hazardous Waste: A Regulatory Training Course, Cincinnati, Ohio, September 1988.

Simmons, G. L., and P. E. Pope

"Development of a Root Growth Model for Yellow-Poplar and Sweetgum Seedlings Grown in Compacted Soil," Annual Meeting of the Soil Science Society of America, Atlanta, Georgia, November 1987.

Sloop, F. V., L. R. Shugart, K. F. Jacobson, L. Adams, B. D. Jimenez, and J. F. McCarthy

"Biomarkers of Metal Pollutants: Metal-Binding Proteins in Redbreast Sunfish," Eighth Annual Meeting of the Society of Environmental Toxicology and Chemistry, Pensacola, Florida, November 1987.

Smith, J. G.

"Structure and Functional Organization of the Benthic Macroinvertebrate Community in a Stressed Stream," Annual Meeting of the North American Benthological Society, Tuscaloosa, Alabama, May 1988.

Solomon, D. K.

"Groundwater Hydrology," Agency for Toxic Substances and Disease Registry Workshop, Atlanta, Georgia, February 1988.

"Geochemical Tracers of Hydrologic Processes," University of Waterloo, Waterloo, Ontario, Canada, April 1988.

Solomon, D. K., and C. R. Olsen

"Rapid Transport During Storms," ESD Annual Information Meeting, Oak Ridge, Tennessee, June 1988.

Southworth, G. R.

"Use of ^{90}Sr as an Effluent Exposure Tracer in PCB Contaminated Channel Catfish," Eighth Annual Meeting of the Society of Environmental Toxicology and Chemistry, Pensacola, Florida, November 1987.

Spalding, B. P.

"In Situ Grounding of Buried Transuranic Waste with Polyacrylamide," Oak Ridge Model Conference, Oak Ridge, Tennessee, October 1987.

"In Situ Grounding of Buried Waste with Polyacrylamide," Waste Management Technology Center Workshop on Waste Forms, Oak Ridge, Tennessee, April 1988.

Spalding, B. P., and G. K. Jacobs

"In Situ Vitrification Demonstration for Buried Wastes at ORNL," ESD Information Meeting, ORNL Quarterly Colloquium, Oak Ridge, Tennessee, May 1988.

Steinman, A. D.

"A Functional-Form Model for Freshwater Periphyton: Hypotheses, Predictions, and Preliminary Data," Periphyton Colloquium, Louisville, Kentucky, March 1988.

Stow, S. H.

"Disposal of High-Level Nuclear Wastes: What Are We Doing About It?" Washington and Lee University, November 1987; James Madison University, Harrisonburg, Virginia, November 1987.

"Employment Opportunities in the Geosciences," Meeting of the Geological Society of America, Phoenix, Arizona, November 1987.

"Perspectives on Education and Communication: From College to Congress: Are the Geosciences Responding to Waste Management Needs?" Meeting of the Geological Society of America, Columbia, South Carolina, March 1988.

Suter, G. W., II

"Ecological Endpoints," Ecological Assessments of Hazardous Waste Sites, Seattle, Washington, July 1988.

"Risk Assessment Models for Terrestrial Effects of Pesticides," International Workshop: Terrestrial Field Testing of Pesticides, Cambridge, England, September 1988.

Tolbert, V. R., and J. E. Breck

"Predicting the Effects of Chemical Nerve Agent Spills on the Fish Biomass of Small Streams," Annual Conference of the National Association of Environmental Professionals, Orlando, Florida, April 1988.

"Predicting Mortality of Fish in Streams as the Result of Pulse Exposure from Chemical Nerve Agent Spills," Annual Meeting of the North American Benthological Society, Tuscaloosa, Alabama, May 1988.

Toran, L.

"Calculation of Hydraulic Conductivity from Slow Water Level Recovery," First Tennessee Hydrology Symposium, Nashville, Tennessee, June 1988.

"Carbon Isotopes as Evidence for Contaminant Dilution," Meeting of the American Chemical Society, Los Angeles, California, September 1988.

Toran, L., and A. V. Palumbo

"Column Studies of Bacteria-Sized Particles: Retention Versus Transport," Meeting of the American Geophysical Union, Baltimore, Maryland, May 1988.

"Microbial Transport Experiments," ESD Annual Information Meeting, Oak Ridge, Tennessee, May 1988.

Tripathi, V. S., J. W. Elwood, G. T. Yeh, J. Montana, and R. B. Cook

"Adsorption vs. Precipitation of Al^{3+} in Soils and Streams: Implications for Aluminum Concentration and Speciation," Fall Meeting of the American Geophysical Union, San Francisco, California, November 1987.

Tschaplinski, T. J., and T. J. Blake

"Carbohydrate Mobilization Following Shoot Decapitation in Hybrid Poplar," Meeting of the American Society of Plant Physiologists, Reno, Nevada, July 1988.

Tschaplinski, T. J., R. J. Norby, D. W. Johnson, and D. E. Todd, Jr.

"Optimum Nitrogen Nutrition in Short Rotation Sycamore Plantations," Annual Sub-contractors' Meeting of the Short Rotation Woody Crops Program, Tacoma, Washington, August 1988.

Turner, M. G.

"Analyzing Landscape Data and Extrapolating Across Spatial Scales," invited paper, Symposium on Spatial and Temporal Analysis Using Geographic Information Systems, Annual Meeting of the Ecological Society of America, Davis, California, August 1988.

Turner, M. G., R. V. O'Neill, R. H. Gardner, and B. T. Milne

"The Effect of Spatial Scale on the Analysis of Landscape Pattern," Third Annual Landscape Ecology Symposium, University of New Mexico, Albuquerque, March 1988.

Turner, R. S.

"Effects on Aquatic Systems: Discussions of Major Criteria," American Pollution Control Association International Conference on Acidic Precipitation: A Technical Amplification of NAPAP's Findings, Pittsburgh, Pennsylvania, January 1988.

Turner, R. S., C. C. Brandt, D. A. Wolf, M. F. Johnson, and D. L. Sterns

"Relationships Among Soil Physical and Chemical Characteristics and Surface Water Chemistry," Annual Meeting of the Soil Science Society of America, Atlanta, Georgia, November 1987.

Van Miegroet, H.

"Comparison of Buffer Capacity Between Red Alder and Douglas-Fir Soils," Annual Meeting of the Soil Science Society of America, Atlanta, Georgia, November 1987.

Van Miegroet, H., D. W. Cole, and P. S. Homann

"The Effect of Alder Forest Cover and Alder Forest Conversion on Site Fertility and Productivity," Seventh North American Forest Soils Conference, Vancouver, British Columbia, Canada, August 1988.

Van Winkle, W.

"Overview: Review of the Draft Report on Generic Framework for Individual-Based Fish Population Models," Peer Review Meeting, Houston, Texas, February 1988.

"Introductory Comments," Walker Branch Watershed Briefing, Germantown, Maryland, June 1988.

Von Damm, K. L.

"Hydrothermal Seawater-Basalt-Sediment Interaction Chemistry," Chemrawn IV, Keystone, Colorado, October 1987.

"Geochemical Controls on Shale Groundwater Chemistries," Fall Meeting of the American Geophysical Union, San Francisco, California, December 1987.

"Geochemistry of Shale Groundwaters: Applications to High-Level Waste Disposal," ESD Annual Information Meeting, Oak Ridge, Tennessee, May 1988.

"Chemistry of Submarine Hydrothermal Solutions from Sediment Covered Ridge Crests," Meeting of the American Chemical Society, Toronto, Ontario, Canada, June 1988.

"Deep Sea Vents: Complex Systems Creating Complex Systems Creating Complex Environments," Gordon Research Conference on Environmental Sciences: Water, New Hampton, New Hampshire, June 1988.

- Walton, B. T., M. S. Hendricks, T. A. Anderson, and S. S. Talmage
"Structure-Activity Relationships for Selected Organic Chemicals Affecting Soil Microbial Respiration," Annual Meeting of the Society of Environmental Toxicology and Chemistry, Pensacola, Florida, November 1987.
- Walton, B. T., and S. S. Talmage
"Biological Monitoring in Terrestrial Ecosystems," Workshop on Biological Studies of Complex Mixtures, Electric Power Research Institute, Carmel, California, May 1988.
- Wilson, G. V.
"Hydrologic Transport in Walker Branch Watershed," Walker Branch Watershed Briefing, Germantown, Maryland, June 1988.
- Wilson, G. V., P. M. Jardine, and R. J. Luxmoore
"Spatial Variability of Hydraulic Properties of Two Forested Watersheds," S-185 Regional Soil Physics Meeting, Blacksburg, Virginia, March 1988.
- Wilson, G. V., R. J. Luxmoore, P. M. Jardine, and J. R. Jones
"Scaling of Hydrologic Properties for Simulation of Watershed Drainage," Annual Meeting of the American Society of Agronomy and the Soil Science Society of America, Atlanta, Georgia, November 1987; International Conference Workshop on Validation of Flow and Transport Models for the Unsaturated Zone, Ruidoso, New Mexico, May 1988.
- Wright, L. L., P. A. Layton, and J. W. Ranney
"Progress and Direction of Research in the SRWCP," Poplar Council of the U.S. Program Guide, Ames, Iowa, August 1988.
- Wright, L. L., J. W. Ranney, and P. A. Layton
"Recent Progress in the SRWCP," Southern Biomass Conference, Auburn, Alabama, July 1988.
- Yeh, G. T.
"A Lagrangian-Eulerian Method with Zoomable Hidden Fine-Mesh Approach to Solving Advection-Diffusion Equations (LEZOOM)," Seventh International Conference on Computational Methods in Water Resources, Cambridge, Massachusetts, June 1988.
- "A Subregional Block Iteration to 3-D Finite Element Modeling of Subsurface Flow," Seventh International Conference on Computational Methods in Water Resources, Cambridge, Massachusetts, June 1988.
- "A Zoomable and Adaptable Hidden Fine-Mesh Approach to Solving Advection-Diffusion Equations," Seventh International Conference on Computational Methods in Water Resources, Cambridge, Massachusetts, June 1988.

Yeh, G. T., and V. S. Tripathi

"On the Moving Boundary Approach to Dissolution-Precipitation Controlled Solute Transport," Fall Meeting of the American Geophysical Union, San Francisco, California, December 1987.

3.12 PROFESSIONAL ACTIVITIES

ADAMS, M. B.

Participant: Fourth Annual Gatlinburg Acid Rain Conference, Gatlinburg, Tennessee, October 1987; 20th Annual Meeting of the American Society of Agronomy, the Crop Science Society, and the Soil Science Society of America, Atlanta, Georgia, November 1987; Air Pollution Control Association Workshop, State College, Pennsylvania, April 1988; Seventh North American Forest Soils Meeting, Vancouver, British Columbia, Canada, July 1988.

Ad hoc reviewer: *Canadian Journal of Forest Research*; USDA Competitive Grants proposals.

ADAMS, S. M.

Chairman: National Meeting of the American Fisheries Society, Winston-Salem, North Carolina, October 1987; Awards Committee, American Fisheries Society.

Participant: 117th Annual Meeting of the American Fisheries Society, Winston-Salem, North Carolina, October 1987; 118th Annual Meeting of the American Fisheries Society, Toronto, Ontario, Canada, September 1988.

Faculty: Adjunct Faculty, Ecology, The University of Tennessee.

Advisor: M. S. Bevelheimer, Ph.D. candidate; K. L. Shepard, M.S. candidate; K. R. Seeley, Ph.D. candidate; Denise Benson, M.S. candidate; Mike Horn, M.S. candidate (all The University of Tennessee).

Ad hoc reviewer: *Canadian Journal of Fisheries and Aquatic Science*; American Fisheries Society; Sea Grant proposal.

Other: Editor, *Biological Communities of the Southeastern U.S.*

ASHWOOD, T. L.

Participant: DOE High School Honors Program, Oak Ridge, Tennessee, July 1988.

AUERBACH, S. I.

Chairman: EPA Science Advisory Board, Long-Range Ecological Effects Panel.

Member: Executive Committee, EPA Science Advisory Board; Steering Committee, EPA Science Advisory Board Research Strategies Committee; Committee on Magnetic Fusion, National Academy of Engineering.

Participant: Polish Academy of Sciences-U.S. Academy of Sciences Workshop on Ecological Research and Environmental Protection, Warsaw and Krakow, Poland, October 1987; Science, Universities, and Government, Chicago, Illinois, Ithaca, New York, and Davis, California, December 1987; Second U.S.-U.S.S.R. Symposium, Gatlinburg, Tennessee, September 1988.

Faculty: Adjunct Professor, Ecology, The University of Tennessee.

Ad hoc reviewer: NSF proposals.

Other: Editorial Board, *Journal of Environmental and Experimental Botany*; Editorial Board, *Environment International*.

BAES, C. F., III

Participant: Oak Ridge Model Conference, Oak Ridge, Tennessee, October 1987; 1988 Installation Restoration Management Conference sponsored by the Naval Facilities Engineering Command, Port Hueneme, California, March 1988; Spectrum '88 Nuclear and Hazardous Waste Management International Topical Meeting sponsored by the American Nuclear Society, Pasco, Washington, September 1988.

Ad hoc reviewer: *Health Physics*; *Canadian Journal of Forestry Research*.

