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OAK RIDGE NATIONAL LABORATORY

UNION CARBIDE

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Environmental Sciences Division Annual Progress Report for Period Ending September 30, 1980

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ENVIRONMENTAL SCIENCES DIVISION
ANNUAL PROGRESS REPORT
For Period Ending September 30, 1980

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Environmental Sciences Division Publication No. 1730

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ABSTRACT

AUERBACH, S. I., et al. 1981. Environmental Sciences Division Annual Progress Report for Period Ending September 30, 1980. ORNL-5700. Oak Ridge National Laboratory, Oak Ridge, Tennessee. 212 pp.

Research conducted in the Environmental Sciences Division for the Fiscal Year 1980 included studies carried out in the following Division programs and sections: (1) Advanced Fossil Energy Program, (2) Nuclear Program, (3) Environmental Impact Program, (4) Ecosystem Studies Program, (5) Low-Level Waste Research and Development Program, (6) National Low-Level Waste Program, (7) Aquatic Ecology Section, (8) Environmental Resources Section, (9) Earth Sciences Section, and (10) Terrestrial Ecology Section. In addition, Educational Activities and the dedication of the Oak Ridge National Environmental Research Park are reported.

Research related to Advanced Fossil Energy Systems emphasized development of data for comparative technology assessments. Emphasis continued to shift toward larger-scale, longer-term studies with planning and initiation of pond experiments for assessing effects and fate of synthetic oil spills. Greater efforts were expended in evaluating potential hazards of solid residues with efforts initiated to compare combustion and conversion ashes and to identify the potential role of microbial systems in mobilizing trace elements contained in the residues.

The bioaccumulation of Tc under field and small-pond conditions provided more realistic concentration factors for regulatory models. More information on the chemistry of Pu in natural waters, the dissolution characteristics of Pu-contaminated soil, and the bioaccumulation of the transuranium elements was obtained. Laboratory studies made substantial progress in defining a simple geochemical model for predicting ^{99}Tc migration from breached repositories.

Environmental impact assessments were prepared on specific energy projects regarding nuclear power plants, uranium mines and mills, geothermal power plants and process heat users, oil-fired power plants ordered to burn coal, the fusion energy development program, and a large facility to process high-level nuclear waste from defense plants. Guidance documents were prepared to aid DOE in consideration of environmental matters especially related to competitive procurement and large demonstration facilities. State-of-the-art strategies for monitoring and environmental assessment were published as were specific protocols for use of terrestrial enclosures and artificial streams as monitoring tools.

Ecosystem studies during the past year centered on systems analysis (including succession modeling, error analysis, and studies of spatial heterogeneity), stream spiralling (dealing with phosphorus cycling and stream experiments), global carbon modeling (including analysis of land-use patterns and extant global models), and fuels from woody biomass (including research in woody production and harvest and environmental effects of tree harvesting and agricultural residue utilization).

Processes and mechanisms controlling the escape of radionuclides from low-level waste disposal sites were investigated. Rock-jointing was found to control near-surface solution cavity development and subsequent hydrology and radionuclide transport. Remedial actions for stopping radionuclide escape were developed.

The National Low-Level Waste Management Program Office at ORNL began full-scale operation during the past year. Detailed program plans and budgets were developed for FY 1981 and 1982; program guidance was provided to participating DOE contractors; and cooperation was initiated with other U.S. and foreign waste programs.

A major and growing area of research in the aquatic ecology section deals with ecological processes in southeastern reservoirs, which is supported by assessment work on environmental issues related to small-scale hydroelectric development. A second major area of research deals with analysis and modeling of aquatic populations and ecosystems, including continued involvement in the Hudson River Power Plant Case. Research continues on particular components of impacts associated with power plants, such as toxicant formation in condenser cooling systems and association of Legionnaire's Disease Bacterium with cooling towers. A new and expanding project in the section is Multimedia Environmental Transport Modeling, which involves research on formulation of physicochemical processes, operation of the Unified Transport Model, and development, verification, and validation of atmospheric, terrestrial, and aquatic transport models.

Regional studies focused on site-specific as well as generic problems and included the completion of activities related to the U.S. Forest Service RARE II (Roadless Area Review and Evaluation). Systems analysis activities continued to be closely allied with research project planning and analysis. Numeric data activities emphasized mapping routines for global carbon projects, completion of the US IBP Abstracts series, pulling together of inventories related to global carbon, updating of the Remote Batch Station computing facilities, publication of the Geoecology Data Base, and several projects dealing with research data management.

Leachate studies of advanced coal wastes reveal that although these wastes will not be considered hazardous by RCRA testing, the problem may be in meeting secondary drinking water regulations at the site boundary. Preliminary evaluation of the EPA EP extracts from six landfills show that four would be classified as hazardous, where direct ground-water concentrations indict two landfills. Several new initiatives related to earth science interests were pursued and are showing promise of increasing involvement by the staff.

Terrestrial activities reported this year include initial results on relative effects of humidity on plant uptake of O_3 and SO_2 as determined in the new controlled fumigation facility, assistance to the DOE gaseous diffusion plants in dealing with cooling tower windage, results on acid rain impacts on vegetation, and atmospheric deposition of trace organics on Walker Branch Watershed. Basic studies completed show considerable progress in developing southeastern U.S. tree-ring chronologies and evaluating a "symptomology" for determining air pollution stress on white pines.

ENVIRONMENTAL SCIENCES DIVISION AWARDS AND HONORS

The Environmental Sciences Division of the Oak Ridge National Laboratory received the Award of Distinction from the Miami University Institute of Environmental Sciences in recognition of the relationship between the two institutions.

HAZEL R. DELCOURT

Recipient of 1980 International Youth in Achievement Award from the International Biographical Centre, Cambridge, England, and the American Biographical Institute, Raleigh, North Carolina.

ANNA S. HAMMONS

Communication Competition Award of Merit in the Category of Topical Reports. Presented by the East Tennessee Chapter of the Society of Technical Communication in the 1980 Technical Publications Competition.

R. B. McLEAN

Communication Competition Award of Merit in the Category of Journal Articles. Presented by the East Tennessee Chapter of the Society for Technical Communication in the 1980 Technical Publications Competition.

T. TAMURA

Elected Fellow, Soil Science Society of America, August 1980.
Elected Fellow, American Society of Agronomy, August 1980.

THE OAK RIDGE NATIONAL ENVIRONMENTAL RESEARCH PARK

J. T. Kitchings
L. K. Mann J. D. Story D. C. West

The Department of Energy's (DOE) Oak Ridge Reservation has been recognized for many years as a significant national, regional, and local resource for environmental research. Few sites have such varied natural resources, and none has comparable security and protection in a community containing so much scientific talent. The resources are typical of the southern Appalachian landscapes and represent ecosystems not extensively investigated by other research groups within this region. The site has been designated as a component of the Experimental Ecological Reserve (EER) Network; it is associated with the U.S. Man and Biosphere Reserve Network; and on June 5, 1980, 5500 ha of the site were designated by DOE as a National Environmental Research Park (NERP).

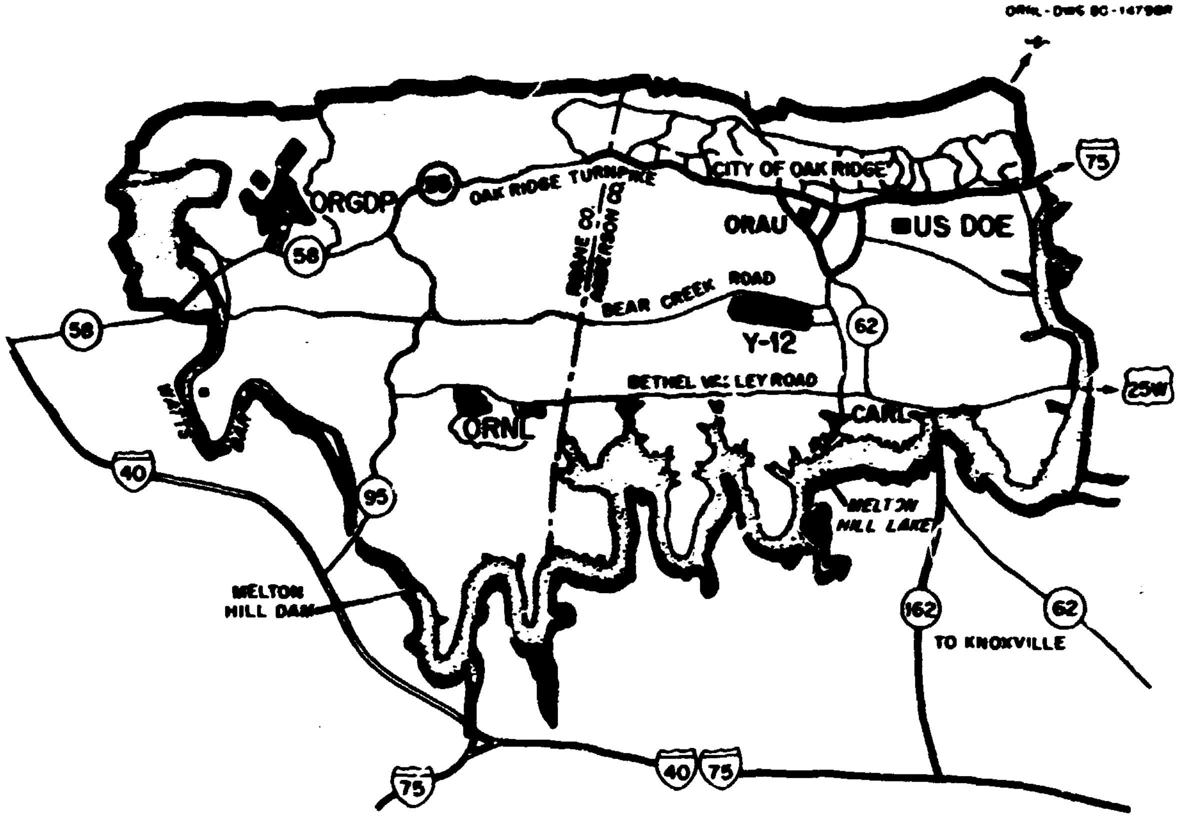
A NERP is an outdoor laboratory in which research may be conducted to achieve environmental goals defined by the National Environmental Policy Act (NEPA), the Energy Reorganization Act (ERA), and the Nonnuclear Energy Research and Development Act. The NEPA heightened the public's interest in environmental quality and established the nation's environmental goals. The NERPs were established under DOE to provide protected land areas for research and education in the environmental sciences and to demonstrate the environmental compatibility of energy technology development and use.

The addition of Oak Ridge to the NERP system brought to five the number of these parks located at DOE sites across the country. The others are at Los Alamos, New Mexico; Idaho Falls, Idaho; Hanford, Washington; and Aiken, South Carolina. Controlled public access to the diversity of biological communities represented on the NERP sites as well as the resources of expert staff and facilities provide a unique opportunity for attaining NERP objectives.

A wide range of research and demonstration programs are necessary to address systematically the environmental impacts of man's activities. Environmental research parks not only provide sites on which to conduct general research but also help environmental research programs (1) to develop methods for assessing and monitoring, both quantitatively and continuously, the environmental impacts of man's activities; (2) to develop methods for predicting the environmental impacts of proposed and ongoing energy-development activities; and (3) to demonstrate the environmental impacts of various activities and evaluate methods for minimizing adverse effects.

The Oak Ridge NERP is an integral part of the ecological programs administered through the Oak Ridge National Laboratory's Environmental Sciences Division (ESD). The core of the park is formed by the land and water areas that ESD has used and protected for long-term ecological projects over the past 20 years (Fig. 1). As part of the oak-hickory association of the ridge and valley province in the southern Appalachians, the Oak Ridge NERP includes a diversity of biological communities and a wide range of geology, topography, and cultural practices. Naturally occurring terrestrial and freshwater aquatic communities range from cedar barrens to streams and associated floodplains and upland hardwood forests, while current land uses include undisturbed mature hardwoods, intensively managed forest plantations, and power line corridors.

Since 1975, ESD members have been involved in inventorying the natural resources within the NERP boundaries. This effort was undertaken to formulate plans to permit management of these resources to meet the DOE goals for the NERP system. Initial efforts were to construct a classification scheme of the forested area over the whole NERP to delineate major forest types. This exercise had a twofold purpose: (1) to highlight major forest types to ensure their inclusion in a system of protected research areas and (2) to aid in identifying areas which are less common on the NERP, such as beech-maple, cedar barrens, and hemlock areas, so that they could be included in an ancillary system of protected natural areas. This task was accomplished by constructing a



Oak Ridge National Environmental Research Park

Fig. 1. The Department of Energy NERP at Oak Ridge, Tennessee, consists of 5500 ha and lies in the heart of an eastern deciduous forest area of streams and reservoirs, mesic hardwood forests, and extensive upland mixed forests.

classification of forest types over the whole area on the basis of overstory (trees >22.8 cm DBH) composition. The previously established 184 continuous forest inventory (CFI) plots (0.08 ha) were used to delineate forest types within the 5500 forested hectares on the Reservation (Curlin 1965). Although not sufficient to identify small-scale unique features, these plots were useful in defining forest type by using two classification (clustering) techniques based on basal area (m^2/ha) of the overstory trees. The result of this initial effort was the categorization of designated NERP lands into specific programmatic activity units as outlined below:

1. Natural areas—protected lands within the Reservation that are habitats for regionally unique, rare, or endangered plant and animal species. Twenty-five of these areas have been identified and encompass approximately 500 ha.

2. Reference or control programs—lands within the Reservation that are representative of the vegetation communities of the southern Appalachian region. These reference areas contain permanent forest inventory plots spanning the range of natural forest community types within the Reservation. Periodic remeasurement of the forest types provides data that can be used to ascertain natural forest successional patterns and constitutes a standard with which to compare potential changes in forest communities resulting from man-induced changes such as management practices and air pollution.

3. Environmental research—generic research on pollutant transport, environmental toxicology, renewable resources, and monitoring of population and community fluctuations.

4. Technology assessment--analysis of anthropogenic activities that affect the Oak Ridge Reservation. These include impacts resulting from forest management, solid waste landfills, cooling towers, coal-fired steam plants, and nuclear fuel cycles, with emphasis on extrapolating this information to other areas in the Southeast.

Within the framework of the activity units, inventories of natural resource components were formulated to contribute to the compilation of a regional environmental encyclopedia, including species lists, characterization of ecosystems, successional stages, and mapping the vegetation, soils, hydrology, etc.

Temporary variable radius plots were used throughout the Reservation to characterize stand composition and volume. Of the 35 forestry compartments, 31 were inventoried in this manner. From these data, compartment maps were drawn showing stand boundaries, composition, and acreage and other land-use categories such as roads, power lines, and dump sites. Although variable radius plot sampling is used for most of the inventory because of the rapidity with which such data can be collected, some areas also have a system of 800-m^2 permanent sample plots. These include the previously mentioned CFI plots, Walker Branch Watershed, most of the natural areas, and one of the research reference areas. These permanent plots, which maintain a record of tree mortality and ingrowth, provide the basis for comparative forest success and productivity.

Concomitant with the forest inventory, wildlife surveys (plant and animal) are being conducted to determine species distribution. To accomplish the surveys, a number of representative stands of habitat types distributed appropriately over the Reservation were selected. These stands are being surveyed to determine the occurrence and general abundance of bird and small mammal species and plant species. As a result of initial surveys, certain habitats may be searched more thoroughly for less common species (i.e., endangered or rare). The survey results can provide information to create habitat maps which are necessary to research and management scenarios for wildlife populations at the species, community, and ecoregion levels.

The Oak Ridge NERP also serves as a refuge for wildlife species that are representative of those in this region; thus, it offers scientists an opportunity to investigate the habitat requirements of these species. Current wildlife research includes studies of white-tailed deer and bobcat populations and niche preference studies of various other animal species.

The DOE and the Tennessee Wildlife Resources Agency use the Oak Ridge NERP for wildlife research to obtain information on the biological characteristics and management of many species in Tennessee. Potential exists for research not only on small game species, such as quail, rabbit, squirrel, and raccoon, but also on skunk, opossum, groundhog, fox, and other species of nongame and nonfurbearing animals. Long-term studies on the status of bobcats on the Reservation were initiated to learn more about the natural history of these animals and to determine any effects on their habitat caused by man's activities. These efforts use the latest in radiotelemetry techniques to supplement observational data.

Rare plant surveys were conducted over most of the Oak Ridge NERP, with approximately 15 species located and their distribution mapped. Habitats for these species are currently in a protected status. Herbaceous and shrub vegetation inventories were also completed in these protected areas. As these surveys were made, plant specimens were added to the NERP herbarium, and the collections were reorganized according to the Missouri Botanical Garden Flora of North America. In addition, a lichen collection was added to the herbarium.

Completion of the inventory processes is of paramount importance to the formulation and ultimate implementation of a natural resource program. Although a data base is available, it is far from complete (Table 1). Highest priority is being given to compilation of a natural resources inventory that archives both natural and human-mediated events. The data base will be readily retrievable by a variety of users. Development of a site classification scheme based on geology, soils, aspect, and slope will allow management scenarios to be formulated, ensuring the presence of a wide range of ecological communities that may be required for research.

The maintenance of a diverse array of habitats potentially supportable on the NERP is a significant management challenge and will require close cooperation and frequent interaction of ecologists and forest

Table 1. Elements to be included in the resource data system

Type	Source and availability of data
Geology	Maps for entire Reservation
Soils	Maps for Roane County, maps overlain on aerial photos for Anderson County
Aspect	Contour maps
Slope	Composite slope class map
Forest inventory	31 of 35 forest inventory compartment maps completed
Land use (road systems, rights-of-way, plant boundaries, borrow areas etc.)	Map of current land use to be prepared 1981
Streams	Maps to be prepared in FY 81
Land-use history	Maps of planting, cutting, fire, etc., to be prepared in FY 81

managers. The use of IMGRID (Information Management on a Grid Cell System, a computer system provided to us by TVA) will provide a convenient system for division staff to search for research sites and input sites being used and to summarize salable timber from sites to be converted to other forest types, seral stages, or uses.

Specifically, the IMGRID system can be used in a variety of applications ranging from simple data storage and retrieval to complex systems modeling. These uses include:

1. Data storage and retrieval—The IMGRID system can be used to store and rapidly retrieve large amounts of geographically referenced data as well as used to identify what, where, and how much of a certain condition, item, or set of circumstances exists in map or tabular form.

2. Data interpretations—Information needs often require interpretations from data in addition to their basic storage and retrieval. The IMGRID system enables data to be directly interpreted to identify specific conditions and attributes. For example, site index, depth to bedrock, and permeability interpretations can be derived from stored soil mapping unit data.

3. Single factor modeling—As a tool to aid decision makers, the IMGRID system can be used to rapidly, clearly, and accurately develop and evaluate alternative actions. This process is accomplished through single factor models or systems models. Data are manipulated to identify areas capable of supporting specific uses or to predict the occurrence of natural conditions.

In the modeling effort, data from several sources are combined. For example, proximity to water and vegetation cover may be combined with road accessibility to produce a wildlife research area model. These models can also be used to develop and evaluate alternatives through comparison of results derived from changes in model criteria. A research siting model may evaluate and rate an area's suitability for research by weighting the required characteristics of the site. Sites initially identified as most suitable may then be compared to alternative sites derived by varying the relative importance of characteristics initially chosen.

This analysis system should also be of interest to Oak Ridge Operations and the "master planners" for locating sites for facilities. Necessary data such as geology, slope, soil types, roads, and other land-use features will be included. In addition to providing objective data for siting, comparisons of site alternatives can be made rapidly with data listings and line printer maps.

Our efforts have been to determine what data bases are currently available, which can be easily obtained, and how these can be utilized in IMGRID. Data coded at this time include soils, geologic strata, and aspect and will be expanded to include slope classes, perennial and wet weather streams, roads, land use, fire and cutting history, and land use prior to land acquisition. Forest inventory data will be included by species and size classes as well as by volume, basal area, and hardwood and softwood composition. Data are being coded on 0.5-ha grid cells for the entire Reservation. This cell size was chosen as being most compatible with the current forest inventory data and will allow reasonably accurate models of site characteristics of sites as small as 5 ha.

Once the data bases are completed we will allocate silvicultural activities to achieve a maximum spatial and temporal diversity of vegetation typical of southern Appalachian Ridge and Valley system on the Reservation. Attempts will also be made to maximize aquatic system diversity. It is important that habitat diversity be developed at federal sites like the ORNL Reservation. Very few university or private sites have the land resource base, interest, and expertise to develop and manage field research of this magnitude.

PART I. ENVIRONMENTAL SCIENCES DIVISION PROGRAMS

1. ADVANCED FOSSIL ENERGY PROGRAM

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Introduction

The United States continues to strive for energy independence with coal and oil shale expected to provide future liquid fuel and petrochemical feedstocks. Emphasis in technology continues to center on construction and operation of large-scale demonstration facilities. Enactment of the Energy Mobilization Act has led to rapid proliferation in type and number of, and location for, demonstration facilities.

The objective and major goals of the program remain relatively unchanged. They are (1) to determine the form, source, and potential concentrations of trace contaminants to man and other components of the biosphere from environmental release of coal conversion materials; (2) to develop a data base for assessing effects of coal conversion technologies on biological populations, communities, and ecosystems; (3) to develop effects data bases which contain information useful for setting standards for acceptable release of currently nonregulated pollutants generated by coal conversion processes; (4) to provide process engineers and control technologists

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[4]University of Tennessee, Knoxville.
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[7]Atmospheric Turbulence Diffusion Laboratory, National Oceanic and Atmospheric Administration.
[8]University of Minnesota, St. Paul.
[9]Virginia Polytechnic Institute and State University, Blacksburg.
[10]North Carolina State University, Raleigh.

with timely data on the potential hazards of effluents, products, and their constituents; and (5) to develop environmental assessments for coal conversion technologies based on information obtained from previous objectives.

Environmental research efforts continue to shift toward larger-scale laboratory and field investigations in spite of unavailable facilities and uncertainty surrounding specific technology development. A major thrust of our research effort now focuses on the potential impacts of oil spills. A series of ponds (20 m^3) have been constructed and are being used to investigate system effects (and resiliency) resulting from a syncrude oil spill. Similar efforts are planned for terrestrial systems.

Investigation of the potential environmental effects of coal liquefaction continued with the development of plans for the sampling and ecological testing of materials from the newly constructed H-Coal Pilot Plant at Catlettsburg, Kentucky. During the next two years, samples of solid wastes, wastewaters, and liquid products will be collected from each of a series of pilot plant process runs using various types of coal and operating modes. The materials will be tested for possible adverse impacts on aquatic and terrestrial ecosystems. An environmental assessment of the H-Coal process will be prepared at the completion of this project.

Terrestrial and Atmospheric Research

The goal of research in this area continues to be to identify potential environmental problems associated with coal liquids technologies development. Data derived from this research will serve as feedback to design engineers and environmental control technologists to permit early identification of potential problems related to air quality or terrestrial ecosystems in advance of commercial-scale technology deployment. This type of research is increasingly serving as a valuable base from which to compare alternative technology options.

The operation of liquefaction facilities is expected to have, as a consequence of storage and transport of liquid product, a potential for rather dispersed contamination of soils and terrestrial ecosystems. This section highlights studies of the potential fate and effects of such spills in the terrestrial environment.

Other environmental issues expected to play an important role in the acceptability of a coal liquids industry are those of solid waste disposal and air quality. Also highlighted in this report are recent research results on the microbial oxidation of sulfur from landfilled solid wastes, phytotoxicity of aqueous extracts of solid wastes, uptake of soil-borne PAH contaminants by plants, and comparative phytotoxicity of five sulfur gas species potentially released to the ambient environment by coal liquids technologies.

Insect Embryotoxicity and Teratogenicity of a Chemically Fractionated Shale Oil, Petroleum Crude Oil, and Coal Liquefaction Product

Experimental evidence from a number of laboratories suggests that accidental spills of shale oil and coal liquids could pose greater environmental hazards than the petroleum products they replace. Comparative toxicity studies in our laboratory indicated that coal liquids are generally more toxic than shale oil and petroleum to eggs of a terrestrial insect, *Acheta domesticus* (L.). In addition, a number of whole oils derived from coal were teratogenic to the insects. Chemical class fractionation of three oils, followed by biological assay of each fraction, was undertaken in a first attempt to isolate the toxic components and the teratogenic compounds in the oils.

A petroleum crude oil, a coal-derived liquid, and a crude shale oil were obtained from the EPA DOE Fossil Fuels Research Materials Facility (Comparative Research Materials 1, 2, and 3) for fractionation. Solvent partitioning and liquid column chromatography were employed to obtain saturates, mono- and diaromatics, polyaromatics, ether-soluble acids, ether-soluble bases, and an insoluble residue. The percent weigh contribution of each fraction to the whole oil was determined, and each fraction was assayed for insect embryotoxicity and teratogenicity.

The ether-soluble bases were the most toxic component of all three fuels. This fraction constituted 0.2, 5.1, and 7.2% by weight, respectively, of the petroleum crude, the coal liquid, and the shale oil and was the only teratogenic fraction. However, ether-soluble bases isolated from crude petroleum were not teratogenic.