BARNTHOUSE, L. W.

Chairman: EPRI Winter Flounder Research Workshop, Narragansett, Rhode Island, June 1988.

Participant: EPA Ecological Risk Assessment All-Investigators' Meeting, Calloway Gardens, Georgia, January 1988; EPRI Review of COMPMECH Generic Modeling Framework, Houston, Texas, February 1988; Hudson River Data Base Review, New York, New York, March 1988.

Ad hoc reviewer: *Environmental Toxicology and Chemistry*; *North American Journal of Fisheries Management*; Hudson River Foundation; EPA.

BARTELL, S. M.

Chairman: Session Chair, Third Annual Landscape Ecology Symposium, International Association for Landscape Ecology, Albuquerque, New Mexico, March 1988.

Member: Ecological Society of America; World Future Society; ESD Education Committee.

Participant: Risk Analysis and Management of Natural and Man-Made Hazards, Society of Chemical Engineers, Santa Barbara, California, November 1987; EPA Ecological Risk Assessment, All-Investigators' Meeting, Calloway Gardens, Georgia, January 1988; Third Annual Landscape Ecology Symposium, Albuquerque, New Mexico, March 1988; Sixth BIOMOVs Workshop, Budapest, Hungary, April 1988; Special Review Committee, Superfund Basic Hazardous Substances Basic Research Program, Phase II, Research Triangle Park, North Carolina, June 1988.

Faculty: Adjunct Faculty, Graduate Program in Ecology, The University of Tennessee.

Advisor: Alan R. Johnson, Ph.D. candidate; Jackie A. Cunningham, Ph.D. candidate (both The University of Tennessee).

Ad hoc reviewer: EPA Competitive Grants proposals; NSF proposals; Superfund Ecological Research proposals; University of Chicago Press; *Environmental Science and Technology*; *Ecological Modelling*.

Other: Visiting Scientist, Instituto de Radioprotecao y Dosimetria, Rio de Janeiro, Brazil, May 21–June 4, 1988; Editorial Board, Springer-Verlag; Editorial Board, *Chemosphere*.

BLASING, T. J.

Member: American Statistical Association; ORNL Study Committee, Energy Alternatives for the Future; American Meteorological Society; American Geophysical Union; Sigma Xi.

Participant: DOE Site Characterization Plan, Comment Resolution Workshop, Washington, D.C., October and November 1987; DOE Project Review: CO₂-Effect Detection in Tree Rings, Germantown, Maryland, May 1988.

Faculty: Adjunct Assistant Professor, Geography, The University of Tennessee.

Ad hoc reviewer: *Journal of Environmental Quality; Environmental Management;* Nuclear Regulatory Commission; Nevada Nuclear Waste Site; NSF proposals.

BLAYLOCK, B. G.

Member: Health Physics Society; Genetics Society of America; American Association for the Advancement of Science.

Participant: Effects of Radiation on Aquatic Organisms, Boston, Massachusetts, October 1987; BIOMOVs Meeting, sponsored by the Swedish National Institute of Radiation Detection and DOE National Council on Radiation Protection and Measurements, Grand Canyon, December 1987; Advisory Group Meeting of the IAEA, Vienna, Austria, January 1988; BIOMOVs Meeting, National Research Institute of Hungary, Budapest, March 1988.

Faculty: Adjunct Professor, Ecology, The University of Tennessee.

Advisor: Richard Graham, Ph.D. candidate; Deborah Mohrbacher, Ph.D. candidate; Alicia Waters, M.S. candidate; Tom Ashwood, Ph.D. candidate (all The University of Tennessee).

Ad hoc reviewer: *Canadian Journal of Fisheries and Aquatic Science; Health Physics.*

Other: U.S. Secretary, International Union of Radioecologists; Fellow, American Association for the Advancement of Science; Judge, 39th International Science and Engineering Fair, Knoxville, Tennessee, May 1988.

BODEN, T. A.

Participant: EPA Briefing on Potential Impacts of Climate Change on Forest Resources, Washington, D.C., September 1988.

BOEGLY, W. J., JR.

Member: Research Committee, Water Pollution Control Federation; Dual Distribution Systems Committee, American Water Works Association; NAS/NRC Working Commission W-62 on Water Supply and Drainage in Building.

Faculty: Associate Professor, Civil Engineering, The University of Tennessee.

BOGLE, M. A.

Participant: Fourth Annual Gatlinburg Acid Rain Conference, Gatlinburg, Tennessee, October 1987.

Ad hoc reviewer: Closure Plan for the Final Closure of the Salvage Yard.

BONDIETTI, E. A.

Chairman: 1987 Annual IFS Review, Pinehurst, North Carolina, February 1988.

Participant: Workshop on Markers of Air Pollution Effects on Trees, Little Switzerland, North Carolina, April 1988.

Ad hoc reviewer: *Journal of Environmental Radioactivity*.

Other: Editorial Board, *Journal of Environmental Radioactivity*.

BORDERS, D. M.

Member: American Society of Civil Engineers.

Participant: Oak Ridge Model Conference, Oak Ridge, Tennessee, October 1987; Stream-flow Synthesis and Reservoir Regulation Model Workshop, Portland, Oregon, October 1987; SARA/OSHA Training for Hazardous Waste Site Activities, Oak Ridge, Tennessee, July 1988.

Faculty: Research Associate, Civil Engineering, The University of Tennessee.

Advisor: David Hyndman, B.S. candidate, University of Arizona.

Ad hoc reviewer: White Oak Lake Survey—The New Definitive Map.

BOSTON, H. L.

Participant: EPA Briefing for Program Managers, Washington, D.C., December 1987; EPA Ecological Risk Assessment All-Investigators' Meeting, Calloway Gardens, Georgia, January 1988; Periphyton Colloquium, University of Louisville, Kentucky, March 1988; DOE Science and Engineering Research Semester Conference, Argonne National Laboratory, Argonne, Illinois, April 1988.

Faculty: Adjunct Professor, Biology, Knoxville College.

Advisor: Deborah A. Mohrbacher, Ph.D. candidate, The University of Tennessee.

Ad hoc reviewer: NSF proposals.

Other: Judge, 39th International Science and Engineering Fair, Knoxville, Tennessee, May 1988.

CADA, G. F.

Participant: Annual Meeting of the National Association of Environmental Professionals, Orlando, Florida, April 1988; U.S. Forest Service Functional Assistance Trip in Nonpoint Source Pollution Management, Little Rock, Arkansas, June 1988; Career Workshop for DOE Honors Program Students, Maryville, Tennessee, July 1988.

Ad hoc reviewer: *Journal of the Tennessee Academy of Sciences*.

CHRISTENSEN, S. W.

Chairman: Session Chairman, Fourth Annual Gatlinburg Acid Rain Conference, Gatlinburg, Tennessee, October 1987; Session Chairman, Eighth Annual Meeting of the Society of Environmental Toxicology and Chemistry, Pensacola, Florida, November 1987.

Participant: Fourth Annual Gatlinburg Acid Rain Conference, Gatlinburg, Tennessee, October 1987; Eighth Annual Meeting of the Society of Environmental Toxicology and Chemistry, Pensacola, Florida, November 1987; EPRI Review of the COMP-MECH Modeling Framework, Project on Compensatory Mechanisms in Fish Populations, Houston, Texas, February 1988; EPA Planning Workshop for the 1990 Final Report for the Aquatic Effects Research Program—Biology, Herndon, Virginia, April 1988; EPA Final Regional Case Studies Project Meeting, Boulder, Colorado, June 1988; EPRI Lake Acidification and Fisheries Project Advisory Committee Meeting, Laramie, Wyoming, July 1988; Planning Workshop for the Economic Analysis of the Aquatic Effects of Acidification for the NAPAP 1990 Assessment, Seattle, Washington, September 1988; Research Session, Third Biennial National Workshop on Micro-Computer Applications in Fish and Wildlife Programs, Stateline, Nevada, September 1988.

Ad hoc reviewer: *Canadian Journal of Fisheries and Aquatic Sciences*; Hudson River Foundation proposal.

CLAPP, R. B.

Chairman: Session Chairman, Geoscience Information Society, Integrating Technology and Geosciences Applications, Denver, Colorado, September 1988.

Participant: DOE Workshop on the Management of Uranium-Bearing Wastes, Oak Ridge, Tennessee, May 1988; DOE High School Honors Program, Oak Ridge, Tennessee, July 1988.

Ad hoc reviewer: *Water Resources Research*; *Soil Science Society of America Journal*; First International Convention on Field Screening Methods for Hazardous Waste Site Investigations.

COOK, R. B.

Member: Geochemical Society of America; American Society for Limnology and Oceanography; American Association for the Advancement of Science.

Participant: Workshop on the Role of Organic Acids in Surface Water Acidification, Tucson, Arizona, February 1988; Scientific Committee on Problems of the Environment/United Nations Environment Program Symposium on Carbon and Sulfur Interactions in Lakes, Irkutsk, U.S.S.R., September 1988.

Advisor: Cheryl A. Kelley, M.S. candidate, University of North Carolina; Jana Compton, ORAU Semester, Earlham College.

Ad hoc reviewer: *Limnology and Oceanography*; *Canadian Journal of Fisheries and Aquatic Science*; *Water, Air and Soil Pollution*; *Biogeochemistry*; *Water Resources Research*; DOE; EPA.

COUTANT, C. C.

Chairman: Federal Energy Regulatory Commission Workshop on Turbine-Induced Fish Mortality, Charleston, West Virginia, December 1987; Cochair, ORNL—University of Tennessee Distinguished Lecture Series in the Life Sciences.

Member: President, Water Quality Section, American Fisheries Society; National Oceanic and Atmospheric Administration; ORNL Seminar Committee.

Participant: Annual Meeting of the Southern Division of the American Fisheries Society, Mobile, Alabama, October 1987; American Fisheries Society Instream Flow Workshop, Smithville, Tennessee, October 1987; FERC Upper Ohio River Basin Recreation Workshop, Tygart Lake State Park, West Virginia, November 1987; Ohio River Modeling Workshop, Cincinnati, Ohio, January 1988; Albermarle Sound Striped Bass Workshop, Morehead City, North Carolina, February 1988; TVA Reservoir Policy Advisory Workshop, Knoxville, Tennessee, April 1988; EPA Technology Transfer Workshop, Annapolis, Maryland, June 1988; International Symposium and Educational Workshop on Fish-Marking Techniques, Seattle, Washington, June 1988; Annual Meeting of the American Fisheries Society, Toronto, Ontario, Canada, September 1988.

Faculty: Adjunct Professor, Graduate Program in Ecology, The University of Tennessee.

Advisor: Denise L. Benson, M.S. candidate; Mark S. Bevelheimer, Ph.D. candidate (both The University of Tennessee).

Ad hoc reviewer: *The Prairie Naturalist*; *Environmental Biology of Fishes*; *Canadian Journal of Fisheries and Aquatic Sciences*; Hudson River Foundation; University of Nevada-Las Vegas proposal; EPA/NC Albermarle-Pamlico Estuarine Study; NSF proposal; International Symposium and Educational Workshop on Fish-Marking Techniques; EPA; New York Sea Grant Program; U.S. Fish and Wildlife Service.

Other: President, Southern Division, American Fisheries Society; President, American Fisheries Society Water Quality Section; Robertsville Junior High School Seminar, Oak Ridge; Judge, Jefferson Junior High School Science Fair, Oak Ridge; Judge, 39th International Science and Engineering Fair, Knoxville, Tennessee, May 1988; Teacher, Stream Ecology Classes, Tremont Environmental Education Center, Oak Ridge; Editorial Board, *Transactions of the American Fisheries Society*.

CUSHMAN, J. H.

Chairman: Herbaceous Energy Crops Program's Annual Subcontractors' Workshop, Auburn, Alabama, July 1988.

Member: Planning Committee, Southern Biomass Conference.

Participant: DOE Annual Management Review, Biofuels and Municipal Waste Technology Division, Washington, D.C., April 1988; Rapeseed Research Review, Tifton, Georgia, April 1988; Research in Thermochemical Biomass Conversion, Phoenix, Arizona, May 1988; State Biomass Energy Coordinators Meeting, Duluth, Minnesota, July 1988; Herbaceous Energy Crops Program Contractors' Review, Auburn, Alabama, July 1988.

Ad hoc reviewer: Solar Technical Information Program; Southeastern Regional Biomass Energy Program proposals.

Other: Alternate, Planning Committee, Southeastern Regional Biomass Energy Program.

CUSHMAN, R. M.

Chairman: DOE High School Science Honors Program, Oak Ridge, Tennessee, July 1988; U.S.-U.S.S.R. Symposium on Air Pollution Effects on Vegetation, Gatlinburg, Tennessee, September 1988.

Participant: Controlling and Adapting to Greenhouse Warming, Washington, D.C., June 1988; The Changing Atmosphere, Toronto, Ontario, Canada, June 1988.

Ad hoc reviewer: American Fisheries Society.

CUTSHALL, N. H.

Participant: DOE Performance Assessment Workshop, Las Vegas, Nevada, March 1988; DOE Site Characterization Plan Workshops, Las Vegas, Nevada, April, May, and August 1988; Program Review, Lawrence Berkeley Laboratory, Hydrology and Geophysics, Berkeley, California, July 1988.

Other: Treasurer, Sigma Xi.

DALE, V. H.

Chairman: Session Chairman, Third Annual Landscape Ecology Symposium, Albuquerque, New Mexico, March 1988; ESD Seminar Committee; Environmental Quality Advisory Board, City of Oak Ridge.

Member: NSF Advisory Committee on Scientific and Technological Planning on Long-Term Ecological Research.

Participant: Working Meeting of the Land Use Researchers for the DOE Carbon Cycle Program, Washington, D.C., October 1987; Workshop on Biological Response to Environmental Change, Woods Hole, Massachusetts, October 1987; NSF Workshop on Forest History and Ecological Succession, Duke University, January 1988; Briefing on Long-Term Ecological Reserve Program of NSF, Washington, D.C., November 1988; Third Annual Landscape Ecology Symposium, Albuquerque, New Mexico, March 1988; Meeting of the Ecological Society of America, Davis, California, August 1988; Meeting of the American Chemical Society, Los Angeles, California, September 1988.

Advisor: Patrick Dumstorff, Megan Vaughn, and Jeremy Rehwaldt (all DOE High School Honors Program).

Ad hoc reviewer: *Canadian Journal of Forest Research*; *Canadian Journal of Botany*; *Landscape Ecology*; *Bulletin of the Ecological Society of America*; NSF, DOE proposals; Man and the Biosphere Program proposal.

DAVIS, E. C.

Participant: Spring Convention of the American Society of Civil Engineers, Nashville, Tennessee, May 1988; DOE SARA Training for General Site Workers, Oak Ridge, Tennessee, May 1988; DOE High School Honors Program in Environmental Sciences, Oak Ridge, Tennessee, July 1988.

Other: Judge, 39th International Science and Engineering Fair, Knoxville, Tennessee, May 1988.

DeANGELIS, D. L.

Chairman: NSF U.S.-Japan Joint Seminar in the Environmental Sciences, Honolulu, Hawaii, April 1988.

Member: Membership Committee, Society for Mathematical Biology.

Participant: EPRI Review of Generic Modeling Framework, COMPMECH Project, Houston, Texas, February 1988; NSF Review of University of Washington Science and Technology Center Proposal, Seattle, Washington, July 1988; NSF Review, University of Wisconsin Science and Technology Center Proposal, Madison, Wisconsin, July 1988.

Faculty: Adjunct Faculty, Graduate Program in Ecology, The University of Tennessee.

Advisor: Anett S. Trebitz, M.S. candidate; Jeffrey Hyman, Ph.D. candidate (both The University of Tennessee).

Ad hoc reviewer: *Journal of Mathematical Biology*; *Science*; NSF proposals; *Ecology* Special Features Section.

Other: Judge, 39th International Science and Engineering Fair, Knoxville, Tennessee, May 1988.

DOYLE, T. W.

Participant: Forest Growth Modeling Conference, Gulf Shores, Alabama, April 1988; DOE CO₂ Forest Response Project Review, Germantown, Maryland, May 1988; LEF Long-Term Ecological Reserve Modeling Workshop, El Verde, Puerto Rico, May 1988; ORNL Biomass Program Review, Knoxville, Tennessee.

Advisor: Betsy Groton, Ph.D. candidate, The University of Tennessee; Karen Buzby, Ph.D. candidate, State University of New York.

Ad hoc reviewer: *Forest Science*.

DREIER, R. B.

Participant: Theoretical and Practical Consideration of Flow in Fractured Rocks, Tucson, Arizona, December 1987; DOE High School Honors Workshop, Oak Ridge, Tennessee, July 1988.

Faculty: Adjunct Assistant Professor, Geology, The University of Tennessee.

Advisor: J. McReynolds, M.S. candidate, The University of Tennessee; P. J. Lemiszki, Ph.D. candidate, The University of Tennessee; M. B. Leat, B.S. candidate, South Dakota School of Mines.

Other: Judge, 39th International Science and Engineering Fair, Knoxville, Tennessee, May 1988.

EARLY, T. O.

Participant: Groundwater Geochemistry Conference, Denver, Colorado, February 1988.

Other: Section Coeditor, *Nuclear Safety*.

EDDLEMON, G. K.

Participant: Annual Meeting of the U.S. Navy Inactive Fleet Site Directors, Pearl Harbor, Hawaii, March 1988; Annual Conference of the National Association of Environmental Professionals, Orlando, Florida, April 1988.

Other: Area Representative, East Tennessee Chapter of the Health Physics Society.

EDWARDS, N. T.

Participant: Annual Meeting of the Ecological Society, American Institute of Biological Sciences, Davis, California, August 1988.

Advisor: Diane Fellers, Clinton High School Teacher, STRIVE Program; Mark Jen, B.S. candidate, California State University; Donna Smith, A.S. candidate; Grace Jones, A.S. candidate; and Tim Buchanin, A.S. candidate (all Roane State Community College).

Ad hoc reviewer: NSF proposals.

Other: Judge, South Clinton Elementary School Science Fair; Advisor, Clinton High School STRIVE Program.

ELWOOD, J. W.

Member: NSF Ecosystem Studies Advisory Panel.

Participant: Aquatic Effects Research Planning Workshop for Acidic Deposition, Herndon, Virginia, April 1988; DOE Walker Branch Watershed Project Research Planning Workshop, Oak Ridge, Tennessee, August 1988.

Faculty: Adjunct Professor, Graduate Program in Ecology, The University of Tennessee; Adjunct Professor, Institute of Environmental Studies, University of Illinois; Adjunct Professor, General Biology, Vanderbilt University.

Advisor: Amy D. Rosemond, Ph.D. candidate, Vanderbilt University; Seungdo Kim, Ph.D. candidate, The University of Illinois.

Ad hoc reviewer: *Journal of Environmental Quality*; *Journal of the North American Benthological Society*; *Canadian Journal of Fisheries and Aquatic Science*; *Ecology*; *Limnology and Oceanography*; *Transactions of the American Fisheries Society*; EPA, NSF proposals; DOE reports.

EMANUEL, W. R.

Member: NASA Global Topography Mission Working Group; EOS Evaluation Committee.

Participant: ERDAS Users' Group Meeting, Pine Mountain, Georgia, March 1988; Global Vegetation Modeling Conference, International Institute for Applied Systems Analysis, Vienna, Austria, April 1988; U.S.-U.S.S.R. Symposium on Air Pollution Effects on Vegetation, Gatlinburg, Tennessee, September 1988.

Faculty: Faculty Associate, The University of Tennessee.

Ad hoc reviewer: *National Geographic*; *Ecology*; NSF, NASA proposals.

Other: Associate Research Scholar, International Institute for Applied Systems Analysis, Vienna, Austria.

FARRELL, M. P.

Chairman: The Biogeochemistry of the Greenhouse Effect, Los Angeles, California, September 1988.

Participant: DOE Program Review: CDIAC, Oak Ridge, Tennessee, February 1988; DOE Program Review: Global Carbon Cycle, Germantown, Maryland, February 1988; DOE Program Review: Land-Use Research, Germantown, Maryland, April 1988; DOE Program Review: Carbon Cycle Models, Germantown, Maryland, May 1988.

FAULKNER, M. A.

Member: American Association for the Advancement of Science; Association for Women in Science, East Tennessee Chapter; Digital Equipment Users Society.

Participant: Fundamentals of Ground-Water Contamination Seminar, Washington, D.C., October 1987; ARC/INFO Training Course, Atlanta, Georgia, November 1987.

FITTS, R. B.

Participant: Oak Ridge Environmental Survey Program Review, Oak Ridge, Tennessee, January 1988.

FRANCIS, C. W.

Participant: Swiss Workshop on Land Disposal of Solid Waste, Gerzensee, Switzerland, March 1988; DOE Workshop on the Management of Uranium-Bearing Wastes, Oak Ridge, Tennessee, May 1988.

Ad hoc reviewer: DOE proposal; *Environmental Science and Technology*.

FRIEND, A. L.

Participant: Annual Meeting of the Ecological Society of America, Davis, California, August 1988.

GARDNER, R. H.

Chairman: Session Chairman, Annual Meeting of the International Association for Landscape Ecology, Albuquerque, New Mexico, March 1988.

Faculty: Adjunct Professor, Ecology, The University of Tennessee.

Ad hoc reviewer: *Landscape Ecology*; *Environmental Management*; EPA; NSF proposal.

GARLAND, S. B., II

Participant: Oak Ridge Model Conference, Oak Ridge, Tennessee, October 1987; Corrective Action for Containing and Controlling Ground Water Contamination, Atlanta, Georgia, March 1988; RCRA/CERCLA Treatment Alternatives for Hazardous Wastes, Oak Ridge, Tennessee, May 1988; EPA Design of Hazardous Waste Landfills, Dallas, Texas, July 1988; DOE Tumulus Disposal Demonstration Project Readiness Review and Audit, Oak Ridge, Tennessee, March and September 1988.

GARTEN, C. T., JR.

Participant: Fourth Annual Gatlinburg Acid Rain Conference, Gatlinburg, Tennessee, October 1987; NAPAP Atmospheric Chemistry (Task Group II) Review, Knoxville, Tennessee, March 1988; Gordon Conference on Chemistry and Physics of Isotopes, Tilton, New Hampshire, June 1988.

Advisor: Jacqueline Henrot, Ph.D. candidate, The University of Tennessee.

Ad hoc reviewer: *Journal of Environmental Quality; Health Physics; Journal of Environmental Radioactivity; Nuclear Safety.*

Other: Co-coordinator, ESD 1988 United Way Campaign.

GEHRS, C. W.

Chairman: ORNL Eighth Life Sciences Symposium, Oak Ridge, Tennessee, March 1988.

Ad hoc reviewer: *Environmental Science and Technology.*

GODBOUT, L.

Participant: EPRI Lakes Acidification and Fisheries Project, Laramie, Wyoming, July 1988.

GRAHAM, R. L.

Participant: 21st International Symposium on Remote Sensing of the Environment, Environmental Research Institute of Michigan, Ann Arbor, October 1987; Third Annual Landscape Ecology Symposium, Albuquerque, New Mexico, March 1988; NSF Workshop on Flora of North America, Washington, D.C., May 1988; 14th Annual Scientific Research Meeting of the Southeast Region, Gatlinburg, Tennessee, May 1988; LANDSAT Final Results Working Group Session, College Park, Maryland, August 1988.

Advisor: Jorge Ortiz, B.S. candidate, University of Puerto Rico; Pat Rickert, M.A. candidate, Louisiana State University; Dev Niyogi, B.A. candidate, Swarthmore College.

Ad hoc reviewer: *Flora of North America.*

Other: Vice President and Secretary, Association for Women in Science, East Tennessee Chapter.

GRIZZARD, T.

Advisor: Roger O'Dell, A.S. candidate; Roger Coffey, A.S. candidate (both Roane State Community College); First Annual High School Honors Program.

GUNDERSON, C. A.

Other: Judge, South Clinton Elementary School Science Fair.

HANSON, P. J.

Chairman: Session Chairman, Forest Growth, Process Modeling of Responses to Environmental Stress, Gulf Shores, Alabama, April 1988.

Participant: Fourth Annual Gatlinburg Acid Rain Conference, Gatlinburg, Tennessee, October 1987; An Integrated Approach to the Study of Environmental Stress on Plant Growth, Assloman, California, February 1988; Forest Growth: Process Modeling of Responses to Environmental Stress, Gulf Shores, Alabama, April 1988; Functional Supervisory Review of Research Work Unit NC-4152, Rhinelander, Wisconsin, May 1988; Annual Meeting of the American Society of Plant Physiologists, Reno, Nevada, July 1988.

Ad hoc reviewer: *Environmental Pollution; Forest Science; Journal of Environmental Quality*; NSF, DOE proposals.

HAYNES, G. J.

Participant: Annual Meeting of the North American Benthological Society, Tuscaloosa, Alabama, May 1988; Kepner-Tregoe Lab Tech Workshop, Oak Ridge, Tennessee, August 1988.

HERBES, S. E.

Chairman: ESD Education Committee.

Faculty: Adjunct Associate Professor, Graduate Program in Ecology, The University of Tennessee.

Advisor: C. Deane Little, Ph.D. candidate, Florida State University; John J. Niedzielski, M.S. candidate, The University of Tennessee.

Ad hoc reviewer: Wisconsin Sea Grant College Program proposal.

Other: Judge, 39th International Science and Engineering Fair, Knoxville, Tennessee, May 1988.

HILDEBRAND, S. G.

Participant: The Future of Hydro: Planning a Licensing/Relicensing Strategy, Washington, D.C., April 1988; International Hydrological Program Working Group, Paris, France, May 1988.

Faculty: Faculty Associate, Ecology, The University of Tennessee.

Ad hoc reviewer: EPRI Hydroelectric Research Program.

HOFFMAN, F. O.

Chairman: Methods for Evaluating Reliability of Environmental Radiological Assessment Models, Athens, Greece, October 1987; International BIOMOVs Conference, Grand Canyon, Arizona, November 1987 and Budapest, Hungary, April 1988; Research Program on Model Validations in the Urban, Terrestrial and Aquatic Environments—Multiple Pathways Scenario, Vienna, Austria, May 1988; Vice-Chairman, DOE/OHER Model Validation Committee.