The mono- and diaromatic fraction and the polyaromatic fraction from the coal liquid were also highly toxic; however, these fractions from the shale oil were only moderately toxic, while those obtained from the petroleum crude were practically nontoxic. The aromatic fractions differed quantitatively as well as qualitatively among the fuels. Mono-, di-, and polyaromatics comprised 70% by weight of the coal liquid, 41% of the shale oil, and 23% of the petroleum crude. Further separation of the embryotoxic and teratogenic fraction is under way for analysis by infrared spectroscopy and combined gas chromatography/mass spectrometry to identify specific chemicals with the greatest embryotoxic and teratogenic activity.

In this study, crude synthetic fuels were found to be more toxic than crude petroleum because of the relatively higher concentration and potency of the ether soluble bases and aromatics present in the coal and shale oils. If this generalization proves to be true for other species of organisms, preventive measures to reduce the likelihood of synthetic fuel spills or to reduce the content of ether soluble bases and aromatics prior to transport should be considered.

Decomposition of Coal Liquefaction Product Spills by Soil Microflora

Because the production, storage, and transport of coal liquefaction products will predominantly occur on land, accidental spills of these materials will likely contaminate terrestrial ecosystems. Microbial decomposition of the organic compounds in spilled oils is one of the most important potential fates of these contaminants in soils because this process most often leads to detoxification and even complete mineralization of potentially hazardous chemicals. The purpose of this project is to determine factors that affect the rate and extent of microbially mediated decomposition of synthetic oils spilled onto terrestrial ecosystems.

Because of the inherent complexities of soil ecosystems, the approach involves three experimental systems: (1) initial laboratory studies done with soil suspensions, (2) greenhouse studies done with soil microcosms, and (3) field studies done with plots of land and/or soil contained in large metal cylinders.

In a comparative study of the degradation of three different oils obtained from the ORNL/EPA sample repository, petroleum crude A, shale oil A, and coal oil A were added to suspensions of an Etowah silt loam (collected from the ORNL reservation) in a mineral salts solution. Temporal changes in the numbers of oil-degrading microorganisms and the amounts of residual oil in the soil suspensions were measured. After an incubation period of three months, enumeration results indicated that the addition of shale oil or petroleum crude caused a 10-fold or 11-fold increase, respectively, in shale oil degrading or petroleum degrading microorganisms. But levels of coal oil degrading microorganisms were undetectable both at the start ($<3 \times 10^2$ organisms per milliliter of soil suspension) and three months later ($<3 \times 10^0$ organisms per milliliter). The residual oil in the soil suspensions after one month of incubation was extracted, and the analytical results indicated that none of the oils had undergone significant degradation. However, extraction and recovery of the added oils were very poor because of the loss of volatile components during evaporative removal of the extraction solvent.

A unique opportunity to acquire soil contaminated with an actual accidental spill of a coal liquefaction product was offered in June 1980, and a trip was made to collect control and contaminated soils from the spill area. Because the spill was more than six months old at the time of collection, it was hoped that, unlike the Etowah silt loam, an active coal oil degrading microbial community had had time to develop in this soil. Because this material is unique, it is also being made available to other researchers in the Advanced Fossil Energy Program. Experimental results using this soil are not yet available.

Sulfur Oxidation in Coal Conversion Wastes

A commercial coal gasifier is expected to produce approximately 2.7×10^6 kg (3000 tons) of solid wastes per day. The dominant wastes, mixtures of slag and ash, will contain 0.3 to 4.0% inorganic reduced sulfur which may eventually be oxidized to sulfuric acid during landfill disposal and storage. This sulfuric acid may cause environmental problems directly by contaminating ground and/or surface waters and indirectly by enhancing weathering and the release of toxic heavy metals. The purpose of this research was to determine the potential for microbial (and chemical) oxidation of reduced sulfur contained in coal gasifier solid wastes.

The solid wastes that were included in this study were (1) a gasifier slag, containing ~4% sulfur, that had been shown to release sulfate when continuously leached with distilled water; (2) unleached slag/ash mixtures from five coal gasifier processes that contained 0.3 to 4.0% sulfur; and (3) three coal gasifier slag/ash mixtures that had been inoculated either with soil from their respective proposed landfill sites or with a coal gasifier waste that had demonstrated the biological production of sulfate in a previous experiment.

Coal gasifier slag/ash waste that had released sulfates in the column leaching study was found to contain 1.3×10^7 sulfur-oxidizing bacteria per gram. The combined rate of microbial and chemical oxidation in batch suspensions of this waste was nearly double the rate of chemical oxidation alone in sterile control suspensions. The addition of thiosulfate to batch suspensions resulted in a sixfold increase in sulfate production in unsterilized wastes, indicating that the sulfur-oxidizing bacteria were limited by the availability of reduced sulfur in the wastes. The levels of sulfur-oxidizing bacteria in five solid wastes were undetectable ($<3 \times 10^3$ organisms per gram of waste). Combined rates of sulfur oxidation in unsterile suspensions ranged from 1.2 to 4.4 times the corresponding chemical rate of oxidation in sterile controls. Biological sulfur oxidation was lowest in waste which contained 0.4% sulfur and highest in wastes with 4.0 and 1.7% sulfur. Inoculation of wastes with landfill soils ($<3 \times 10^3$ sulfur-oxidizing bacteria per gram of soil) or with a microbially active sample of waste (9×10^3 to 9×10^4 sulfur oxidizers per gram of waste) had no effect on rates of biological sulfur oxidation in these wastes.

For coal-gasified slags and ashes that contain reduced forms of inorganic sulfur, the potential exists for microbial and chemical oxidation to sulfuric acid, which, if not recognized, may mobilize toxic metal ions in the waste. The transformation of reduced sulfur appears to be dependent on the initial sulfur content of the wastes, which implies that coal gasification processes that produce low-sulfur solid wastes should be encouraged. The low rates of biological sulfur oxidation in some wastes may be due to an inadequate microbial inoculum, and this possibility is being examined further.

Phytotoxicity Tests of Coal Wastes and SCR II Oil-Contaminated Soil

The U.S. Resource Conservation and Recovery Act (RCRA) was enacted to provide control of hazardous wastes from their origin to their final destination. One characteristic of a hazardous waste is toxicity to organisms. A number of simple test systems were developed for EPA here at ORNL for testing the potential toxicity of solid waste to both aquatic and terrestrial organisms. We have extended the use of these test systems to the identification of (1) potentially hazardous waste from coal gasification and liquefaction facilities and (2) potentially toxic water and soil that may have been contaminated with synthetic fuel oils. The following describes results from acute toxicity tests using radish and sorghum plants.

Water extracts of two samples of bottom ash and one sample of cyclone char collected from the University of Minnesota-Duluth (UMD) gasifier did not inhibit root growth in radish and sorghum grown for 48 and 72 h, respectively. One bottom ash did inhibit radish root growth but not at tenfold dilution of the extract. Acetic acid extracts of one of the bottom ash samples caused root growth inhibition in both sorghum and radish even at a tenfold dilution. Previous experiments would indicate that the inhibition was due to the acetic acid and not to the bottom ash. A sulfuric acid extract of the same bottom ash had no effects on radish and sorghum root growth.

These results illustrate the importance of using extraction techniques which simulate "real-world" leaching situations for tests on biological systems. Specifically, if the real-world situation dictates the use of an acid extractant, let us be sure the extractant in the concentrations used does not in itself directly affect the organisms used in the test.

A water extract of H-Coal vacuum still bottoms did not inhibit root growth in either plant species. A water extract of soil contaminated with SRC II oil reduced radish root growth at a 1% concentration but inhibited sorghum root growth only at a 100% concentration.

Uptake, Translocation, and Metabolism of PAH by Plants

The fate of PAH compounds (some of them carcinogenic and/or mutagenic) released during the burning of fossil fuels requires careful study. One portion of PAH food chain pa ways which has not been adequately studied to date is the uptake of PAHs by terrestrial plants. A confounding problem with such studies is that plants apparently synthesize their own PAHs, using them in as yet unknown ways but possibly as plant growth regulators. As a result, PAH compounds are found in low concentrations in all terrestrial environments. However, PAH concentrations have been found to be significantly higher in soil near industrial centers than in rural areas. Therefore, we must determine whether plants can assimilate these additional amounts of PAHs from their environment, thus serving as a link in the food chain to man

Studies on the uptake of ^{14}C-anthracene were continued this year. Last year's studies (Auerbach et al. 1980) showed that soybeans grown in nutrient solutions containing anthracene took up, translocated, and metabolized some of the anthracene. This year's studies were undertaken to determine the effects on uptake of varying the anthracene concentration in the plant's root environment and also to determine whether uptake of anthracene will occur in plants growing in soil. Plants grown for four days in nutrient solutions containing 0.0036, 0.005, and 0.0117 μg/mL of $^{9-14}$C anthracene assimilated 69.3, 52.6, and 75.9% of the ^{14}C activity available to them, respectively (Table 1.1). Most of the ^{14}C activity was in the roots, though significant amounts were found in the stems and leaves.

Increasing the anthracene concentration in the nutrient solutions by a factor of 1.4 did not result in an increase in ^{14}C activity in the tot plant, but the activity in the roots more than doubled (Table 1.2). Increasing the concentration by a factor of 3.3 resulted in about a fourfold increase in ^{14}C activity in the roots and seven- and fivefold increases in the stems and leaves, respectively.

Table 1.1. Comparison of the distribution of ^{14}C activity (%) in soybean plants grown for four days in nutrient solutions containing different concentrations of $^{9-14}$C anthracene

Concentrations were 0.0036, 0.005, and 0.0117 μg/mL in cultures 1, 2, and 3, respectively; values are mean percentages of total ^{14}C activity.

Component	Cultures 1	2	3
Roots	64.8	46.2	68.5
Stems	3.2	2.9	5.8
Leaves	1.3	9.5	1.6
Total plant	69.3	52.6	75.9
Nutrient solution	16.2	28.1	12.1
Volatilized	1.2	1.8	4.2
Unaccounted for	13.3	17.5	7.8

Table 1.2. Effects of varying anthracene concentration on anthracene uptake and translocation in soybean plants grown in nutrient cultures

Values given are ^{14}C activity ratios of a high-concentration treatment (culture 3) and a medium-concentration treatment (culture 2) to a lower-concentration treatment (culture 1); concentrations in nutrient solutions at T_0 were 0.0036, 0.005, and 0.0117 μg/mL in cultures 1, 2, and 3, respectively.

Component	Ratio of ^{14}C activity	
	Cultures 2 vs 1	Cultures 3 vs 1
Nutrient solution (T_0)[a]	1.39	3.27
Roots (T_4)[b]	2.14	3.99
Stems (T_4)	1.13	7.04
Leaves (T_4)	0.94	4.90
Total plants (T_4)	0.93	4.13

[a]Ratios of concentrations of anthracene present in the solution when plants were added to flasks.
[b]T_4 = 4 days after plants were added to flasks; ratios are on a per-plant basis

Our previous research showed that only a portion of the ^{14}C activity detected in the plant tissues was anthracene; the rest was apparently products of anthracene metabolism by the plants. We are now using an improved extraction technique in order to look more carefully at the potential for plant metabolism of anthracene.

The studies on uptake from soil are incomplete. However, results to date indicate that soybean plants did assimilate ^{14}C compounds from both flooded and moderately moist silt loam soils that were tagged with ^{14}C anthracene.

Comparative Toxicity and Uptake of Sulfur Gases

The ambient pollutant dose to which a plant is exposed is not a direct quantitative measure of the dose that causes a physiological response (i.e., effective dose). The latter is a function of the rate that pollutant molecules arrive at sensitive metabolic sites within the leaf interior. This rate varies substantially with exposure environments and plant species. Thus, only a fraction of pollutant molecules in ambient air react with foliage, and even less are absorbed into the leaf interior. It is proposed that pollutant flux to foliage (micrograms of pollutant per square centimeter of foliage per hour) is a more accurate measure of the dose to which plants respond. The importance of discriminating between ambient and effective dose is shown in Fig. 1.1. In the Air Pollution Effects Research Facility, bean plants (*Phaseolus vulgaris* L.) were exposed to an equivalent atmospheric concentration (500 μg/m^3) of five different sulfur-containing gases that are common effluents from coal conversion technologies. The gases were sulfur dioxide, carbonyl sulfide, carbon disulfide, methyl mercaptan, and hydrogen sulfide. The amount of each pollutant reacting with foliage is recorded as total leaf flux of sulfur. Among gases, sulfur flux varied threefold, from 0.10 to 0.30 μg cm^{-2} h^{-1}. Thus, gases react with vegetation at different rates, so that equivalent atmospheric levels do not result in equal sulfur deposition rates on vegetation. The positive correlation between flux and pollutant solubility in water may be a good criterion for estimating relative deposition rates for unanticipated waste sulfur gases. The issue of ambient versus effective dose has implications for both applied and basic research efforts. For example, it is relevant to establishing acute and chronic rankings of phytotoxicity since effective pollutant dose differs markedly among gases even though

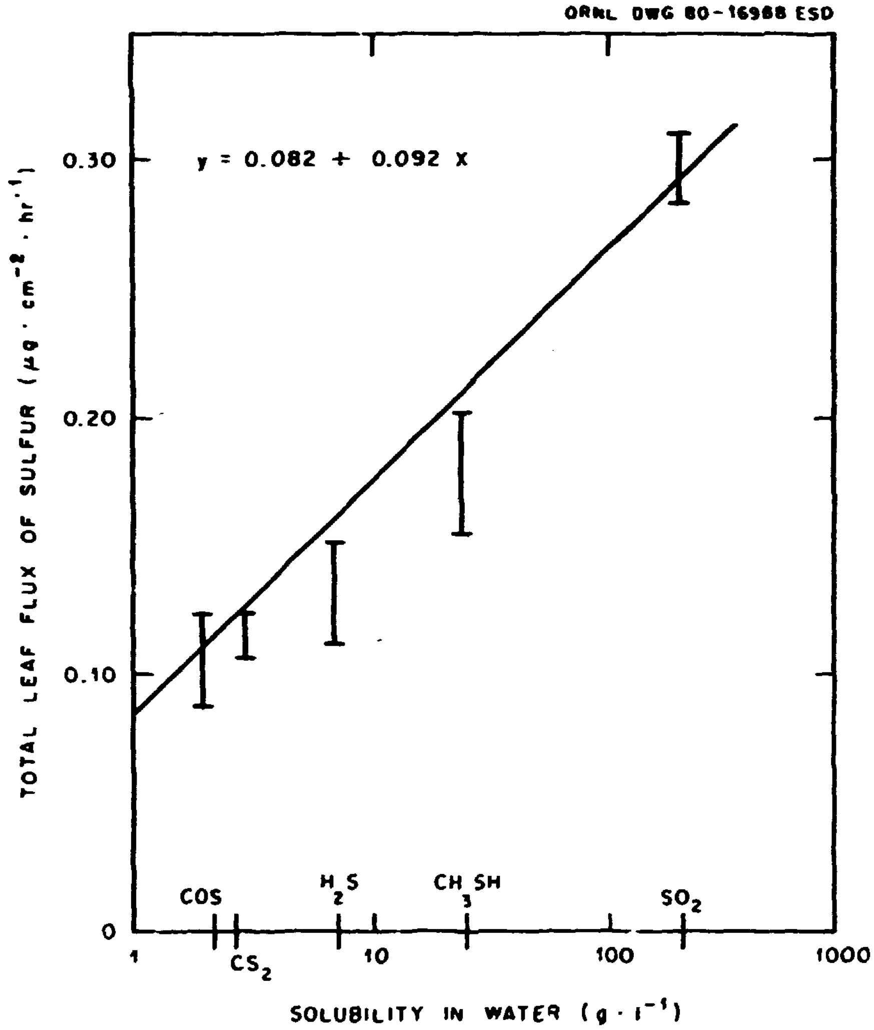

Fig. 1.1. Flux of sulfur to foliage of *Phaseolus vulgaris* exposed to different coal conversion gases at an ambient concentration of 500 μ/m³. COS = carbonyl sulfide, CS_2 = carbon disulfide, H_2S = hydrogen sulfide, CH_3SH = methyl mercaptan, and SO_2 = sulfur dioxide.

ambient dose is equivalent. As for more basic concerns, such as physiochemical mechanism of injury, it it important to assess effective pollutant dose so that model experimental systems can be more effectively designed to represent field conditions.

Aquatic Effects Research

Operation of coal conversion plants located on rivers and streams can result in intentional or accidental release of effluents and products into these waters. It is necessary, therefore, to know the effects these materials may have on aquatic organisms and also whether treatment of the wastes can ameliorate or eliminate the toxicity. The purpose of this research is (1) to determine the lethal and sublethal effects on aquatic organisms of materials from different coal conversion technologies, i.e., comparative toxicology involving effects of different technologies, effects on different organisms, and effects on different ecological organizational levels (individuals, populations, ecosystems); (2) to determine the effects of treatment of the above materials on their toxicity to aquatic life; and (3) to develop a battery of short-term toxicity tests that can be used to predict concentrations of these materials that will have no observable effects on aquatic ecosystems.

Algal Toxicity Tests

Results of tests with *Selenastrum capricornutum* (a green alga) and *Microcystis aeruginosa* (a blue-green alga) revealed that the water-soluble fractions (WSFs) of coal liquefaction products are significantly more toxic than WSFs of petroleum products. As a first step toward identifying the principal toxic constituents of synfuel WSFs, bioassays were conducted on the ether-soluble acid, ether-soluble base, and neutral subfractions of WSFs from five H-Coal products and one petroleum-derived diesel fuel. Each subfraction was tested at 10% of its concentration in the original WSF. Photosynthetic inhibition of the two test species was most severe during exposure to the ether-soluble bases; the neutral subfractions were the least toxic, except in the case of petroleum diesel oil. Ether-soluble bases of coal-derived oils are mainly primary amines and azaarenes; primary amines have been found to be particularly toxic to these two algae. Removal of nitrogen compounds from these oils by hydrotreating (the first step in upgrading and refining) would be expected to reduce the oils' toxicity to algae. Research is under way to determine how the chemistry of WSFs, and their toxicity to aquatic organisms, changes as the oils "weather" under natural conditions.

Daphnia magna Toxicity Tests

Water-soluble fractions of five products from the H-Coal process were tested for acute and chronic toxicity to *D. magna*. They were prepared by adding one part of product to eight parts of distilled water, stirring gently for 16 h in the dark, and separating and filtering the aqueous phase. The extracts were also separated into acid, base, and neutral fractions. Each fraction and a reconstituted extract, which was prepared from the fractions, were tested for acute toxicity to *D. magna*. The results of the acute toxicity tests are presented in Tables 1.3 and 1.4. They are expressed as the percent concentration of the water extract or of the acids, bases, or neutral fraction

Table 1.3. Acute and chronic toxicity to *Daphnia magna* of water-soluble fractions (WSFs) of the five H-Coal products and petroleum No. 2 fuel oil

Product	Toxicity of WSF	
	Acute (LC50)[a]	Chronic (NOEC)[b]
Atmospheric still bottoms (syncrude mode) No. 1309	4.64 (3.92 5.69)	0.29
Vacuum still overhead (syncrude mode) No. 1310	2.49 (1.08 4.98)	0.46
Atmospheric still overhead (fuel oil mode) No. 1312	0.24 (0.16 0.36)	0.0078
Atmospheric still bottoms (fuel oil mode) No. 1313	1.04 (0.80 1.26)	0.125
Vacuum still overhead (fuel oil mode) No. 1314	2.46 (1.20 3.95)	(not tested)

[a]Percent concentration (95% fiducial limits) of the water extract estimated to have killed 50% of the test animals in 48 h.

[b]Highest concentration (%) at which no significant effects on reproduction ($P = 0.05$) were observed.

Table 1.4. Acute toxicity to *Daphnia magna* of acid, base, and neutral fractions of water extracts of five H-Coal products

Fraction	Acute toxicity[a]
Atmospheric still bottoms (syncrude mode) No. 1309	
Acids	12.8 (11.2–14.7)
Bases	5.48 (4.56–6.64)
Neutrals	9.20 (6.96–14.08)
Vacuum still overhead (syncrude mode) No. 1310	
Acids	22.8 (20.4–26.8)
Bases	11.2 (9.6–13.6)
Neutrals	14.0 (12.4–15.9)
Atmospheric still overhead (fuel oil mode) No. 1312	
Acids	0.96 (0.84–1.12)
Bases	0.36 (0.06–0.56)
Neutrals	5.40 (4.88–6.00)
Atmospheric still bottoms (fuel oil mode) No. 1313	
Acids	3.92 (3.60–4.32)
Bases	8.28 (2.92–26.80)
Neutrals	4.16 (3.16–5.00)
Vacuum still overhead (fuel oil mode) No. 1314	
Acids	5.24 (4.52–6.16)
Bases	7.68 (6.48–9.24)
Neutrals	1.24 (0.64–2.4)

[a]Percent of the fractionated material from 1 L of water extract that, when dissolved in 1 L of dilution water, was estimated to have killed 50% of the test animals in 48 h.

of the extract that was estimated to have killed 50% of the test animals in 48 h. Four of the water extracts (Nos. 1309, 1310, 1313, and 1314) had 48-h LC50 values that differed by less than a factor of 5 (1.04 to 4.64%), but the fifth extract (No. 1312) was considerably more toxic (48-h LC50 of 0.24%) than the others. For comparison, the 48-h LC50 for *D. magna* and a water extract of a No. 2 diesel fuel oil was estimated to be 6.0%. The base fractions were the most toxic of the three fractions for three of the five water extracts (Nos. 1312, 1309, and 1310). The neutral fraction was the most toxic for extract 1314, while the acid fraction had the highest toxicity for extract 1313.

For all five extracts, the 48-h LC50 values of the reconstituted water extracts were not significantly different from those of the original water extracts. These results confirm some of our previously published data, namely, that our fractionation process does not have a significant effect on the toxicity of the individual fractions. These data also demonstrate that the fractionation process is valuable for identifying the toxic components of water extracts of oils as well as wastewaters.

Chronic toxicity tests, which determined the effects of a 28-d exposure of the water extracts on *D. magna* reproduction, were done with four of the five H-Coal extracts and with a WSF of a No. 2 diesel fuel oil. By the three most sensitive toxicity criteria (number of broods, number of young, and the number of young per brood), the no-observed-effects concentrations (NOECs) for the water extracts were 0.125% for oil No. 1313, 0.0078% for oil No. 1312, 0.46% for oil No. 1310, and 0.29% for oil No. 1309 (Table 1.3). For No. 2 diesel fuel oil, it was

10%. The corresponding application factors (NOEC ÷ 48-h LC50) are 0.12, 0.0325, 0.185, and 0.063, respectively, for the four H-Coal extracts and 0.33 for No. 2 diesel fuel oil. These results indicate that the relationship expressed as the application factor between acute and chronic toxicity is not identical for different water extracts of synthetic oils as it is for other related chemicals. Thus, the use of a single application factor for coal liquids is questionable.

We initiated a study to evaluate the effect of several wastewater treatments on the toxicity of a coal gasification wastewater—a process water from a Holston Ordnance Plant gasifier. The four treatments to be evaluated were steam stripping, an activated sludge bioreactor, ozonation, and charcoal adsorption; however, sufficient wastewater was not available to test the ozonation step alone. The treatments were used in a sequential series. In addition, tars which precipitated out of the raw process water were leached with distilled water and the resulting leachates were tested for toxicity. Each sequential treatment step significantly reduced the toxicity of the wastewater. The wastewater resulting from the final treatment, charcoal adsorption, had a 48-h LC50 of 30.4% compared with 0.22% for the untreated raw process wastewater. The extracts from the tar had relatively low toxicities compared with the treated wastewaters.

The acute toxicities of solid waste leachates from seven coal conversion processes were determined. The leachates were laboratory derived by extraction with distilled water, according to a procedure similar to the one developed by the U.S. Environmental Protection Agency, which uses acetic acid as the extraction medium. The extract concentrations that killed 50% of the *D. magna* in 48 h ranged from 9 to 100% (i.e., undiluted). Generally, these synthetic fuel leachates were about as toxic as those from conventional power plants but less toxic than industrial waste leachates. Subsamples of one synthetic fuel leachate were also extracted with both acetic acid and sulfuric acid. It was tested for acute toxicity to *D. magna* and also in a 21-d chronic toxicity test for effects on *D. magna* reproduction. In the acute toxicity tests, the sulfuric acid and water extracts showed little or no toxicity and the acetic acid extract was slightly toxic. In the chronic toxicity test, the water and acetic acid extracts did not significantly affect *D. magna* reproduction but the sulfuric acid extracts did. On the basis of these and results from other studies, which showed that acetic acid may be toxic to the test organism, distilled water is considered to be a more appropriate medium than acid for the extraction of toxicity test materials.