Member: National Council on Radiation Protection Measurements.

Participant: Procedures for Evaluating Reliability of Environmental Transfer Models, Athens, Greece, October 1987; International BIOMOVs Conference, Grand Canyon, Arizona, November 1987 and Budapest, Hungary, April 1988; National Cancer Institute Meeting on Reconstruction of Exposures from the Nevada Test Site Operations, Oak Ridge, Tennessee, January 1988; National Cancer Institute Meeting on the Application of Uncertainty Analysis to Dose Reconstruction Analyses, Fort Collins, Colorado, February 1988 and New York, New York, July 1988; Consultants Meeting on a New IAEA Document on Assessing Reliability of Environmental Models, Oak Ridge, Tennessee, April 1988; IAEA Coordinated Research Program on Model Validation, Vienna, Austria, May 1988; Technical Consultants Meeting on Model Validation, Vienna, Austria, May 1988; Derived Reference Levels for Radiation Incidents, Tours, France, June 1988; Task Force on Dose Assessment Modelling, Bethesda, Maryland, August 1988.

Advisor: E. L. Deming; D. A. Mohrbacher; R. H. Graham (all Ph.D. candidates, The University of Tennessee).

Ad hoc reviewer: *Health Physics*; *Journal of Environmental Radioactivity*; National Cancer Institute.

Other: Educational assistant for Robertsville Junior High School, Tremont Environmental Center, Oak Ridge, Tennessee.

HUFF, D. D.

Chairman: ORNL Groundwater Monitoring Seminar, Oak Ridge, Tennessee, February 1988; First Tennessee Hydrology Symposium, Nashville, Tennessee, June 1988.

Participant: ORNL Groundwater Monitoring Seminar, Oak Ridge, Tennessee, February 1988; First Tennessee Hydrology Symposium, Nashville, Tennessee, June 1988.

Faculty: Adjunct Associate Professor, Ecology, The University of Tennessee.

Other: President, Tennessee Section, American Institute of Hydrology.

HUNSAKER, C. T.

Chairman: Session Chairman, 60th Annual Conference, Water Pollution Control Federation, Philadelphia, Pennsylvania, October 1987; Session Chairman, Toxics in the Environment: Management Options and Solutions, Orlando, Florida, April 1988; Vice-Chairman, Ecology Committee, Water Pollution Control Federation.

Member: DOE Science and Engineering Research Advisory Council.

Participant: Third Annual Landscape Ecology Symposium, Albuquerque, New Mexico, March 1988; WATtec '88, President's Program, Knoxville, Tennessee, March 1988; International Workshop on Land/Inland-Water Ecotones: Strategies for Research and Management, Sopron, Hungary, May 1988; DOE High School Honors Workshop, Oak Ridge, Tennessee, July 1988.

Advisor: Steven Kopp, M.A. candidate, Indiana State University.

Ad hoc reviewer: *The Environmental Professional*; *Water, Air, and Soil Pollution*; EPA; Cambridge University Press; Reidel Publishing Co.

Other: Secretary and Executive Board, Association for Women in Science; Advisory Board, *The Environmental Professional*.

HUSTON, M. A.

Chairman: Evolution and Maintenance of Biotic Diversity in Tropical Ecosystems, La Selva, Costa Rica, June 1988; Environmental Sciences Cochair, 39th International Science and Engineering Fair, Knoxville, Tennessee, May 1988.

Participant: Biological Response to Environmental Change, Woods Hole, Massachusetts, October 1987; Ecosystem Modeling in the Puerto Rican Long-Term Ecological Reserve, El Verde, Puerto Rico, March 1988; NSF Research Priorities in Conservation Biology, Marathon, Florida, April 1988; Ecosystem Modeling Group Workshop, Charlottesville, Virginia, April 1988.

Faculty: Adjunct Professor, Ecology, The University of Tennessee.

Advisor: Michael Sebert, B.S. candidate, Duke University; Larry Pounds, Ph.D. candidate, The University of Tennessee; Karl DeLong, sabbatical leave, Grinnell College.

Ad hoc reviewer: *American Naturalist*; *Ecology*; Organization for Tropical Studies proposal; DOE; NSF proposal.

Other: Judge, Jefferson Junior High School Science Fair, Oak Ridge, Tennessee; Secretary, Environmental Quality Advisory Board, Oak Ridge, Tennessee.

HYDER, L. K.

Participant: Tracor Northern TN-5500 X-Ray Analysis System Operator's Training Session, Madison, Wisconsin, November 1987; ESD High School Honors Workshop, Oak Ridge, Tennessee, July 1988; ORNL Solid Low-Level Waste Generator Training Program, Oak Ridge, Tennessee, August 1988.

JACOBS, G. K.

Chairman: Materials Research Society, Scientific Basis for Nuclear Waste Management-LLW Session, Boston, Massachusetts, December 1987.

Participant: Oak Ridge Model Conference, Oak Ridge, Tennessee, October 1987; Annual Meeting of the Geological Society of America, Phoenix, Arizona, November 1987; Materials Research Society, Scientific Basis for Nuclear Waste Management, Boston, Massachusetts, December 1987; Southeast Section Meeting of the Geological Society of America, Columbia, South Carolina, April 1988.

Faculty: Adjunct Faculty, Geological Sciences, The University of Tennessee.

Advisor: J. Lincoln Foreman, Ph.D. candidate, The University of Tennessee.

Ad hoc reviewer: ORAU; Materials Research Society.

Other: Judge, 39th International Science and Engineering Fair, Knoxville, Tennessee, May 1988.

JARDINE, P. M.

Participant: National Meeting of the Soil Science Society of America, Atlanta, Georgia, November 1987; Southern Region Soil Physics Workshop, Blacksburg, Virginia, March 1988; Validation of Flow and Transport Models for Unsaturated Zone, Ruidoso, New Mexico, May 1988; Mobility of Colloidal Particles in Subsurface: Chemistry and Hydrology of Colloidal Aquifer Interactions, Manteo, North Carolina, October 1988.

Advisor: Nora Weber, B.S. candidate, Blackburn College; Leslie Powell, M.S. candidate, University of Atlanta.

Ad hoc reviewer: Soil Science Society of America; *Journal of Environmental Science; Water Resources Research.*

Other: Technical Representative for Subsurface Transport Initiative, DOE, Washington, D.C., August–October 1988.

JIMENEZ, B. D.

Member: American Association for the Advancement of Science.

Participant: Chemically Contaminated Aquatic Food Resources and Human Cancer Risk, Research Triangle Park, North Carolina, September 1988; 196th National Meeting of the American Chemical Society, Los Angeles, California, September 1988.

Faculty: Ad Honorem Professor, Marine Sciences, University of Puerto Rico.

Advisor: Peter Melendez, B.S. candidate; Nannette Olmeda, B.S. candidate; Luis Cruz, Ph.D. candidate (all University of Puerto Rico).

Ad hoc reviewer: *Aquatic Toxicology.*

Other: Judge, 39th International Science and Engineering Fair, Knoxville, Tennessee, May 1988.

JOHNSON, D. W.

Member: Organizing Committee, Forest Growth: Process Modeling of Responses to Environmental Stress, Gulf Shores, Alabama, April 1988; Advisory Committee, Eastern Brook Lakes Project, Mammoth, California; Steering Committee, Symposium on Forest Decline.

Participant: U.S.-German Research Symposium on Acid Deposition, Burlington, Vermont, October 1987; Annual Meeting of the American Society of Agronomy, Atlanta, Georgia, November 1987; Target Loadings for Air Pollution in Wilderness Areas, U.S. Forest Service, Millbrook, New York, April 1988; National Research Council Markers of Air Pollution in Forests, Little Switzerland, North Carolina, April 1988; Modeling Soil and Water Acidification, EPRI, London, England, July 1988; Nutritional Consequences of Intensive Forest Harvesting, IEA, Park Forest, Washington, July 1988.

Faculty: Adjunct Professor, Forestry, Wildlife, and Fisheries, The University of Tennessee.

Ad hoc reviewer: *Journal of Forestry; American Naturalist; Environmental and Experimental Botany; Environmental Pollution; Soil Science; Biogeochemistry; Soil Science Society of America Journal; Canadian Journal of Forest Research; Water, Air, and Soil Pollution; EPA.*

Other: Technical Group Contact, International Energy Agency CPC-10, Nutritional Consequences of Intensive Forest Harvesting; Lead U.S. Participant, IEA Task II, Nutrients and Growth Relations in Short-Rotation Forestry; Steering Committee, Symposium on Forest Decline; Editorial Board, *Journal of Environmental Quality.*

JOHNSTON, J. W.

Participant: International Crop Loss Assessment Conference, Raleigh, North Carolina, October 1987; Southern Commercial Forest Research Cooperative Fall Review, Raleigh, North Carolina, November 1987; Herbaceous Energy Crops Program Annual Contractors' Review, Auburn, Alabama, July 1988; Southern Biomass Workshop, Auburn, Alabama, July 1988.

Advisor: Martha Bamford, B.S. candidate, University of the South.

JOSLIN, J. D., JR.

Participant: Fourth Annual Gatlinburg Acid Rain Conference, Gatlinburg, Tennessee, October 1987; Effects of Atmospheric Pollutants on the Spruce-Fir Forests of the Eastern U.S. and the Federal Republic of Germany, Burlington, Vermont, October 1987; Annual Meeting of the American Society of Agronomy, the Soil Science Society of America, and the Crop Science Society of America, Atlanta, Georgia, November 1987; Fourth Annual Gatlinburg Acid Rain Conference, Gatlinburg, Tennessee, November 1987; Southern Appalachian Cloud Water Collectors Workshop, Knoxville, Tennessee, May 1988.

Ad hoc reviewer: *Journal of Environmental Quality; Water, Air and Soil Pollution.*

Other: TVA representative, NAPAP.

KANCIRUK, P.

Chairman: Steering Committee for the Energy Systems User Advisory Committee, Scientific and Technical Computing.

Participant: SAS User's Group International, Orlando, Florida, March 1988.

Advisor: Kevin Birdwell, M.S. candidate, Murray State University; Bill Masters, B.S. candidate, University of Arizona.

KEARL, P. M.

Member: American Geophysical Union; National Water Well Association.

Participant: Modeling of Fluid Flow and Contaminant Transport on Fractured or Granular Porous Media, Indianapolis, Indiana, August 1988.

KELLY, J. M.

Chairman: Annual Meeting of the Soil Science Society of America, Division S-7, Atlanta, Georgia, November 1987; Divisional Chair and Board Member, Soil Science Society of America.

Faculty: Adjunct Professor, Forestry, and Graduate Program in Ecology, The University of Tennessee; Adjunct Professor, Forestry and Natural Resources, Purdue University; Visiting Professor, Agronomy, Purdue University.

Advisor: Andrew Gillespie, Ph.D. candidate, Purdue University.

Ad hoc reviewer: *Water, Air and Soil Pollution; Journal of Environmental Quality; Journal of Forestry; Forest Science; Soil Science Society of America Journal.*

Other: Associate Editor, *Soil Science Society of America Journal.*

KIMMEL, B. L.

Member: International Committee, North American Lake Management Society; Advisory Committee, Murray State University Center of Excellence in Ecosystem Studies; Project Team, Lake and Reservoir Management Guidance Manual.

Participant: Annual Meeting of the International Symposium on Lake and Reservoir Management, Orlando, Florida, November 1987.

Faculty: Faculty Associate, Graduate Program in Ecology, The University of Tennessee; Adjunct Professor, Zoology and Biological Station, University of Oklahoma.

Advisor: Clell J. Ford, M.S. candidate, The University of Tennessee; Mary Evans Culver, M.S. candidate, The University of Tennessee; Charles P. West, B.S. candidate, Millsaps College.

Ad hoc reviewer: *Limnology and Oceanography*; *Lake and Reservoir Management*; *The Southwestern Naturalist*; *Ecological Monographs*; NSF proposal.

Other: Judge, 39th International Science and Engineering Fair, Knoxville, Tennessee, May 1988; Editorial Board, *Limnology and Oceanography*; Editorial Board, *Lake and Reservoir Management*.

KING, A. W.

Chairman: Session Chairman, Third Annual Landscape Ecology Symposium, Albuquerque, New Mexico, March 1988.

Participant: Briefing on Carbon Cycle Modeling Component of Global Carbon Cycle Research, Washington, D.C., May 1988; Workshop on Climate Feedbacks and the Role of Peatlands in the Global Carbon Cycle, Oak Ridge, Tennessee, May 1988; Briefing on Ocean Research Needs, Washington, D.C., July 1988.

Advisor: James Watson, ORAU Semester.

Ad hoc reviewer: USDA, DOE proposals.

KOONER, Z. S.

Member: American Chemical Society; New Zealand Institute of Chemistry.

Participant: National Meeting of the American Chemical Society, Los Angeles, California, September 1988.

KORTE, N. E.

Ad hoc reviewer: *Environmental Science and Technology*.

KSZOS, L. A.

Member: Society of Environmental Toxicology and Chemistry; Water Pollution Control Federation.