Midge Larvae Toxicity Tests

To add to the battery of aquatic bioassays, a method was developed for testing the toxicity of pure compounds and complex mixtures to fourth-instar larvae of the aquatic insect *Chironomus tentans* (Diptera:Chironomidae). Midges are widespread and important members of the benthos (bottom-dwelling community). The benthic community is significant in the processing of organic matter in aquatic ecosystems and as food for fish. Thus, a study of toxic effects on midges yields information on an important component of the food web. The test is a 48-h static bioassay, with glass wool added as a relatively inert substrate for the burrowing larvae. To validate the bioassay method and to provide comparative data for results with *D. magna*, fish, and algae, 48-h LC50 values were determined for the azaarenes acridine and quinoline and the phenols β-naphthol and phenol. The calculated values were acridine, 1.96 mg/L; quinoline, 57.2 mg/L, β-naphthol, 4.60 mg/L; and phenol, 106 mg/L. Generally the insects were more resistant to these compounds than algae, *D. magna*, rainbow trout embryos, and fathead minnows but were more sensitive than snails.

Snail Toxicity Tests

In this new test, the acute toxicity of six compounds, which are important components of most synthetic oils, were evaluated for acute toxicity to adults of the pond snail *Physa heterostropha* to provide comparative data for results with other test organisms. The testing of snails provides data on these often dominant grazers in lentic (standing-water) communities. The 48-h LC50 values for these chemicals were acridine, 11.1 mg/L;

naphthalene, 8.2 mg/L; phenanthrene, 2.1 mg/L; β-naphthol, 25.2 mg/L; quinoline, 183.1 mg/L; and phenol, 258.4 mg/L. Generally, the snails were the most resistant of the test organisms (algae, midges, *D. magna*, and fish).

Rainbow Trout Toxicity Tests

Embryo-larval tests were done with four of the six compounds tested with snails (see above). Based on median lethal concentrations, the order of decreasing toxicity was phenanthrene, β-naphthol, phenol, and acridine. Corresponding LC50 values were 0.04, 0.07, 0.15, and 0.32 mg/L and LC1 values were 14.6, 0.2, 1.1, and 58.1 μg/L. The debilitating effects of the four toxicants were not only limited to embryo-larval lethality but also included significant frequencies of teratogenesis. Anomalies observed in the trout exposed to the test compounds involved vertebral column defects and included lordosis, scoliosis, kyphosis, and rigid coiling. The embryonic stages of the trout were much more sensitive than early larvae to toxicant exposure. The embryo-larval stages of rainbow trout were the most sensitive of the test organisms to these single chemicals.

Bacterial Studies

Studies were conducted on the effects of coal conversion contaminants on microbial processes in freshwater sediments. Phenanthrene, a model polyaromatic hydrocarbon; a coal hydrogenation wastewater; and synthetic fuel oils were examined as potential environmental contaminants. A multivariate approach was used to examine the impact of these contaminants on the activity, biomass, and structure of microbial communities in both freshwater sediments and experimental microcosms. The objectives of these studies were to predict contaminant effects on components of the microbial community and to provide information for validating the use of aquatic microcosms in predicting contaminant effects in natural sediment environments.

Effects of Coal Conversion Materials on Microbial Communities

Methanogenesis in freshwater sediments was found to be relatively insensitive to environmental contamination. High concentrations of phenanthrene (100 ppm) and a waste effluent from a coal hydrogenation process (3%) demonstrated significant inhibition of methanogenesis 20 to 60%, respectively. Glucose mineralization was not effected by 100 ppm of phenanthrene, and no changes were observed in the standing crop of viable heterotrophic bacteria during long-term dosing conditions. As previously reported, alkaline phosphatase activity is marginally stimulated by low levels of phenanthrene (1 ppm). Results of preliminary studies indicate that nitrification can proceed in river sediments amended with H-Coal synthetic oil at concentrations up to 5.0%. Nitrification is not inhibited by phenanthrene up to concentrations of 100 ppm. Studies have been recently initiated to examine the effects of synthetic oil on respiration and heat output during metabolic activity by natural mixed microbial populations.

The results of microcosm studies demonstrated minor differences among the microbial populations and their activity in control microcosms and those treated with H-Coal product and No. 2 diesel fuel oil. Quantitatively, the microcosm microbial processes are similar in magnitude to those observed in Melton Hill Lake sediments. However, the data are insufficient to demonstrate conclusively that microcosms accurately simulate the environment from which they are drawn. For example, temporal and spatial variation remains to be examined for microcosm sediments.

Aquatic Transport

This year aquatic transport studies shifted in primary emphasis from determination of behavior of contaminants released in aqueous discharges (e.g., treated wastewater effluents) to examination of contaminants dissolving into underlying water from synthetic fuel product spillage. Objectives of initial studies have been (1) to identify major contaminant compounds which dissolve from synthetic fuel liquids and (2) to quantify rates of contaminant dissolution under controlled laboratory conditions. Additional studies initiated include investigation of effects of wind velocity and sunlight on contaminant dissolution. These laboratory studies will supply data for development of a model of contaminant dissolution from oil spills, which will be tested in a series of pond experiments planned to begin in the summer of 1981.

During the past year research on transport and transformation of polycyclic aromatic hydrocarbons (PAHs) was continued but at a lower priority. Studies on sorption of PAH to particles in surface waters and microbial transformations of PAH were completed and submitted for publication. Transport of nitrogen-containing PAH (azaarenes) was investigated with studies on bioaccumulation by fish, which paralleled previous PAH studies. Although major emphasis was shifted to synthetic fuel spills, continuing low-level efforts on (1) elucidation of the role of sediment in transport of PAH and azaarenes and (2) application of non-steady-state models to PAH and azaarenes transport through surface waters are planned for the coming year.

Dissolution of Contaminants from Synthetic Fuel Spills

Evaluation of petroleum industry statistics suggests that a high probability exists for some synthetic fuel spillage into surface waters when commercial facilities are operated. Tests in the Aquatic Effects Group have demonstrated high toxicity of some synthetic fuels (relative to petroleum) to aquatic organisms. Data on the rate of dissolution of toxic components and levels of toxicants which might occur in the event of a spill are necessary in order to assess adequately hazards of synfuel spillage. The objective of this work is therefore to quantitate rates of dissolution and levels of solubilized contaminants as a function of oil composition and river characteristics.

Mass transfer of contaminants across an oil-water interface can be expressed according to two-film theory in terms of mass transfer coefficients in oil (k_o) and in water (k_w) and the oil-water partition coefficient (P):

$$\text{Mass flux (units of contaminant mass/area time)} = \frac{k_o k_w}{k_w + k_o P}(C_o - PC_w)\,,$$

where C_o and C_w are contaminant concentrations in the oil and water, respectively. To apply the theory to study of dissolution of contaminants in synthetic fuel liquids, a glass cylinder (30 × 15.4 cm ID) was constructed and equipped with valved ports for sampling and covered with a glass plate. In use, oil is layered on water, which is agitated with a reciprocating magnetic stirrer, increases in contaminant concentrations are monitored in the underlying water over time until equilibrium is attained.

Tests of dissolution of 11 representative compounds ranging in solubility from catechol ($P = 0.0015$) to 1-methylnaphthalene ($P = 8000$) from a model oil demonstrated close agreement of measured and predicted dissolution rates. Studies were then continued with a series of five synthetic fuel liquids ranging from a heavy, viscous raw syncrude to a liquid distillate fraction; an aromatic petroleum crude was tested for comparison purposes. Oils were layered over water (1:140 v/v) in the laboratory extraction apparatus; water samples were collected over 48 h. Acidic, basic, and neutral components were isolated by solvent extraction and quantified by gas chromatography (GC). Compound identifications were confirmed by GC-mass spectrometry.

Assemblages of water-soluble contaminants from all five synthetic liquids were quite similar, although concentrations varied over an order of magnitude between oils. As anticipated, principal water-soluble contaminants are phenols and cresols, with lower levels of xylenols, and C3- and C4-substituted phenols; total concentrations of phenolics ranged from 50 to 250 mg/L after 48 h equilibration. Major neutral compounds are toluene, xylene, and naphthalene, which were detected at concentrations of 5 to 20 mg/L. Basic constituents are aniline and C1- to C3-substituted anilines, found at concentrations of 0.2 to 4 mg/L. No evidence for dissolution of multiring phenols (e.g., naphthol), alkylnaphthalenes, pyridines, or multiring anilines has been found.

although these compounds may be present at levels below analytical detection limits (approximately 0.1 mg/L). No phenols or bases (except for aniline) were detected in water underlying the petroleum crude tested. Rates of contaminant dissolution follow theoretical predictions, with phenol being most rapidly dissolved and less-water-soluble contaminants dissolving more slowly. Dissolution rates appear to be highly dependent upon oil viscosity: the time required to reach 50% dissolution of phenol varied from 6 min for a nonviscous refined synthetic distillate to more than 2 h for a highly viscous heavy distillate.

Preliminary studies were initiated this year to elucidate the effects of wind speed on dissolution of toxic contaminants from synthetic fuel liquids. To determine rates of evaporation of oil spill constituents, weight loss of oil films several millimeters thick from 30 × 30 cm glass plates were determined under differing wind speeds. Loss of individual constituents was measured by use of radiolabeled compounds. Under moderate wind velocities (several km/h) at 23°C, one raw syncrude lost 10% of initial weight within 6 h and 38% within 70 h. Complete loss of ^{14}C-benzene occurred within several minutes; phenol, naphthalene, and aniline volatilized with half-residence times of 6, 16, and 68 h, respectively. Tests will be continued with other oils under different conditions of wind speed, temperature, and film thickness. Initial results indicate that evaporation may reduce dissolution of monoaromatics into water underlying a synthetic oil spill but may have substantially less effect on dissolution of phenols, anilines, and diaromatics.

Initial work was also undertaken to examine effects of sunlight on formation of toxic water-soluble oxidants in synthetic fuel spills, as has been reported to occur for petroleum distillates (Larson et al. 1979) Films of four synthetic oils, a petroleum crude, and a petroleum-based No. 2 fuel oil were layered onto water (140:1 v/v water/oil) in a stirred 3.5-L extractor, and exposed under a quartz glass cover to midsummer sunlight. A water bath maintained the temperature of the oil and water at 24 to 28°C. Aliquots of underlying water were removed at intervals of up to 5 d; oxidant concentrations were determined by a modified amperometric titration. Oxidants were produced in water underlying two synthetic liquids at rates comparable to the petroleum-based No. 2 fuel oil, resulting in concentrations after five days of more than 500 mg/L (expressed as tetralin hydroperoxide). No oxidants were produced from irradiation of the petroleum crude. Although acidity of underlying water increased markedly compared with nonirradiated controls, GC scans of extracted phenols did not differ qualitatively or quantitatively from nonirradiated control extracts. Further studies are under way to characterize the oxidants produced during irradiation and to relate formation of oxidants to toxic effects of underlying water on aquatic organisms.

Solid Waste Research

Development of a synthetic fuel industry will result in copious quantities of solid waste. These wastes will result largely from the implementation of plans to produce liquid and gaseous products from coal and liquids from oil shale. The management of solid wastes from these technologies will have a significant influence on the environmental impact from each technology. Work at ORNL in the Advanced Fossil Energy Program is directed at assessing the environmental impact of disposing of solid wastes from the various coal conversion processes. The major component of the solid waste stream in coal conversion processes is the slag ash produced in coal gasification. Early work has revealed that coal gasification wastes would be considered nontoxic under the most recent (May 19, 1980) revision of the Resource Conservation and Recovery Act of 1976 (RCRA). However, this does not imply disposal of these wastes is free from adverse environmental impacts. To identify these possible adverse impacts, work has centered on the physicochemical character of the solid waste and relating these characteristics to what may occur under various disposal regimes. For instance, some of these wastes in column leaching experiments have effluent leachates which are very acidic (<pH 3) and contain concentrations of sulfate exceeding 10,000 mg/L.

Leaching Characteristics of a Gasification Slag

The chemistry of coal process wastes is being studied to provide guidelines for product treatment and/or identification of conditions whereby leaching of toxic components from landfills might be mitigated. Reported here are experiments on the leachability and chemical characteristics of a coal gasification slag based on sequential acid extractions.

The waste contained three morphologically different fractions: glasslike rods and glasslike shards (~42%), particle aggregates (~50%), and fines (5-μm particle diameter, ~8%). These fractions appeared to result from variations in conditions during gasification, although specific information was not available to make direct correlations with operating conditions. Each isolated fraction was subjected sequentially to an increasingly harsh series of leaching media: deionized water, dilute HNO_3 (pH ~ 1.2), a 1:1 mixture of H_2O, HCl, and HNO_3, and 50% HF. Each leachate was analyzed for Fe, Pb, Cd, Zn, Ni, As, Se, Mo, and Cr by standard graphite furnace atomic absorption methods.