Participant: Eighth Annual Meeting of the Society of Environmental Toxicology and Chemistry, Pensacola, Florida, November 1987; 36th Annual Meeting of the North American Benthological Society, Tuscaloosa, Alabama, May 1988; *Ceriodaphnia* and *Daphnia* Bioassay Workshop, Philadelphia, Pennsylvania, September 1988.

Advisor: Mary L. Holtz, B.A. candidate, Lawrence University.

LARSEN, I. L.

Participant: American Society of Testing and Materials Radionuclide Counting Round Robin Evaluation, May 1988.

Advisor: Evelith Olmeda-Miro, M.S. candidate, University of Puerto Rico.

LAYTON, P. A.

Chairman: Registration, Mentoring Workshop, Association for Women in Science, East Tennessee Chapter.

Member: Association for Women in Science, East Tennessee Chapter; Society of American Foresters.

Participant: IEA Poplar Exchange Workshop, Ottawa, Ontario, Canada, October 1987; Biotechnology for Fuels and Chemicals, Gatlinburg, Tennessee, May 1988; Annual Meeting of the Poplar Council of the U.S., Ames, Iowa, August 1988; SRWCP Sub-contractors' Workshop, Tacoma, Washington, August 1988; IEA Willow Breeding and Biotechnology Development Meeting, Bristol, England, September 1988; SRWCP Annual Technical Program Review, Knoxville, Tennessee, March 1988.

Ad hoc reviewer: SRWCP Database Guide; Herbaceous Energy Crops Program Annual Report; USDA Competitive Grants proposals.

Other: Newsletter Editor, Society of American Foresters; Secretary/Treasurer, East Tennessee Chapter of the Society of American Foresters.

LEE, S. Y.

Chairman: Southern Regional Soil Survey Working Planning Conference, Knoxville, Tennessee, June 1988.

Member: USDA Committee on the Mineralogy of Southeastern U.S. Soils.

Participant: 36th Annual Clay Mineral Conference, Socorro, New Mexico, October 1987; Meeting of the American Society of Agronomy and the Soil Science Society of America, Atlanta, Georgia, November 1987; International Working Meeting on Soil Micromorphology, San Antonio, Texas, July 1988.

Faculty: Adjunct Associate Professor, Plant and Soil Science, The University of Tennessee.

Advisor: D. H. Phillips, M.S. candidate; R. E. Lambert, M.S. candidate (both The University of Tennessee).

Ad hoc reviewer: *Soil Science; Soil Science Society of America Journal*; International Soil Micromorphology Workshop Proceeding; DOE proposal.

LINDBERG, S. E.

Chairman: Cochair, Workshop on Aerosol Interactions with Natural Surfaces, Lund, Sweden, September 1988; Vice-Chairman and Chairman-Elect, U.S. National Atmospheric Deposition Program; Chairman, Peer Review of NAPAP Task Group II, Sessions on Atmospheric Chemistry and Deposition, Knoxville, Tennessee, March 1988; Session Chairman, USFS Workshop on Air Pollution in Wilderness Areas, Millbrook, New York, May 1988; Panel Chairman, European Aerosol Conference, Lund, Sweden, August 1988.

Member: Technical Organizing Committee, Seventh International Conference on Heavy Metals in the Environment; Planning Committee, Conference on Global Atmosphere/Biosphere Interactions; Conference Committee, International Conference Series: Heavy Metals in the Environment.

Participant: Annual Technical Meeting of the U.S. National Atmospheric Deposition Program, Minneapolis, Minnesota, October 1987; Annual Review, EPRI Integrated Forest Study, Pinehurst, North Carolina, February 1988.

Advisor: Chris Potter, Ph.D. candidate, Emory University.

Ad hoc reviewer: *Atmospheric Environment; Tellus; Science; Canadian Journal of Forest Research; Journal of Environmental Quality; Water, Air and Soil Pollution*; NSF proposal; Cornell University Press; Springer-Verlag.

Other: Visiting Scientist, University of Göttingen, Institute of Bioclimatology, Göttingen, Federal Republic of Germany; Editorial Board, *Advances in Environmental Science*.

LOAR, J. M.

Chairman: Working Group on Aquatic Habitats, Oak Ridge Reservation Resource Management Committee.

Ad hoc reviewer: *Journal of the Tennessee Academy of Science*.

LUTZ, C. T.

Participant: Annual Meeting of the Geological Society of America, Phoenix, Arizona, October 1987; Meeting of the Rocky Mountain Section of the Geological Society of America, Sun Valley, Idaho, May 1988.

LUXMOORE, R. J.

Chairman: Problems of Ecophysiology in Coniferous Forest Species, Tallinn, Estonia, U.S.S.R., September 1988; International Symposium on Forest Tree Physiology, Nancy, France, September 1988.

Participant: Assessment of Crop Loss from Air Pollutants, Raleigh, North Carolina, October 1987; Biological Response to Environmental Change Workshop, Woods Hole, Massachusetts, October 1987; Agricultural Effects of Global Climate Change, Bethesda, Maryland, April 1988; Workshop on Markers of Air Pollution Effects on Forest Trees, Little Switzerland, North Carolina, April 1988; Forest Growth: Process Modeling of Responses to Environmental Stress, Gulf Shores, Alabama, April 1988.

Faculty: Adjunct Professor, Life Sciences Consortium, The University of Tennessee.

Advisor: Mark G. Tjoelker, M.S. candidate, The University of Tennessee.

Ad hoc reviewer: *Journal of Contaminant Hydrology; Journal of Forest Ecology and Management*; OHER proposal; United Kingdom Natural Environment Research Council proposal; Proceedings, International Symposium on Water Quality Modeling of Agricultural Non-point Sources.

Other: Board Member, Tennessee Citizens for Wilderness Planning; Associate Editor, *Tree Physiology*; Associate and Technical Editor, *Soil Science Society of America Journal*.

MANN, L. K.

Chairman: Poster Session, Annual Meeting of the Soil Science Society of America, Atlanta, Georgia, November 1987.

Member: Soil Science Society of America; Ecological Society of America; British Ecological Society.

Participant: Annual Meeting of the Soil Science Society of America, Atlanta, Georgia, December 1987; IEA Forest Productivity Workshop, Seattle, Washington, August 1988; DOE Walker Branch Watershed Planning Workshop, Oak Ridge, Tennessee, August 1988.

Ad hoc reviewer: *Canadian Journal of Forest Research*; *Soil Science Society of America Journal*; Proceedings, IEA Forest Productivity Workshop; Agricultural Research Service.

Other: Secretary/Treasurer, Soil Conservation Service Board of Supervisors, Roane County, Tennessee.

MARLAND, G.

Chairman: Cochair, Prospects for Mitigating Climate Warming by Carbon Dioxide Control, sponsored by the American Association for the Advancement of Science, Boston, Massachusetts, February 1988.

Participant: U.S. Navy Installation Restoration Management Conference, Port Hueneme, California, March 1988; National Academy of Engineering, Workshop on Technology and the Environment, Woods Hole, Massachusetts, August 1988.

Ad hoc reviewer: *The Environmental Professional*; EPRI proposals; World Resources Institute program plan.

Other: Judge, 39th International Science and Engineering Fair, Knoxville, Tennessee, May 1988; Judge, Woodland School Inventors' Fair, Oak Ridge, Tennessee.

MARSH, J. D., JR.

Member: Continuing Education Committee, Health Physics Society.

McCARTHY, J. F.

Chairman: Biomarkers of Environmental Contamination, American Chemical Society, Los Angeles, California, September 1988.

Participant: ORNL Life Sciences Symposium on Bioindicators: Exposure and Effects, Knoxville, Tennessee, March 1988; DOE Workshop on Savannah River Deep Probe Project, Atlanta, Georgia, April 1988; Second U.S.-U.S.S.R. Symposium on Air Pollution Effects on Forests, Gatlinburg, Tennessee, September 1988.

Faculty: Adjunct Faculty, Graduate Program in Ecology, The University of Tennessee.

Advisor: Marsha C. Black, Ph.D. candidate, The University of Tennessee; Willodean D. Burton, Ph.D. candidate, The University of Tennessee; Nora Weber, B.S. candidate, Blackburn College.

Ad hoc reviewer: Environmental Science and Technology; Environmental Toxicology and Chemistry; Journal of Environmental Quality; American Chemical Society; DOE.
Other: Judge, 39th International Science and Engineering Fair, Knoxville, Tennessee, May 1988.

McCONATHY, R. K.

Participant: WATtec Conference, Knoxville, Tennessee, February 1988.

McCORD, R. A.

Participant: GIS '87, San Francisco, California, October 1987; Environmental Systems Research Institute Users Conference, Palm Springs, California, March 1988.

McLAUGHLIN, S. B.

Member: National Research Council Committee on Biomarkers of Pollutant Impacts on Forests; Sigma Xi.

Participant: Symposium on the Effects of Atmospheric Pollutants on Spruce Fir Forests in the Federal Republic of Germany and the Eastern United States, Burlington, Vermont, October 1987; EPA Workshop on Response of Trees to Air Pollutants: The Role of Branch Chambers, Boulder, Colorado, November 1987; NAPAP Annual Program Review, Corpus Christi, Texas, April 1988; National Research Council Symposium: Biomarkers of Air Pollutant Effects on Forests, Little Switzerland, North Carolina, April 1988; Sixth World Congress of Plant Pathology, Kyoto, Japan, August 1988; Commission of the European Communities Symposium on Interrelationships of Above- and Below-Ground Influences of Air Pollutants on Forest Trees, Gennep, The Netherlands, December 1987.

Advisor: Alan Stam, Ph.D. candidate, The University of Tennessee; Tod Leiminger, Ph.D. candidate, Virginia Polytechnic Institute and State University.

Ad hoc reviewer: Canadian Journal of Forest Research; Forest Science; Ecology; Environmental and Experimental Botany; EPRI.

McMASTER, W. M.

Member: National Water Well Association.

MILLEMAN, R. E.

Faculty: Adjunct Professor, Graduate Program in Ecology, The University of Tennessee.

MOORE, G. K.

Member: National Water Well Association; American Water Resources Association; American Institute of Hydrology.

Participant: Suspended Sediment and Associated Chemicals Symposium, Cookeville, Tennessee, February 1988; International Conference on Fluid Flow in Fractured Rocks, Atlanta, Georgia, May 1988; First Tennessee Hydrology Symposium, Nashville, Tennessee, June 1988.

Advisor: Gregory Swanson, M.Env.E. candidate, The University of Tennessee.

MULHOLLAND, P. J.

Member: Coweeta Long-Term Ecological Reserve Advisory Board, NSF.

Participant: The Role of Dissolved Organic Carbon in Surface Water Acidification, Tucson, Arizona, February 1988; Annual Meeting of the American Society of Limnology and Oceanography, Boulder, Colorado, June 1988; DOE Walker Branch Watershed Project Review, Germantown, Maryland, June 1988.

Advisor: David B. Kirschtel, M.S. candidate, University of Louisville; Terry E. Flum, Ph.D. candidate, The University of Tennessee.

Ad hoc reviewer: *Journal of the North American Benthological Society; Ecology; Water, Air and Soil Pollution;* NSF, Australian Research Council, Hudson River Foundation proposals.

NORBY, R. J.

Participant: Biological Response to Environmental Change, Woods Hole, Massachusetts, October 1987; Integrated Forest Study Nutrient Cycle Modeling Workshop, Lafayette, California, April 1988; Biological Markers of Air Pollution Exposure in Trees, Little Switzerland, North Carolina, April 1988; Annual Meeting of the American Society of Plant Physiologists, Reno, Nevada, July 1988; Second U.S.-U.S.S.R. Symposium, Gatlinburg, Tennessee, September 1988.

Faculty: Faculty Associate, Graduate Program in Ecology, The University of Tennessee.

Advisor: Yohan Weerasuriya, B.A. candidate, College of Wooster; Ralph DiCosty, B.S. candidate, University of Michigan.

Ad hoc reviewer: *Environmental Pollution; Ecology;* DOE proposals.

Other: Editorial Review Board, *Tree Physiology*.

OLSEN, C. R.

Participant: Workshop on Accelerator Mass Spectrometry—Environmental Applications, Baltimore, Maryland, May 1988; DOE Workshop on Research in the Mid-Atlantic Bight and Continental Ocean Margin, Savannah, Georgia, July 1988.

Advisor: Evelith Olmeda-Miro, M.S. candidate, University of Puerto Rico.

Ad hoc reviewer: *Health Physics; Environmental International; Estuaries; Earth and Planetary Science Letters;* DOE, DOC, Hudson River Foundation proposals.

OLSON, R. J.

Chairman: Session Cochairman, Integrating Technology and Geoscience Applications, Denver, Colorado, September 1988.

Participant: The Nature Conservancy Science Review Panel, Washington, D.C., October and November 1987.

O'NEILL, E. G.

Member: Ecological Society of America; U.S. Soil Ecology Society; American Institute of Biological Sciences.

Participant: Workshop on Basidiospore Germination and Tissue Culture Techniques for Agarics, Davis, California, August 1988; Workshop on Identification of Mycorrhizal Associations, Davis, California, August 1988; 73rd Annual Meeting of the Ecological Society of America, Davis, California, August 1988.