The fines exhibited the highest concentration of leachable cationic trace elements on a per-gram basis in each extraction, followed by the aggregates and glass shards. Maximum concentration of leachable oxyanions varied considerably between different morphological fractions and acid leachates. However, the total concentration of each element was highest in the aggregate fraction except for Pb and Cd (higher in the fine fraction) and Cr (higher in glass shards). The shards contained the lowest levels of all other trace elements except Cd (40% lower in the aggregates). Considering the proportion of the total waste mass included in each fraction, the aggregates contributed the largest percentage of each element to the waste (ranging from 40 to 90%) except for Cr (glass shards contributed 80%) and Cd (~35% each was contributed by the fine and glass shard fractions).

These data allow estimation of the water and dilute acid solubility of these elements in each fraction and in the total waste for prediction of leachate concentrations following ground- or surface-water interactions. The range of these solubilities is determined from the ratios of water soluble (WS) or water plus dilute nitric acid soluble (DAS) concentrations to total (Σ) element concentrations [i.e., WS/Σ and (WS + DAS)/Σ]. The following is a summary of the calculated total concentration of each element in the unfractionated solid (μg/g) and the range in calculated solubilities (%), respectively: Fe (1.9×10^5 μg/g, 0.01–13% soluble), Cr (1.2×10^3 μg/g, <0.01–3%), Zn (530 μg/g, 0.7–1.7%), Ni (260 μg/g, 4–28%), Mo (77 μg/g, 0.06–0.3%), As (39 μg/g, 0.02–0.3%), Pb (16 μg/g, 0.2–5%), and Cd (0.6 μg/g, 28–56%). The Cd exhibits the highest solubility but is also present in the lowest concentration. Only Ni exhibits both a relatively high concentration and solubility. Under acidic conditions it is apparent that the leachate will be dominated by Fe, present initially as Fe^{2+} from the dissolution of iron sulfides.

The solubility experiments with the individual morphological fractions indicated higher solubilities for the aggregate and fine fractions, because of a particle-size effect. X-ray fluorescence (XRF), combined with scanning electron microscopy, indicated that the surfaces of glass shards were essentially small and free of particles. The primary constituents of the shards were Al, Si, Ca, and Fe distributed uniformly throughout an amorphous glass matrix. The aggregates and fines were agglomerations of smaller opaque particles consisting primarily of Al, Si, Fe, and Ca with smaller amounts of S, K, Ti, Pb, Cr, and Zn. This morphology may account for the more readily soluble trace elements from these fractions because of the inverse relationships between particle size and both trace element concentration and solubility in combustion ashes.

If these particle fractions result from known variations in gasification parameters, it may be possible to select against the aggregate fraction, which is more readily subject to trace element leaching, in favor of the glassy fraction as a relatively stable waste. This type of selective control in the gasification process, combined with pH/Eh controls at the disposal site (Auerbach et al. 1980), could potentially lead to disposal with minimum environmental risk.

Comparison of Solid Wastes from Coal Combustion and Coal Gasification

The electric utility industry is especially interested in coal-gasification-based generating systems. These combined cycle systems (gas turbine–generator/steam turbine–generator) appear to offer distinct environmental advantages over, and to be economically competitive with, conventional direct coal-fired plants with flue gas cleaning systems (Holt et al. 1980). The main environmental advantages of entrained flow gasifiers are purported to be the production of a dense inert slag and the absence of tar and other troublesome by-products. In addition, by-product sulfur can be produced in elemental form, which has greater potential for beneficial utilization and requires less space for storage and disposal than conventional flue gas desulfurization sludges.

Research sponsored by EPRI involves physical/chemical characterization of solid wastes and their leachates from the Combustion Engineering gasifier (entrained flow) and from a conventional coal-fired power plant (450-MW wet-bottom slagging boiler) firing the same feed coal (Pittsburgh seam). Comparative studies of solid wastes generated by two or more processes from the same coal feedstock offer the opportunity to evaluate the contribution of process to solid waste characteristics. For example, if it can be demonstrated that similar solid waste characteristics are produced regardless of whether a given coal is combusted or gasified, then available knowledge on the environmental behavior of combustion solid wastes can be validly used to determine the most environmentally appropriate disposal practices for gasification solid wastes.

Slag from the gasifier and bottom ash from the conventional plant are very similar in appearance and physical characteristics (glassy shards) and are reasonably similar in chemical composition. Calcium content (5.5%) of the combustion bottom ash was significantly higher than that (1.8%) of the gasifier slag, but the difference is consistent with the difference in calcium content of the respective feed coals which originated in different mines. Other smaller differences in waste composition were also attributable to differences in feed coal composition. However, both feed coals fell within the compositional range of Pittsburgh seam coal based on compositional data obtained from the National Coal Resources Data System.

Particulates collected from the flue (combustion fly ash) and product (gasification char) gases, respectively, are recycled (reinjected) at both the combustion plant and the gasifier and thus do not constitute solid waste streams. By-product elemental sulfur from gasification could potentially become a solid waste if adequate markets do not develop. Sulfur from the Combustion Engineering gasifier is impure (Table 1.5), containing carbon, residual Stretford chemicals (vanadium, sodium), and some volatile trace elements apparently sorbed

Table 1.5. Partial elemental analysis of sulfur by-product (Stretford Process) from Combustion Engineering gasifier; values given are mean ± standard deviation of analyses on four samples collected over a 30-h period

Sulfur, %	7.6 ± 4.6
Carbon, %	11.4 ± 0.9
Sodium, %	3.1 ± 0.4
Hydrogen, %	1.26 ± 0.12
Nitrogen, %	0.55 ± 0.02
Aluminum, %	0.19 ± 0.02
Iron, %	0.17 ± 0.02
Vanadium, ppm	726 ± 96
Arsenic, ppm	53 ± 8
Mercury, ppm	4.7
Selenium, ppm	4.8 ± 0.4
Antimony, ppm	5.1 ± 0.1

from the product gas stream. Many of these contaminants would probably not be present in sulfur produced at a commercial-scale plant. However, the contamination of elemental sulfur by arsenic, selenium, and mercury has been predicted on theoretical grounds by Anderson et al. (1979), who suggested that this contamination could render the product sulfur unfit for many industrial applications.

The combustion and gasification solid wastes have been submitted to a variety of leaching tests including the USEPA RCRA extraction procedure (Fed. Reg. 1980) and the ASTM distilled water extraction. Both the RCRA and ASTM results (Table I.6) suggest that the gasification slag is comparable to the combustion bottom ash in leaching behavior. Both wastes yielded low concentrations of nearly all the primary and secondary drinking water metals. Iron and nickel were higher in the gasification slag, with iron in the slag leachate exceeding U.S. Public Health Service crieria for drinking water. Based on these results, neither the bottom ash nor the slag would be classified as toxic under RCRA.

The aqueous extracts (Table I.6) of gasification sulfur sludge yielded some high (relative to drinking water standards) concentrations of As, Pb, Ag, Cr, Hg, Fe, Mn, and sulfate. Although none of these concentrations would result in a toxic classification under current RCRA regulations, they could present ground-water contamination problems if sulfur sludge of similar characteristics were disposed in landfills. The high concentration of mercury (45 µg/L) in the RCRA extract is especially notable because it is over 20 times the interim primary drinking water standard and represents about 20% of the mercury in the solid phase. The reason for the much lower extractability of mercury by the ASTM method is unknown but is under study.

The above results suggest that the primary solid waste (slag) generated by entrained flow gasifiers will be quite similar to bottom ash generated in conventional slagging boilers firing the same feedstock and will not present unexpected disposal problems. The relatively high concentration of most metals and sulfate in the RCRA and ASTM extracts of the sulfur sludge suggest the need for concern if (1) a sufficient market for recovered sulfur does not develop and this by-product is to be disposed of by landfilling or (2) residues (concentrated impurities) from sulfur sludge cleanup are disposed of by landfilling.

Table I.6. Results of RCRA and ASTM extractions of solid wastes generated by combustion or gasification of Pittsburgh seam coal

Values given are averages of duplicate extractions and analyses; sulfate is in mg/L and other constituents are in µg/L

	Combustion bottom ash		Gasification slag		Gasification sulfur sludge		Drinking water criteria[a]
	RCRA extract	ASTM extract	RCRA extract	ASTM extract	RCRA extract	ASTM extract	
As	9.0	0.5	0.2	0.07	152.0	400	50
Se	<0.05	<1	<0.5	5.0	1.8	<5	10
Ba	2.4	0.35	7.2	118.0	71.0	40	1000
Pb	0.14	<0.2	<0.2	0.2	62.0	150	50
Ag	<0.05	<0.1	<0.04	0.4	34.0	74	50
Cd	0.10	0.05	0.03	0.12	1.4	3.2	10
Cr	<0.1	1.9	0.19	0.43	20.0	685	50
Hg	0.003	<0.01	0.02	0.09	45.0	0.10	2
Zn	0.61	2.3	0.64	4.8	18.0	3,450	5000
Cu	0.74	0.55	0.59	6.3	17.0	530	1000
Fe	275.0	51.0	600.0	960.0	3.0	118,000	300
Mn	1.3	0.35	1.7	21.0	0.22	806	50
Ni	0.28	<0.5	153.0	1000.0	80.0	111	2000
SO_4	1.30	1.1	6.1	25.0	1210	6,050	250

[a] National Interim Primary Drinking Water Standard or U.S. Public Health Service Criteria.

Organic Characterization of Solid Wastes from Fossil Fuel Technologies

The solid waste produced by coal conversion processes in the form of various types of ash and slag is considerable. Solid wastes generated at proposed commercial coal conversion facilities are expected to exceed 6000 tons/d. Given the variety of potentially toxic organic chemicals in coal, the production of toxic compounds in combustion processes, and the fact that most coal conversion solid wastes have significant total carbon contents, the question arises as to what type of hazard, if any, may be presented by the organics present in the wastes. This investigation was initiated (1) to determine the forms and amounts of organics present in these wastes, (2) to determine the mobility of these compounds in aqueous systems, and (3) as necessary, to establish means of attenuating the movement of these compounds into surface- and ground-water systems.

Solid wastes selected for examination represent a variety of gasification processes and feed coals and also transitionally stored solids from two liquefaction/gasification processes. In the first phase these solids were exhaustively extracted (Soxhlet) with methylene chloride and the extracts duly analyzed for organic components. To provide direct evidence of the leachability of the organics, aqueous equilibrations (24 h) of these solids were conducted in systems buffered and unbuffered with regard to pH. Methylene chloride extracts of the water were made and the organics therein characterized.

The methylene chloride extracts from solids and waters were partitioned between cyclohexane and nitromethane to effect an aliphatic/aromatic separation. Identification and quantification were done by capillary GC-MS. The efficiency of the methylene chloride extraction of the solids was checked by measuring the recovery of ^{14}C-labeled benz(*a*)anthracene (13 ng/g) from each solid. The recoveries ranged from 2 to 100%.

In general, the transitionally stored solids (H-Coal vacuum bottoms and SRC-I mineral ash residue) were substantially higher in total carbon content (>40%) than were the gasification wastes (1 to 33%, median <10%). This was reflected in the extractability of organics from these solids by the methylene chloride. By and large, the gasification wastes were devoid of recoverable aromatics. The exceptions were samples from one process showing 1 to 2 μg/g of alkyl-substituted and unsubstituted three- and four-ring PAHs and another showing a few μg/g of alkyl-substituted naphthalenes. In contrast, for the stored solids the H-Coal vacuum bottoms and the SRC-I mineral ash residue (MAR) showed on the order of 120 and 760 μg/g, respectively, in total aromatics. The MAR extracts showed compounds having from two to four fused benzene rings, some of which were alkyl substituted. H-Coal vacuum bottom extracts showed a substantial component of four-ringed PAHs which constituted 30% of the total.

Although the aliphatics were measurable amounts in several of the gasification wastes, again the contrast with the stored solid was substantial. Thus, while the MAR showed an aliphatic content of ~1.3 mg/g, the gasification wastes showed a range of 0 to ~30 μg/g with several samples showing none. These aliphatics were predominantly in the C-11 to C-12 range, although a few were as low as C-8.

Preliminary indications from the aqueous equilibrations of the solids are that the MAR contains a substantial fraction of organics that are readily leachable. This is also true for the H-Coal vacuum bottoms but to a lesser extent.

Solid Waste Extractions for Biotesting

Work in ESD has shown that the extraction procedure (EP) for assessing the toxicity of a solid waste under RCRA is not satisfactory for biotesting protocols (Epler et al. 1980). The major limitation is that the acetic acid in the EP is not compatible with the biotesting protocols (phytotoxicity and aquatic toxicity tests using *Daphnia magna*). Thus, distilled water has been used to make solid waste extracts for biotesting as well as to detect potentially toxic elements or compounds in the solid waste. The extract concentrations of the eight elements listed in the National Interim Primary Drinking Water Regulations (Ag, As, Ba, Cd, Cr, Cu, Hg, and Se) have been extremely low (in μg/L) for many of the gasification wastes and are in most instances very close to the analytical detection limits for that element. For this reason, it is very difficult to assess the error directly associated with the extraction process. Data to date indicate that the major source of error in the water extractions of gasification wastes is the heterogeneity of the sample.