Advisor: Ralph J. Dicosty, B.S. candidate, University of Michigan.

Ad hoc reviewer: *Landscape Ecology*; *Pedobiologia*.

O'NEILL, R. V.

Participant: NSF Theoretical Ecology, Asilomar, California, February 1988; Landscape Workshop, Albuquerque, New Mexico, March 1988; Ecological Society Meeting, Davis, California, August 1988.

Faculty: Adjunct Associate Professor, Ecology, The University of Tennessee.

Advisor: Jackie Cunningham, Ph.D. candidate; Jeff Hyman, Ph.D. candidate (both The University of Tennessee).

Ad hoc reviewer: *Ecology*; *Limnology and Oceanography*; NASA-EOS, DOE-OHER, NSF proposals; John Wiley.

Other: Visiting Scientist, University of New Mexico, Albuquerque.

PALUMBO, A. V.

Participant: DOE/OHER Investigators Meeting, Deep Probe Project, Atlanta, Georgia, January 1988; Annual Meeting of the American Society for Microbiology, Miami, Florida, May 1988.

Advisor: William Eng, B.S. candidate, St. Cloud State University; Tim McLellen, B.S. candidate, Eastern New Mexico University; Patricia Deroos, Teacher, Jefferson Junior High School, STRIVE Program, Oak Ridge, Tennessee.

Ad hoc reviewer: *Pedobiologia*; *Limnology and Oceanography*; DOE proposal; Jeffers Research Grant proposal.

PARR, P. D.

Participant: Oak Ridge National Environmental Research Park Review, Oak Ridge, Tennessee, November 1987; NERP Manager's Meeting, Batavia, Illinois, January 1988; Association of Southeastern Biologists, Biloxi, Mississippi, April 1988; NERP Manager's Meeting, Hanford, Washington, May 1988.

Advisor: Lorenzo Fisher, B.S. candidate, Centenary College.

PENG, T.-H.

Member: ESD Seminar Committee.

Participant: Workshop on DOC and DON in Seawater: Methods of Measurement Inter-comparison, Woods Hole, Massachusetts, November 1987; V. M. Goldschmidt Conference, Baltimore, Maryland, May 1988; 13th International Radiocarbon Conference, Dubrovnik, Yugoslavia, June 1988.

Ad hoc reviewer: *Journal of Geophysical Research; Earth and Planetary Sciences Letters; Global Biogeochemical Cycle; Science; Nature;* NSF, DOE proposals.

Other: Task Leader, DOE/CDRD Global Carbon Cycle Research Program.

POST, W. M.

Chairman: Effect of Land Clearing on Soil Carbon and Macronutrients, Atlanta, Georgia, November 1987; Role of Northern Ecosystems in the Global Carbon Cycle, Oak Ridge, Tennessee, May 1988.

Participant: DOE Carbon Dioxide Research Division Carbon Cycle Land-Use Research Component, Washington, D.C., October 1987; Biological Effects of Nuclear Winter, Albuquerque, New Mexico, October 1987; Annual Meeting of the Soil Science Society of America, Atlanta, Georgia, December 1987; Global Vegetation Change: Concepts and Models, Laxenburg, Austria, April 1988; NSF Panel for Reviewing Science and Technology Center Research Proposals, Washington, D.C., April 1988; Energy Systems Program Review, Briefing on the Land-Use Component, Washington, D.C., April 1988; Energy Systems Program Review, Briefing on the Carbon Cycle Modeling Component, Washington, D.C., May 1988.

Faculty: Associate Professor, Ecology Program, The University of Tennessee.

Advisor: Louis Provencher, Ph.D. candidate, The University of Tennessee; Andrew Redfearn, Ph.D. candidate, The University of Tennessee; Orin Clay, B.S. candidate, U.S. Naval Academy; John Wilson, Bearden High School.

Ad hoc reviewer: *Nature; Ecology; Journal of Theoretical Biology; Canadian Journal of Forest Research;* NOAA/NSF Draft, U.S. Plan for U.S.-U.S.S.R. Cooperative Research; U.S.-Israel Binational Science Foundation proposal; EPA; DOE; NSF proposals.

RAILSBACK, S. F.

Member: Social and Environmental Objectives Committee, American Society of Civil Engineers; Ecological Society of America; American Fisheries Society.

Participant: Fish Entrainment Workshop, Charleston, West Virginia, December 1987; Water Quality Modeling Workshop, Cincinnati, Ohio, January 1988; Critical Water Issues and Computer Applications, Norfolk, Virginia, June 1988.

RANNEY, J. W.

Chairman: International DOE Workshop on Short-Rotation Forestry, Tacoma, Washington, August 1988.

Participant: USDA Forest Service Energy Program, Washington, D.C., March 1988; EPA Workshop on Agriculture and Climate Change, Washington, D.C., March 1988; EPA Workshop on Utilities and Climate Change, Washington, D.C., April 1988; DOE Annual Management Review, Biofuels and Municipal Waste Technology Division, Washington, D.C., April 1988; International Thermochemical Conversion Workshop, Prescott, Arizona, May 1988; Canadian Forest Energy Program Evaluation, Toronto, Ontario, Canada, May 1988; USDA Forest Service Engineering Research Program Review, Houghton, Michigan, August 1988.

Faculty: Advisory Committee, Forestry, The University of Tennessee; Guest Lecturer, Forestry, University of Washington.

Advisor: Doris Garcia, Teaching Staff, Metropolitan University of Puerto Rico.

Ad hoc reviewer: *Ecology*; *Journal of Forestry*; Agency for International Development proposals; Forestry Departmental Review, The University of Tennessee.

Other: Forest Manager, Agency for International Development Forestry Support Group; Task Leader, ESD Long-Range Plan; International Energy Agency Technical Participant on Forest Growth and Production.

REED, R. M.

Faculty: Faculty Associate, Graduate Program of Ecology, The University of Tennessee.

Advisor: Michael Beringer, M.Env.S., Indiana University.

REICHLE, D. E.

Member: Real Estate, Science, Land Stewardship, and Governmental Affairs Committee, The Nature Conservancy; Executive Committee, DOE Global Environmental Research Council; Public Responsibility Committee, American Institute of Biological Sciences; Association of Ecosystem Research Centers; Board of Visitors, School of Public and Environmental Affairs, Indiana University; Graduate Admissions Committee, Graduate Program in Ecology, The University of Tennessee; Waste Management Research and Educational Institute Advisory Committee, The University of Tennessee; Accreditation Affirmation Committee of Duke University, Southern Association of Colleges and Schools.

Faculty: Adjunct Professor, Graduate Program in Ecology, The University of Tennessee.

Other: U.S. Member, Editorial Board, *Pedobiologia*; Editorial Board, *Journal of Soil Biology and Ecology*; Consulting Environmental Editor, Springer-Verlag.

RYAN, P. F.

Participant: Planning Meeting of the NAPAP Task Group II Aquatic Effects, Seattle, Washington, May 1988; Work Planning Conference of the Southern Regional Soil Survey, Knoxville, Tennessee, June 1988; Direct/Delayed Response Project Data and Modeling Workshop, Oak Ridge, Tennessee, August 1988; Review Meeting of the Aquatic Effects Research Project Task Group VI, Herndon, Virginia, September 1988.

Ad hoc reviewer: *Geochimica et Cosmochimica Acta*; NSF proposal.

RYON, M. G.

Ad hoc reviewer: Southwestern Naturalist.

Other: Instructor, DOE High School Science Honors Program.

SALE, M. J.

Member: Technical Advisory Committee, Pacific Gas & Electric Company Project.

Participant: Oak Ridge Model Conference, Oak Ridge, Tennessee, October 1987; Instream Flow Workshop for Fish Biologists, Cookeville, Tennessee, October 1987; Third Annual Symposium of the Ohio River Basin Consortium for Research and Education, Indianapolis, Indiana, November 1987; Workshop on ECPA 8(d) Draft Staff Report, Washington, D.C., November 1987; Water Quality Modeling Review for Ohio River Basin EIS, Cincinnati, Ohio, January 1988.

Faculty: Thesis Advisor and Ph.D. Committee Member, Geography and Environmental Engineering, The Johns Hopkins University.

Advisor: G. M. Kondolf, Ph.D. candidate, The Johns Hopkins University.

Ad hoc reviewer: American Fisheries Society; American Water Resources Association, U.S. Forest Service; EPA, DOE proposals.

SCHAEFER, D. A.

Participant: Fourth Annual Gatlinburg Acid Rain Conference, Gatlinburg, Tennessee, October 1987; Integrated Forest Study Annual Workshop, Pinehurst, North Carolina, February 1988; Meeting of the Ecological Society of America, Davis, California, August 1988.

Ad hoc reviewer: Journal of Environmental Quality; Biogeochemistry; Environmental and Experimental Botany; Canadian Journal of Forest Research; NAPAP; NSF proposal; Proceedings, 1987 Central Hardwoods Conference.

Other: Judge, Murray F. Buell Award Committee, Ecological Society of America.

SELFRIEDGE, R. J.

Member: Society of Geophysicists; American Geophysical Union; National Water Well Association.

Participant: Introduction to Geophysics Workshop, Oak Ridge, Tennessee, August 1988.

Advisor: Mercedes Padilla, B.S. candidate, University of Puerto Rico.

SHARPLES, F. E.

Member: Public Affairs Committee, Ecological Society of America.

Participant: First International Conference on Release of Genetically Engineered Microorganisms, Cardiff, Wales, April 1988; Ecological Society of America Workshop on Release of Genetically Altered Organisms, Washington, D.C., April 1988; Environmental Biology Peer Review Panel, Gatlinburg, Tennessee, May 1988.

Ad hoc reviewer: NSF proposal.

Other: President-Elect, Oak Ridge Chapter of Sigma Xi; Judge, 39th International Science and Engineering Fair, Knoxville, Tennessee, May 1988.

SHRINER, D. S.

Chairman: Second U.S.-U.S.S.R. Symposium on Air Pollution Effects on Forests, Gatlinburg, Tennessee, September 1988.

Member: Ecological Effects Committee, Air Pollution Control Association.

Participant: National Crop Loss Assessment Program Symposium, Raleigh, North Carolina, October 1987; Air Pollution Control Association Specialty Conference on NAPAP 1987 Assessment, Pittsburgh, Pennsylvania, January 1988; NAPAP Forest Response Program-Program Review, Corpus Christi, Texas, February 1988; 20th National Air Pollution Workshop, State College, Pennsylvania, March 1988; Workshop to Plan NAPAP 1990 Assessment, Washington, D.C., April 1988.

Faculty: Adjunct Professor, Plant Physiology and Pathology, Virginia Polytechnic Institute and State University; Graduate Committee Member, Environmental Sciences and Engineering, University of California, Los Angeles.

Advisor: Dean E. Carpenter, Ph.D. candidate, University of California, Los Angeles.

Ad hoc reviewer: *Canadian Journal of Forest Research*; U.S. Forest Service, EPA proposals; NAPAP plan.

SHUGART, L. R.

Chairman: Symposium on Biological Markers of Environmental Contaminants, Los Angeles, California, September 1988.

Member: Bioindicators Task Group of Biological Field Tests Subcommittee.

Participant: Non-Mammalian Toxicity Assessment Research Review, Frederick, Maryland, August 1988.

Faculty: Adjunct Professor and Advisory Committee, Graduate School of Biomedical Sciences, The University of Tennessee.

Advisor: Christine Gettys, B.S. candidate, Western Carolina University; David Lair, B.S. candidate, Millsaps College; David Dean, B.S. candidate, Millsaps College.

Ad hoc reviewer: *Aquatic Toxicology*; *Cancer Research*; *Marine Environmental Research*; Greenpeace proposal.

Other: Judge, 39th International Science and Engineering Fair, Knoxville, Tennessee, May 1988.

SIGAL, L. L.

Chairman: Environmental Auditing Workshop, Oak Ridge, Tennessee, March 1988.

Participant: International Conference: Assessment of Crop Loss from Air Pollutants, Raleigh, North Carolina, October 1987; Preparation and Review of Environmental Impact Statements, West Point, New York, November 1987; Power Communication Skills, Oak Ridge, Tennessee, November 1987; Environmental Auditing Conference for Federal Agencies, Atlanta, Georgia, March 1988; Annual Conference of the National Association of Environmental Professionals, Orlando, Florida, April 1988.

Ad hoc reviewer: *Australian Journal of Ecology*; *Canadian Journal of Botany*; *The Bryologist*.

SIGMON, C. F.

Chairman: Awards Committee, Association for Women in Science, East Tennessee Chapter.

Member: By-Laws Committee, Tennessee Society of Hazardous Materials.

Participant: Seventh Annual PCB Regulatory Briefing, Washington, D.C., November 1987; Certification Training: Asbestos Abatement Supervisor, Oak Ridge, Tennessee, December 1987; Hazardous Waste Management—Superfund, Durham, North Carolina, April 1988; Management of Hazardous Waste: A Regulatory Training Course, Oakland, California, June 1988.

Ad hoc reviewer: DOE.

Other: Treasurer, Association for Women in Science.

SIMMONS, G. L.

Participant: 20th Air Pollution Workshop, State College, Pennsylvania, April 1988; ROPIS Review, Stanford Component, State College, Pennsylvania; Forest Growth: Process Modeling of Responses to Environmental Stress, Gulf Shores, Alabama, April 1988; ROPIS Review, Boyce Thompson Institute, Ithaca, New York, August 1988.

SMITH, E. D.

Chairman: Publicity and Arrangements Committee, Association for Women in Science.

Other: Section Coeditor, *Nuclear Safety*.

SMITH, J. G.

Advisor: Patricia A. Lipoma, B.S. candidate, U.S. Naval Academy.

SOLOMON, D. K.

Participant: Flow Through Fractured Porous Media, Tucson, Arizona, October 1987; Tennessee Hydrology Symposium, Nashville, Tennessee, June 1988; Agency for Toxic Substances and Disease Registry Workshop, Atlanta, Georgia.

Faculty: Adjunct Lecturer, Geology, Emory University.

Advisor: Diana Wickliff, M.S. candidate, University of Arkansas.

Ad hoc reviewer: *Limnology and Oceanography*.

SOUTHWORTH, G. R.

Participant: Annual Meeting of the Society of Environmental Toxicology and Chemistry, Pensacola, Florida, November 1987.

Ad hoc reviewer: *Environmental Science and Technology; Water, Air and Soil Pollution*.

SPALDING, B. P.

Participant: Oak Ridge Model Conference, Oak Ridge, Tennessee, October 1987; DOE Waste Management Advisory Committee, Chattanooga, March 1988, and Oak Ridge, June 1988.

STEINMAN, A. D.

Participant: Periphyton Colloquium, Louisville, Kentucky, March 1988.

Ad hoc reviewer: *Journal of Phycology*; *Journal of the North American Benthological Society*.

STEWART, A. J.

Member: Ecological Society of America; North American Benthological Society; Society of Environmental Toxicology and Chemistry; American Society of Limnology and Oceanography.

Participant: Periphyton Colloquium, Louisville, Kentucky, March 1988.

Faculty: Faculty Associate, Ecology, The University of Tennessee.

Advisor: Michael Horn, M.S. candidate, The University of Tennessee; Martha Bamford, B.S. candidate, University of the South; Myrna Martinez, B.S. candidate, University of Puerto Rico.

Ad hoc reviewer: *Journal of Environmental Quality*; *Canadian Journal of Fisheries and Aquatic Science*; NSF proposals.

Other: Editorial Board, *Journal of Freshwater Ecology*.

STOW, S. H.

Chairman: Geoscience Aspects of Hazardous and Radioactive Waste, Geological Society of America, Columbia, South Carolina, March 1988; Hydrology Committee, City of Farragut, Tennessee.

Member: Councilor, Geological Society of America; Education Committee, American Geological Institute; Hydrogeology of Hazardous and Radioactive Wastes Commission, International Association of Hydrogeologists; ESD Education Committee; ORNL Energy Technology R&D Committee.

Participant: Annual Meeting of the Geological Society of America, Phoenix, Arizona, November 1987; Meeting of the Geological Society of America, Southeastern Section, Columbia, South Carolina, March 1988; Waste Management '88, Tucson, Arizona, March 1988; Advanced Martin Marietta Management, Newport, Tennessee, August 1988; American Association for the Advancement of Science Commission on Professionals in Science and Technology, Washington, D.C., September 1988.

Faculty: Adjunct Professor and Advisory Committee, Geological Sciences, The University of Tennessee; Geosciences Chairman, Advisory Committee, College of Science and Mathematics, Auburn University.

Ad hoc reviewer: *Environmental Geology and Water Sciences*; NSF proposals.

Other: Editorial Board, *Environmental Geology and Water Sciences*; Judge, 39th International Science and Engineering Fair, Knoxville, Tennessee, May 1988.

SUTER, G. W., II

Member: Scientific Review Group, New York State Department of Environmental Conservation; Committee E-47 on Biological Effects and Environmental Fate, American Society for Testing and Materials.

Participant: EPA Ecological Risk Assessment Investigators Meeting, Calloway Gardens, Georgia, January 1988; International Workshop: Terrestrial Field Testing of Pesticides, Cambridge University, Cambridge, England, September 1988.

Advisor: Sara Floit, M.S. candidate, Indiana University.

Ad hoc reviewer: *Environmental Management*; EPA.

Other: Judge, 39th International Science and Engineering Fair, Knoxville, Tennessee, May 1988; Editorial Board, *Environmental Toxicology and Chemistry*; Associate Editor, *SETAC News*.

TAMURA, T.

Chairman: American Society of Agronomy Environmental Quality Research Committee; Section Chairman, Meeting of the American Society of Agronomy and the Soil Science Society of America, Atlanta, Georgia, November 1987.

Member: Awards Committee, Environmental Quality Research Committee, American Society of Agronomy.

Ad hoc reviewer: *Journal of Environmental Quality*; *Environmental Science and Technology*.

TAYLOR, G. E.

Member: EPA Clean Air Science Advisory Board.

Participant: NASA-NSF Workshop on Atmosphere-Surface Exchange Processes, New York, New York, October 1987; International Symposium on Air Pollution Effects on Vegetation, Raleigh, North Carolina, November 1987; Clean Air Science Advisory Committee on Ozone, Washington, D.C., December 1987; Integrated Forest Study Annual Review, Pinehurst, North Carolina, February 1988; Effects of Sulfur and Nitrogen Deposition on Vegetation, Corpus Christi, Texas, February 1988; Tropospheric Ozone and Forest Resources, Corvallis, Oregon, July 1988; Response of Plants to Interacting Stresses, Ithaca, New York, September 1988.

Ad hoc reviewer: *New Phytologist*; *Atmospheric Environment*; *Environmental and Experimental Botany*; Elsevier; EPA, DOE proposals.

TOLBERT, V. R.

Chairman: Session Chair, Annual Meeting of the North American Benthological Society—Aquatic Toxicity and Effects of Acidification, Tuscaloosa, Alabama, May 1988; North American Benthological Society Exhibits Committee.

Participant: Achieving Communication Effectiveness, Oak Ridge, Tennessee, June 1988; Annual Meeting of the National Association of Environmental Professionals, Orlando, Florida, April 1988.

Advisor: Elizabeth Adler, B.S. candidate, Cornell University; Christopher E. Tucker, B.S. candidate, DePaul University.

Other: Treasurer, North American Benthological Society; Judge, 39th International Science and Engineering Fair, Knoxville, Tennessee.

TORAN, L. E.

Participant: Deep Probe Investigators Meeting, Atlanta, Georgia, January 1988; OSHA Training, Oak Ridge, Tennessee, March 1988; Spring Meeting of the American Geophysical Union, Baltimore, Maryland, May 1988; First Tennessee Hydrology Symposium, Nashville, Tennessee, June 1988; Annual Meeting of the American Chemical Society, Los Angeles, California, September 1988.

Advisor: Southey Hayes, B.S. candidate, Millsaps College.

TRABALKA, J. R.

Member: Scientific Committee 64, Task Group 9, National Council on Radiation Protection and Measurements.

Ad hoc reviewer: Nuclear Safety.

Other: Judge, 39th International Science and Engineering Fair, Knoxville, Tennessee.

TRIMBLE, J. L.

Member: President, Association for Women in Science, East Tennessee Chapter.

TRIPATHI, V. S.

Chairman: Session Chair, Chemical Modeling in Aqueous Systems II, Los Angeles, California, September 1988.

Participant: Southeast Section Meeting of the Geological Society of America, Columbia, South Carolina, April 1988; Seventh National Conference on Artificial Intelligence, St. Paul, Minnesota, August 1988; National Meeting of the American Chemical Society, Los Angeles, California, September 1988.

Advisor: Forrest Hoffman, B.S. candidate, University of Hawaii.

Ad hoc reviewer: Water Resources Research.

TSCHAPLINSKI, T. J.

Chairman: Panel Cochairman, DOE Annual Subcontractors' Meeting of the Short Rotation Woody Crops Program, Tacoma, Washington, August 1988.

Participant: Annual Meeting of the American Society of Plant Physiologists, Reno, Nevada, July 1988; DOE Annual Subcontractors' Meeting of the Short Rotation Woody Crops Program, Tacoma, Washington, August 1988.

Advisor: Pamela Riggs, B.S. candidate, Albion College.

TURNER, M. G.

Chairman: Third Annual Landscape Ecology Symposium, Albuquerque, New Mexico, March 1988.

Member: Advisory Committee, Project of Science, Mathematics and Technologies, Tanasi Girl Scout Council, Knoxville, Tennessee.

Participant: Peer Review Board, EPA Program on Environmental Effects of Global Climatic Change, Corvallis, Oregon, April 1988.

Ad hoc reviewer: *Ecology; Landscape Ecology; Journal of Range Management;* DOE proposal.

Other: Program Chair, U.S. Chapter of the International Association for Landscape Ecology.

TURNER, R. R.

Participant: Mercury Sampling/Analytical Workshop, Boulder Junction, Wisconsin, May 1988.

Advisor: Ayne VandenBrook, B.S. candidate, Illinois State University; Karen Temple, M.Env.S. candidate, Indiana University.

Ad hoc reviewer: *Water, Air and Soil Pollution; Environment International;* EPA, EPRI proposals.

Other: Judge, 39th International Science and Engineering Fair, Knoxville, Tennessee, May 1988.

TURNER, R. S.

Participant: Mid Appalachian DDRP Technical Caucus, Las Vegas, Nevada, October 1987; Fourth Annual Gatlinburg Acid Rain Conference, Gatlinburg, Tennessee, October 1987; Southern Blue Ridge DDRP Data Validation Workshop, Oak Ridge, Tennessee, November 1987; Aquatic Effects Research Program Report Workshop, Raleigh, North Carolina, November 1987; Annual Meeting of the Soil Science Society of America, Atlanta, Georgia, November 1987; Acid Precipitation: A Technical Amplification of NAPAP's Findings, Pittsburgh, Pennsylvania, January 1988; International Interactive Workshop on Soil Resources, Minneapolis, Minnesota, March 1988; DDRP Mid Appalachian Planning Workshop, Corvallis, Oregon, April 1988; Aquatic Effects Research Program Workshop, Seattle, Washington, May 1988; DDRP Modeler's Workshop, Corvallis, Oregon, August 1988; DDRP Mid Appalachian Sample Class Workshop, Corvallis, Oregon, August 1988; DDRP Level I-III Synthesis Workshop, Oak Ridge, Tennessee, August 1988; NAPAP Task Group VI Review Workshop and Coordination Meeting, Herndon, Virginia, September 1988.

Advisor: Carol G. Holland, B.A. candidate, Western Carolina University.

Ad hoc reviewer: *Water Resources Research; Journal of Environmental Quality;* NAPAP Annual Report; Springer-Verlag; EPA.

VAN HOOK, R. I.

Chairman: Session Chair, Southern Biomass Research Conference, Auburn, Alabama, July 1988.

Participant: Martin Marietta Energy Systems Advanced Management Program, Newport, Tennessee, August 1988.

Other: Editorial Board, *Biomass*.

VAN MIEGROET, H.

Participant: Management of Water and Nutrient Relations to Increase Forest Growth, Canberra, Australia, October 1987; IEA CPC-10 Workshop on Predicting Consequences of Intensive Harvesting, Georgetown, South Carolina, October 1987; Annual Meeting of the Soil Science Society of America, Atlanta, Georgia, November 1987; International Union of Forest Research Organizations Conference on Forest Growth: Process Modeling of Responses to Environmental Stress, Gulf Shores, Alabama, April 1988; Seventh North American Forest Soils Conference on Sustained Productivity of Forest Land, Vancouver, British Columbia, Canada, July 1988; IEA CPC-10 Workshop on Research Strategies for Long-Term Site Productivity, Vancouver, British Columbia, Canada and Seattle, Washington, July 1988.

Advisor: Carla Duncan, Iowa State University, ORAU Summer Program.

Ad hoc reviewer: *Journal of Environmental Quality*; *Soil Science Society of America Journal*; *Canadian Journal of Forest Research*; NSF; IEA; IUFRO.

VAN WINKLE, W.

Member: Admissions Committee; Sigma Xi; ESD Scientific Achievement Award Committee; Recreation Advisory Group, Oak Ridge, Tennessee.

Participant: Walker Branch Watershed Project Review, Oak Ridge, Tennessee, December 1987; EPRI Review of Fish Compensation Modeling Framework, Houston, Texas, February 1988; EPRI Winter Flounder Workshop, Narragansett, Rhode Island, June 1988; Walker Branch Watershed Briefing, Germantown, Maryland, June 1988; EPRI Striped Bass Workshop, New York, New York, and Stockton, California, August 1988; Annual Meeting of the American Fisheries Society, Toronto, Ontario, Canada, September 1988.

Faculty: Adjunct Faculty, Graduate Program in Ecology, The University of Tennessee.

Ad hoc reviewer: Hudson River Foundation and Sport Fishing Institute proposals.

VON DAMM, K. L.

Member: Advisory Committee, NOAA VENTS Program.