An Alternative to Landfill Disposal

The traditional method for disposing ash/slag from direct-fired combustion has been either ash ponds or landfills. Presently, landfill disposal is more desirable because of economic and environmental considerations. An alternative to landfill disposal is land application, which the USEPA has encouraged for sewage sludge. Some energy-related wastes, such as calcium-carbonate-rich fluidized bed combustion (FBC) wastes, appear to be applicable as a substitute for agricultural limestone. Leaching tests on coal gasification wastes at ORNL have indicated that very small quantities of toxic metals are leached from most of the wastes. One of the chemical compounds found to be most abundant in the water leaching studies of these gasification residuals is sulfate.

Sulfur is essential for plant growth, and certain soils in the Southeast are deficient in this element for maximum crop production. A greenhouse experiment using perennial rye grass as a test crop was conducted to assess (1) the plant availability of sulfur in three coal conversion solid wastes and (2) the plant uptake of toxic metals in these wastes. Supplemental data were taken relative to the phytotoxicity of direct seeding in the waste/soil mixtures, and an estimate was made of ground-water contamination (leachates collected from each pot).

Four harvests were conducted, and data showed significant reductions in yield at high waste/soil ratios. Plant yields were less with some solid wastes than others.

Environmetrics

Gasifier in Industry

The Environmental and Health Program for the University of Minnesota Gasification Facility outlines a program to provide data and perform assessments on the low-Btu gasification facility which will permit DOE and other federal agencies to judge potential impacts and the acceptability of this coal conversion technology. The three-year program entails on-line monitoring, sample collections, and laboratory experiments. The primary objective of this project is to develop and implement the data management requirements for researchers directly involved in the UMD program.

Additional objectives of this project are (1) to solicit the data management requirements of persons indirectly engaged in the UMD program and to implement, when feasible, these needs to enhance the assessment capabilities of the UMD program; (2) to establish the sample management facility and develop the archival procedures for the resulting data; and (3) to incorporate the ability to handle data from other gasifier sites within the data management system.

Data management has historically consisted of implementing computer programs for analyzing, summarizing, tabulating, and graphically displaying research data on a crisis basis. In this mode, a great deal of effort is expended over a short time to meet a project deadline. This mode is bearable when only a single researcher is to be accommodated. When more than one researcher or more than one project task requires programming, crisis data management is inefficient and, because of too little time for completely inspecting the results or for completely defining the programming needs, the research project tends to suffer. Experience gained in the U.S. International Biological Program and other research programs in the Environmental Sciences Divison has shown that crisis data management can be eliminated by changing the approach to data management to include working with researchers prior to and during the project to define data formats, codes, and output requirements. The definition of requirements for each task or project feeds into the development and implementation of computer programs for accomplishing the total data management needs of the research program. The need for management of the University of Minnesota Gasifier Program data and the diversity and volume of the data motivate the expenditures for this project in order that that UMD Environmental and Health Assessments can be performed in a timely and organized fashion.

The approach used in this project is to organize the research components that generate data pertaining to the UMD gasifier facility. Several components have been described as to kinds of data, formats, and identifiers. These components include (1) the on-line process data acquisition system, which was a PDP11 system on-site; (2) the environmental monitoring system, which uses cassette recorders on-site; (3) the process sampling scheme, which describes number, location, and volume of samples; and (4) the laboratory tests that perform ecological, biological, and chemical characterizations.

Other components which were organized include the test results relating environmental effects and fate of product (e.g., gas streams) or waste material (e.g., ash, tars) samples, the sample handling and tracking procedures that provide the status of the material samples, and the health effects research results on their UMD samples.

We succeeded in defining the data structure and internal format for the on-line computer acquisition and documented a system of programs for reading and handling the computerized (1) baseline meteorological and air quality and (2) process control measurements tapes from UMD and in tabulating the data, which are being gathered on-site at UMD. Also, data were solicited and received from several working groups in the gasifier program, including Analytical Chemistry (sample characterizations), Industrial Hygiene (carbon monoxide levels and work environment samples characterizations), and Environmental Sciences (solid waste characterizations and ecological effects of leachates and high-volume sample characterizations).

All these data have been formatted and tabulated and computer programs written to store, retrieve, manipulate, and graph the data in raw or summarized form.

Base Program

This activity concentrated on organizing the extant data on toxicity of aqueous effluents from synthetic fuel processes and their acid, base, and neutral fractions. With these data organized, formatted, and computerized, we were able to write computer programs for comparing data sets derived from different experiments. Summary programs were also developed for presenting the data in tables. These capabilities were important in summarizing the current body of information from these toxicity experiments. The initial standards for computer codes and research nomenclature were completed, and a summary of the ongoing research was implemented to allow the inventorying of current and future research in the program.

H-Coal Plan

The H-Coal environmental plan includes the ecological testing of the fate and effects of H-Coal products and wastes. The tests include the evaluation of H-Coal product oil in a algal microcosm, pond ecosystem, cricket, plankton, and seed germination studies. The data management project for the H-Coal program helped establish the experimental designs for these studies and the data formats for organizing and later storing the data from these studies.

Gasifier-in-Industry Project

This activity is a component of the larger site-specific Environmental and Health study being conducted for DOE at the University of Minnesota-Duluth (UMD) campus and the Pike County, Kentucky, gasifier sites. The purpose of these studies is to identify potential impacts arising in the vicinity of the two facilities from their operation. The project is a state-of-the-art assessment activity rather than a research study. Although the UMD facility is currently operating, it now appears that the Pike County project will be terminated. Consequently, the Pike County effort focused on completing the baseline characterization of the site.

University of Minnesota-Duluth Studies

Ambient air quality monitoring, performed under subcontract by Dr. Sagar Krupa of the University of Minnesota-St. Paul beginning in February 1979, continued throughout FY 80. Monitoring was conducted both during periods of gasifier operation and during shutdown periods. The use of two monitoring stations, located 800 m east and 600 m west of the gasifier, has allowed a preliminary analysis of the effects of gasifier emissions on ambient air quality. Combining data on gasifier operation, meteorological conditions, and measured air quality permitted a preliminary assessment that the gasifier did not measurably increase ambient levels of SO_2, NO_x, CO, O_3, hydrocarbons, and total suspended particulates (TSP). Samples of particulates are being analyzed for constituents (trace elements and organics) to determine if they might be attributed to the gasifier. A more detailed analysis of potential air quality effects will be possible with data from the 1980–81 UMD campus heating season. In addition to the above analyses, installation of Tenax traps will allow characterization of vapor-phase organic pollutants in the ambient air.

Solid wastes from two gasifier runs (November–December 1979 and February–March 1980) were collected and shipped to ORNL for chemical and toxicological characterization. Bottom ash from the former run and bottom ash and cyclone char from the latter run were subjected to two laboratory leaching procedures. The extraction procedure (EP) of the USEPA, an acetic acid technique used for determination of "hazardous" wastes as required by the Resource Conservation and Recovery Act (RCRA) of 1976, was used to produce leachates for chemical analysis. A distilled, deionized water technique was also used to produce leachates for chemical analyses and for toxicological testing in a battery of bioassays. The battery included (1) acute toxicity to the zooplankter *D. magna*, (2) inhibition of photosynthesis in the blue-green alga *Microcystis aeruginosa*, and (3) inhibition of radicle (root) elongation in radish and sorghum seedlings.

Chemical and toxicological testing indicate that the solid wastes would qualify as "nonhazardous" according to USEPA's current interpretation of RCRA. In many cases, full-strength (100%) distilled water leachates of the solids did not elicit a toxic response in the battery of tests. In the remaining cases, a toxic response was found only at near-full-strength concentration. When USEPA assumptions are incorporated to account for the likely dilution of leachates as they pass from disposal sites into ground and surface waters, the materials would appear nontoxic to terrestrial or aquatic biota, based on our bioassays. Trace element concentrations in distilled water and EP leachates of the solids did not exceed RCRA standards established by the USEPA for the designation of "hazardous" wastes. Furthermore, in most cases the trace element concentrations would not violate other critieria for ground and surface waters (drinking water, irrigation, livestock watering, and protection of aquatic biota) when assumed dilution is taken into account.

Pike County Studies

Samples of surface water at the site (Shelby Creek and a small tributary) were taken under subcontract by Pikeville College staff for analysis of water quality. Analysis by the college confirmed earlier reports of marginal water quality in the area, a result of regional coal mining and untreated sewage discharges. Organic and trace element analyses are under way for the water samples and for samples of fine sediments (silt/clay) from the streambeds.

During the planning of the air quality monitoring program, it became clear that state-of-the-art meteorological models were not sufficient to allow the optimal placement of monitoring equipment or to simulate the rough terrain of the site. Consequently, the staff of the National Oceanic and Atmospheric Administration's Atmospheric Turbulence and Diffusion Laboratory (ATDL) cooperated with ESD in characterizing air movements at the site. In September 1979, ATDL began operating meteorological equipment on-site (with the assistance of Pikeville College). Equipment located on-site includes two portable battery-operated meteorological stations to measure basic variables (wind direction and speed, temperature, and relative humidity) and an acoustic sounder to record air stability. The ATDL also conducted short-term studies (smoke-bomb releases, pibal and neutral-density balloon releases, and lapse-rate measurements) of air movements at the site.

Meteorological studies in FY 80 showed that the complex terrain of the site will have a major effect on pollutant dispersion. The surface air, which is decoupled from regional air flow, usually extends to ridge height, approximately 300 m above the site. At night, the air is typically calm with frequent fog and ground-based or elevated inversions. During the day, frequent convective air flow interacts with the terrain, producing mechanical turbulence. Mechanical turbulence was verified by the helical pattern and irregular direction of experimental smoke releases.

The potential for ground-level air pollution appears to be high. Terrain-induced flows can produce subsidence over the central portion of the site. Plume impactions with the surrounding terrain are expected during daytime, causing damage to vegetation. Also, plume material that contacts the terrain may lose its buoyancy and sink to lower elevations or be carried down by drainage currents. Although the effective plume height (approximately 100 m) is well below ridge height, the high frequency of weak winds may often allow the plume to extend above the ridge top. The combination of elevated inversions and fog (which cools the plume) suggests that at night the plume will often be contained within the site. Chemical interaction of plume materials with nightime moisture may be an additional problem. These tentative results suggest that any pollutants released at this site should be carefully monitored.

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2. NUCLEAR PROGRAM

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Introduction

Environmental Sciences Division research related to nuclear energy technologies considers the biotic and abiotic behavior of radioelements for which information is needed. In addition to biological accumulation and transport data, research under way also considers environmental chemistry evaluations of long-lived, man-made radioelements for which no geochemical history exists. Major emphasis is on the actinide elements (U, Th, Pu, Am, Cm, Np), Tc, activation products such as ^{95}Nb, and natural radionuclides that are components or analogs of isotopes in nuclear fuel cycles. Collectively, this research effort expands the data base and the understanding of potential impacts of radionuclide releases from nuclear fuel cycle operations. Research support is largely provided by the Department of Energy (DOE), Division of Ecological Research, with lesser funding from the Environmental Protection Agency (EPA) and DOE/Waste Management.

Substantial new information on the behavior of Tc under field conditions was obtained. For ^{99}Tc released from operating gaseous diffusion plants, Tc is not as plant-available as predicted by greenhouse studies. In a small pond ecosystem, Tc was not found to bioaccumulate to a significant degree but retention by ecosystem components does occur. From this work, a model was developed to enable the prediction of Tc dynamics in aquatic systems.

Research results on actinide behavior in Pond 3513 have shed additional light on the role of sediments in fish tissue burdens, on the behavior of Am and Cm in freshwater ecosystems, and on the oxidation state of organically bound Pu.

Studies on simulated lung fluid leaching of Pu-contaminated soils revealed different rates (and amounts) of leachable Pu. A novel idea on the origin of soluble Pu species derived from global fallout was tested experimentally and found plausible.

Innovative research on the geochemistry of the artificial element Tc has further defined the redox regimes where this element loses its mobility.

Additional information on the freshwater bioaccumulation characteristics of ^{95}Nb was obtained this year as well as a comparison of the uptake of Np by plants grown on different soils.

[1]Dual capacity.
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Technetium and Niobium Research

Uptake of ^{95m}Tc by Freshwater Biota

The values used for bioaccumulation factors (Bq per g fresh weight of organism/Bq per g water) for Tc to calculate potential radiation dose to man through the freshwater aquatic food chain are default values based on the behavior of I in the environment. Data collected from a small experimental pond that was tagged with an acute spike of ^{95m}Tc was used to calculate bioaccumulation factors and to determine the tissue distribution of Tc in freshwater fish and snails.