Participant: Chemrawn IV—Modern Chemistry and Chemical Technology Applied to the Ocean and Its Resources, Keystone, Colorado, October 1987; Meeting of the American Geophysical Union, San Francisco, California, December 1987; Ridge Workshop: Mapping and Sampling, Woods Hole, Massachusetts, April 1988; Meeting of the American Chemical Society, Toronto, Ontario, Canada, June 1988; Gordon Research Conference—Environmental Sciences: Water, New Hampton, New Hampshire, June 1988.

Advisor: Ayne VandenBrook, B.S. candidate, Illinois State University.

Ad hoc reviewer: *Geochimica et Cosmochimica Acta*; *Deep Sea Research*; *Journal of Geophysical Research*; *Nature*; *Reviews in Aquatic Sciences*; Oak Ridge Model Conference Proceedings; American Geophysical Union; Geological Society of America; Geochemical Society abstracts; NSF, NOAA proposals.

VOORHEES, L. D.

Chairman: Natural Subgroup, DOE Oak Ridge Reservation Resource Management Organization.

Participant: Analytical Laboratory Services, Houston, Texas, November 1987; SAS Users Group International Conference, Orlando, Florida, March 1988.

WALTON, B. T.

Member: Publication Committee, Society of Environmental Toxicology and Chemistry; Research Strategies Subcommittee, EPA Science Advisory Board.

Participant: Annual Meeting of the Society of Environmental Toxicology and Chemistry, Pensacola, Florida, November 1987; EPA Annual Research Conference, Oklahoma City, Oklahoma, March 1988; EPRI Workshop on Biological Studies of Complex Mixtures, Carmel, California, May 1988.

Faculty: Adjunct Faculty Associate, Ecology, The University of Tennessee.

Advisor: Sylvia S. Talmage, Ph.D. candidate, The University of Tennessee; Linda V. Meyers-Schone, Ph.D. candidate, The University of Tennessee; Todd A. Anderson, M.S. candidate, The University of Tennessee; Sandra Apellaniz, M.S. candidate, University of Puerto Rico; James G. Stout, B.S. candidate, Denison University; Mark S. Jen, B.S. candidate, California State University; Denise V. Deckert, B.A. candidate, Westmont College.

Ad hoc reviewer: *Environmental and Experimental Botany*; *Journal of Industrial Microbiology*.

Other: Editor, Special Publications, Society of Environmental Toxicology and Chemistry.

WATTS, J. A.

Chairman: Publicity Subcommittee, Mentoring Conference Planning Committee, Association for Women in Science, East Tennessee Chapter; Awards Program Committee, Association for Women in Science, East Tennessee Chapter.

Participant: FERC Workshop on Draft Ohio River Basin EIS, Oak Ridge, Tennessee, March 1988; FERC Workshop on Final Ohio River Basin EIS, Oak Ridge, Tennessee, August 1988; DOE Honor Students Reception, Maryville College, Maryville, Tennessee, July 1988.

Other: Vice-President, Association for Women in Science, East Tennessee Chapter; Technical Program Representative, WATtec Sponsors Committee, Association for Women in Science, East Tennessee Chapter.

WEBB, J. W.

Member: ESD Safety Committee.

Participant: Floodplain Hydrology Workshop, University of Texas, Austin, September 1988; EPA Symposium on the Impact of Climate Change on Wildlife, January 1988.

Advisor: D. K. Niyogi, B.A. candidate, Swarthmore College, Summer Program Student.

Ad hoc reviewer: *The Environmental Professional*; NSF proposals.

WEST, D. C.

Participant: ERDAS Users Group Meeting, Atlanta, Georgia, February 1988; Global Vegetation Modeling, Vienna, Austria, April 1988.

Faculty: Faculty Associate, Agriculture and Forestry, Fisheries, and Wildlife, The University of Tennessee.

Ad hoc reviewer: *Ecology*; *BioScience*; *Journal of Forestry*; NSF; DOE.

WHITE, T. W.

Participant: CDIAC Program Review, Oak Ridge, Tennessee, October 1987; Workshop on Sea Level Rise and Coastal Processes, Palm Coast, Florida, March 1988.

WICKER, L. F.

Participant: *Daphnia* Bioassay Workshop, Philadelphia, Pennsylvania, September 1988.

WILSON, G. V.

Member: American Society of Agronomy; Soil Science Society of America; American Geophysical Union; Southern Region of Soil Physics.

Participant: National Meeting of the American Society of Agronomy and the Soil Science Society of America, Atlanta, Georgia, November 1987; Regional Soil Physics, Blacksburg, Virginia, March 1988; International Conference on Validation of Flow and Transport, Ruidoso, New Mexico, May 1988; Walker Branch Watershed Briefing, Germantown, Maryland, June 1988.

Ad hoc reviewer: *Soil Science Society of America Journal*; *Journal of Environmental Quality*; *Water Resources Research*.

Other: Interim Technical Editor, *Soil Science Society of America Journal*.

WRIGHT, L. L.

Chairman: Energy Committee, Poplar Council of the U.S.

Member: Board, Tennessee Citizens for Wilderness Planning.

Participant: Institute of Gas Technology Conference, New Orleans, Louisiana, February 1988; SRWCP Program Review, Knoxville, Tennessee, March 1988; Southern Biomass Workshop, Auburn, Alabama, July 1988.

Ad hoc reviewer: *Journal of the American Benthological Society*.

Other: President and Secretary, Association for Women in Science, East Tennessee Chapter; Judge, 39th International Science and Engineering Fair, Knoxville, Tennessee, May 1988.

YEH, G. T.

Member: Subcommittee N-173, American Society of Civil Engineering.

Participant: Program Review on Groundwater Studies, Taipei, Taiwan, June 1988; MIT Convection-Diffusion Forum, Cambridge, Massachusetts, June 1988; Program Review on the Regulatory Support Program, Oak Ridge, Tennessee, August 1988; Annual Meeting of the SRWCP, Tacoma, Washington, August 1988.

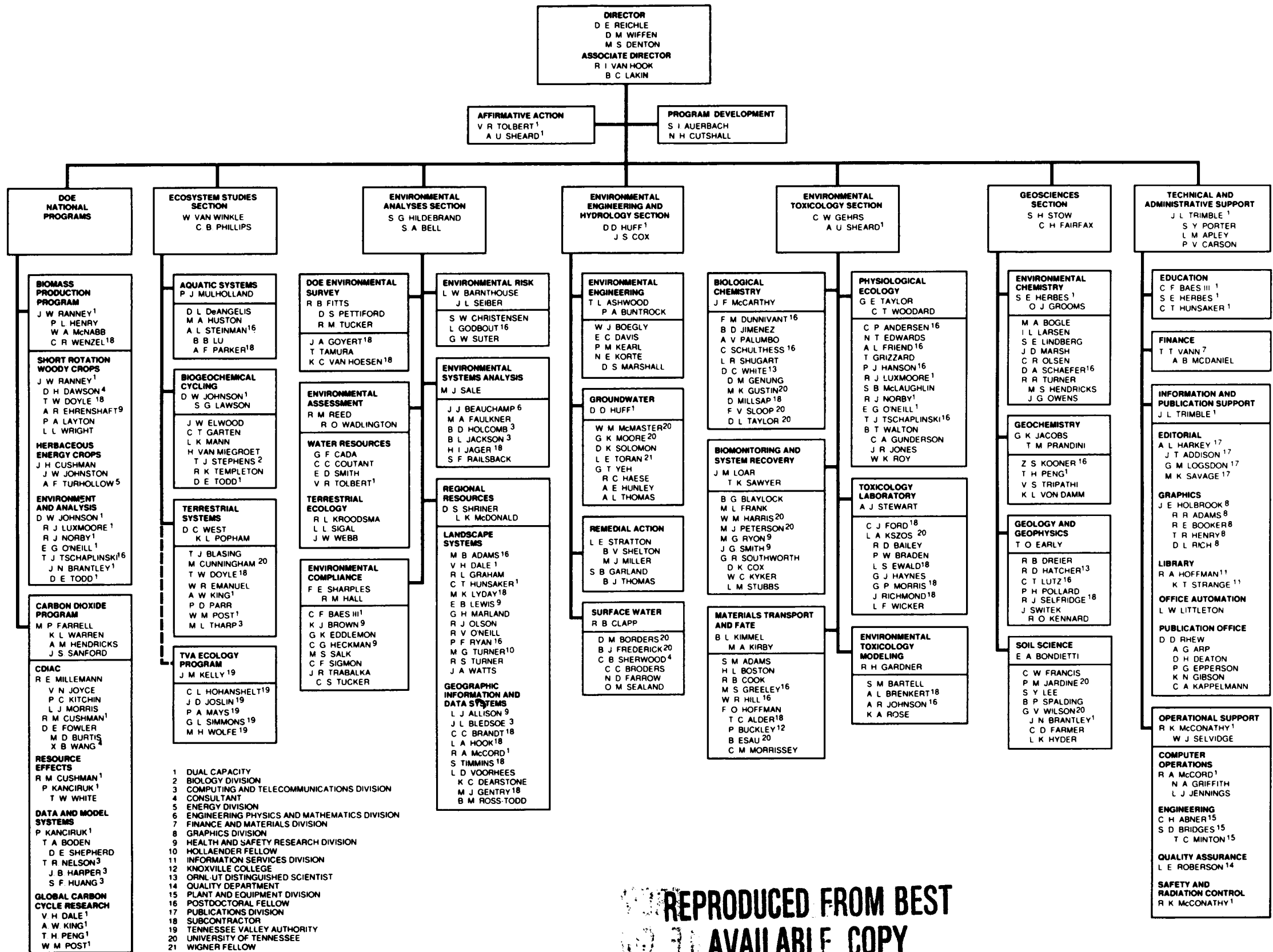
Ad hoc reviewer: *Water Resources Research; Advances in Water Resources; NSF proposals.*

Organization Chart

4

ENVIRONMENTAL SCIENCES DIVISION

SEPTEMBER 1988



REPRODUCED FROM BEST AVAILABLE COPY

ABBREVIATIONS

AEA	Atomic Energy Act
ANC	acid neutralizing capacity
AVHRR	advanced very high resolution radiometer
BHTV	borehole televiewer
BIOMOVs	International Biospheric Model Validation Study
BMAP	Biological Monitoring and Abatement Program
BPP	Biomass Production Program
CDIAC	Carbon Dioxide Information Analysis Center
CDIARP	Carbon Dioxide Information Analysis and Research Program
CDRD	Carbon Dioxide Research Division
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	<i>Code of Federal Regulations</i>
COMPMECH	compensatory mechanisms in fish populations
DDRP	Direct/Delayed Response Project
DIC	dissolved inorganic carbon
DO	dissolved oxygen
DOC	dissolved organic carbon
DOD	U.S. Department of Defense
DOE	U.S. Department of Energy
DPM	Defense Priority Model
ECPA	Electric Consumers Protection Act
EFPC	East Fork Poplar Creek
EIS	environmental impact statement
EPA	U.S. Environmental Protection Agency
EPRI	Electric Power Research Institute
EROD	7-ethoxyresorufin O-deethylase
ESD	Environmental Sciences Division
FERC	Federal Energy Regulatory Commission
GCM	general circulation model
GIS	geographic information system
HHMS	hydraulic head measuring station
HLW	high-level radioactive waste
IAEA	International Atomic Energy Agency
IEA	Institute for Energy Analysis; also International Energy Agency
INEL	Idaho National Engineering Laboratory
IRP	Installation Restoration Program
LLW	low-level radioactive waste
MEI	minority educational institution
METC	Morgantown Energy Technology Center
MFO	mixed-function oxidase
NAPAP	National Acid Precipitation Assessment Program
NAS	National Academy of Sciences

NASA	National Aeronautics and Space Administration
NATO	North Atlantic Treaty Organization
NDP	numeric data package
NEPA	National Environmental Policy Act
NERP	National Environmental Research Park
NOAA	National Oceanic and Atmospheric Administration
NRC	National Research Council; also Nuclear Regulatory Commission
NSF	National Science Foundation
NWPA	Nuclear Waste Policy Act of 1982
OCRWM	Office of Civilian Radioactive Waste Management
OEА	Office of Environmental Audit
ОHER	Office of Health and Environmental Research (DOE)
ORAU	Oak Ridge Associated Universities
ORGDP	Oak Ridge Gaseous Diffusion Plant
ORNL	Oak Ridge National Laboratory
ORR	Oak Ridge Reservation
PCB	polychlorinated biphenyls
PEIA	programmatic environmental impact analysis
PIP	Performance Improvement Process
PURPA	Public Utility Regulatory Policies Act
PVC	polyvinyl chloride
QA	quality assurance
RCRA	Resource Conservation and Recovery Act of 1976, as amended
RISC	reduced instruction set computer
SAI	surface area index
SARA	Superfund Amendments and Reauthorization Act of 1986
SERP	Sedimentary Rock Program
SRIC	short-rotation intensive culture
SRWCP	Short Rotation Woody Crops Program
STRIVE	Science Teachers Research Involvement for Vital Education
SWSA	solid waste storage area
TCE	trichloroethylene
TF	throughfall
TM	thematic mapper
TRC	total residual chlorine
TVA	Tennessee Valley Authority
USDA	U.S. Department of Agriculture
USGS	U.S. Geological Survey
WBW	Walker Branch Watershed
WOC	White Oak Creek
WUE	water-use efficiency