A model of the pond ecosystem that treated each organism separately was developed to predict the long-term, steady-state body burden of Tc in two species of fish and one species of snail. Transfer coefficients for the model relied on the uptake and elimination of ^{95m}Tc by the organisms. The mean concentrations of ^{95m}Tc in carp, mosquitofish, and snails during uptake and elimination of ^{95m}Tc are shown in Fig. 2.1. The data points (±1 SE) were used with a Marquardt nonlinear least-squares technique to determine the uptake and elimination rates of ^{95m}Tc. The effective biological half-life of ^{95m}Tc calculated for carp, mosquitofish, and snails was 2.5, 4.3, and 21.3 d, respectively.

ORNL-DWG 80-17051 ESD

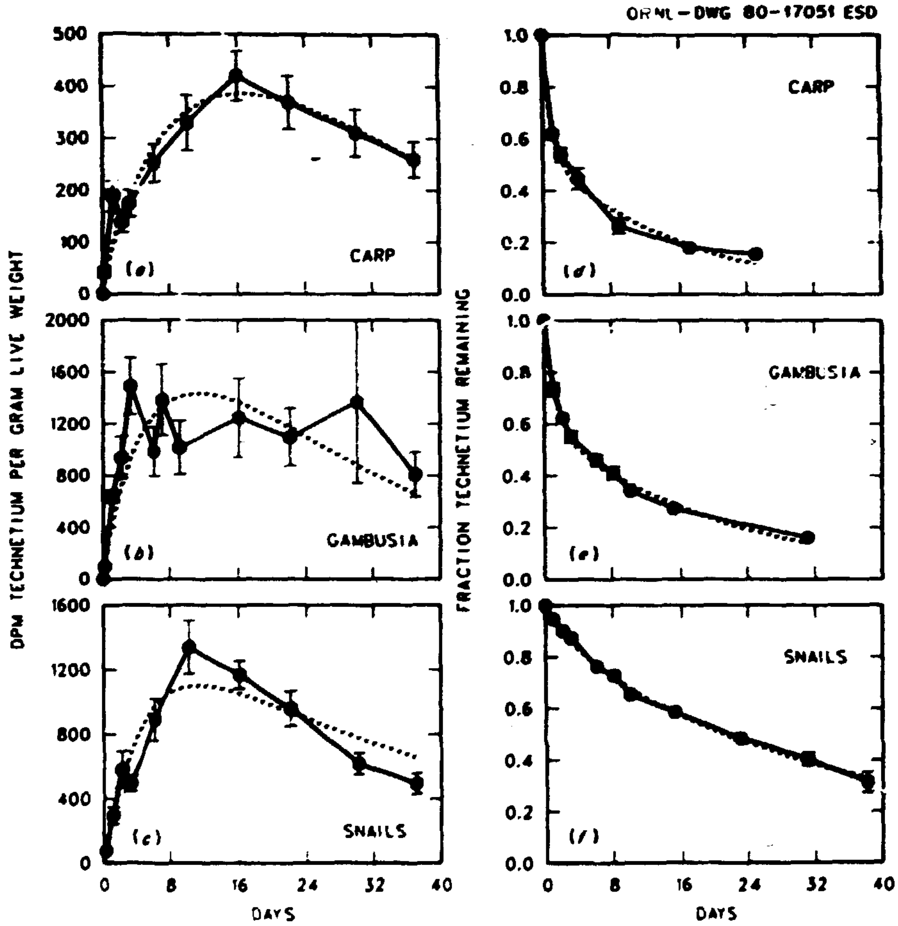

Fig. 2.1. Uptake of ^{95m}Tc is shown for (*a*) carp, (*b*) Gambusia, and (*c*) snails in an experimental freshwater pond that received an acute, or "spike," pulse release of ^{95m}Tc. Elimination of ^{95m}Tc is shown for (*d*) carp, (*e*) Gambusia, and (*f*) snails after they were removed from the pond. The effective biological half-lives were 2.5, 4.3, and 21.3 d for carp, Gambusia, and snails, respectively. The solid line connects data points representing the mean concentration of ^{95m}Tc (±1 SE). The data points were used with a Marguardt nonlinear least-squares technique to determine the uptake and elimination rates of the isotope.

Bioaccumulation factors for carp, mosquitofish, and snails based on steady-state body burdens calculated with the pond ecosystem model were 11, 75, and 121, respectively. The value for carp is less than the default value of 15 that is commonly used in radiation dose calculation for man; however, the calculated bioaccumulation factor for mosquitofish exceeded the default value by a factor of 5. The calculated concentration factor for snails was 24 times the recommended default value of 5 for invertebrates.

The difference in the concentration of ^{95m}Tc in the two species of fish is probably related to their feeding habits. A tissue analysis of the fish showed that a large proportion of the body burden of ^{95m}Tc was present in the digestive system of the fish. Gill tissue contained the second highest concentration of ^{95m}Tc, and muscle tissue had the lowest concentration of any of the tissues examined.

Technetium-99 Behavior near Uranium Enrichment Facilities

Technetium-99 was measured in vegetation and soils collected near three operating gaseous diffusion facilities to obtain estimates of the soil-to-vegetation concentration factor. The plants are located in Oak Ridge, Tennessee; Paducah, Kentucky; and Portsmouth, Ohio. The ratio of measured plant and soil concentrations (plant/soil) constitutes the soil-to-plant concentration factor. Analyses performed by ORNL's Analytical Chemistry Division primarily used radiochemical separations and low-level beta counting techniques, with selected samples checked by isotope dilution mass spectrometry. Sampling of ^{99}Tc in vegetation and soil near the three uranium enrichment facilities produced 24 vegetation/soil concentration factors. No differentiation could be made between the ^{99}Tc in vegetation obtained from direct aerial deposition and that obtained from the soil. The highest values were associated with Paducah, and the most variability was associated with concentration factors calculated for Portsmouth. The concentration factors for the Oak Ridge Gaseous Diffusion Plant ranged from 3.3 to 16.0 with a mean of 7.0. The range for Paducah was 5.1 to 44 with a geometric mean of 16. The Portsmouth range was 1.4 to 26 with a geometric mean of 7.4. The pooled assemblage of concentration factors appeared to be lognormally distributed with a geometric mean of 9.5 (Table 2.1). These field soil-to-vegetation concentration factors are one to two orders of magnitude less than those derived from laboratory experiments using potted soils. These field studies indicated that the radiological impact of Tc releases to food chains may be substantially less than those predicted by assessment models using data derived solely from laboratory experiments.

Table 2.1. Statistical summary of soil-to-plant concentration factors combined from all sampling sites

Number of values	24
Maximum value (Paducah)	44
Minimum value (Portsmouth)	1.4
Arithmetic mean	14
Standard deviation	10
Standard error	2.0
Geometric mean[a]	9.5
Geometric standard deviation[b]	2.4

[a]Geometric mean = exponential of the mean of log-transformed data.

[b]Geometric standard deviation = exponential of the standard deviation of log-transformed data.

Concentration of ^{95}Nb in Freshwater Biota

Two studies have been conducted with ^{95}Nb in experimental ponds to determine the distribution and concentration of Nb in freshwater ecosystems. The initial experiment involved the release of ^{95}Nb at a constant rate for a period of 30 d, and the second was a short-term release study with ^{95}Nb to obtain data on uptake and elimination rates in aquatic biota. In these experiments, water, sediments, and aquatic biota were collected routinely and analyzed for ^{95}Nb. Elimination studies were conducted on fish, crayfish, and snails by removing them from the pond after 30 d of exposure to ^{95}Nb. Tissue analyses were conducted on three species of fish, crayfish, snails, and clams.

In the initial experiment after approximately 30 d of exposure, snails and crayfish contained higher concentrations of ^{95}Nb than did any of the fish species. The whole-body bioaccumulation factor (Bq per g fresh weight/Bq per g water) w[illegible]6 for snails and 67 for crayfish. The bioaccumulation factors for carp, bluegill, and mosquitofish were 16, 12, and 11, respectively. Analyses of elimination experiments showed that at least 50% of the body burden of ^{95}Nb in the organisms tested was in the fast component of the elimination curve. Therefore, the effective biological half-lives were relatively short. The half-lives for carp, mosquitofish, and snails were 2.3, 1.4, and 0.4 d, respectively; the biological half-life for crayfish was 7.9 d. If only the slow components of the elimination curves were considered, the biological half-lives for carp, mosquitofish, snails, and crayfish were 21.0, 11.5, 14.5, and 10.2 d, respectively.

Tissue analyses of carp, mosquitofish, and bluegill agreed with the data from the elimination experiments. In fish from the pond, the GI tract and its contents accounted for 65 to 95% of the body burden of ^{95}Nb; however, this percentage dropped rapidly to approximately 10% of the body burden after they had been removed for three days. In all three species of fish the muscle tissue contained the lowest concentration of ^{95}Nb of all tissues examined. The ^{95}Nb content in carp bone was about ten times the concentration of ^{95}Nb in muscle tissue.

Elimination studies and tissue analyses on snails and clams taken directly from the ^{95}Nb-tagged pond showed that approximately 80% of the body burden of ^{95}Nb was in the body tissues and the remainder in the shell. After removal from the tagged pond, ^{95}Nb was rapidly eliminated from the body tissues and the percentages in the body tissue and shell were reviewed.

Previous analyses of the data from this experimental pond showed that ^{95}Nb is rapidly lost from the water to the sediments and that periphyton and macrophytes accumulate ^{95}Nb rapidly. Information from the elimination studies and tissue analyses indicate that ^{95}Nb was accumulated primarily through the food chain. The maximum bioaccumulation factor calculated for fish was 16, which is much less than the bioaccumulation factor of 3×10^4 listed in USNRC Regulatory Guide 1.109 and recommended for calculating potential radiation exposure to man.

Actinides in Biota

Tissue Distribution of U, Pu, Cm, and Am in Freshwater Fish

The patterns of actinide distribution in tissue/organ fractions for goldfish, bluegill, and catfish exposed to actinides in Pond 3513 for one full year (1977–1978) were qualitatively similar despite differences in trophic position. Absolute concentrations were highest in goldfish because of their greater association with the sediment-water interface. The ranking of tissues/organs according to ^{239,240}Pu concentration was as follows: GIT (digestive tract) $\gg$ gill, kidney $>$ liver $>$ gonad, bone + RST (residual soft tissues). Quantitative differences between absolute concentrations of actinides were observed within tissue/organ types, but these did not affect the relative position within the rankings. The ranking according to relative tissue/organ fractional body burdens was affected by sample mass and thus differed from that for concentration. Gill and

GIT were excluded from the fractional body burden comparisons because of potential sediment contamination. The ranking for $^{239,240}Pu$ in goldfish (percent of total activity in compartment) was as follows: bone + RST (71%) > liver (13%), kidney (11%) > gonad (4%). Muscle tissue was included in the RST fraction and has not been analyzed separately thus far because of constraints of sample size and expected low activity levels.

Differential Uptake of Actinides by Fish as a Function of Source Characteristics

Concentrations of actinides (Pu, Am, Cm, and U isotopes) were determined in the livers of goldfish that had been exposed for 1 year in 1977–1978, 1 year in 1978–1979, and 1.5 years in 1978–1979, respectively, in Pond 3513 and in the artificial stream and net enclosure isolation groups described previously (Auerbach et al. 1978). The results indicate that ^{244}Cm and $^{239,240}Pu$ concentrations and ^{238}Pu:$^{239,240}Pu$ ratios in liver of fish exposed to the 1978 accidental spike (1978–1979 groups) were not significantly different than those in samples obtained before the spike, despite the fact that average ^{244}Cm and $^{239,240}Pu$ concentrations in pond water were greatly increased (e.g., $^{239,240}Pu$ concentrations in water were 0.045, 0.23, and 0.20 Bq/L in the three periods, respectively.) These observations cannot be explained by Pu oxidation state effects because the accidental spike was dominated by oxidized Pu, the most biologically available state (in the absence of chelates). In addition, the ^{238}Pu:$^{239,240}Pu$ activity ratio of the spike was 0.6 as opposed to the ambient value of 0.09; thus, the activity ratio in the liver samples should have been significantly lower if water was a significant source of Pu. These observations seem to provide additional reinforcement for the concept that the critical abiotic source of transuranics in Pond 3513 is sedimentary particulates rather than the overlying solution.

Neptunium in Plants

The uptake of ^{235}Np by fescue grass from five USA soil series was studied in the laboratory. The soils used were a Captina silt loam from Tennessee, a Muscatine silt loam from Illinois, a Salinas clay loam from California, and a Dothan sand and a Fuquay sand from South Carolina. Replicate soils were kept moist for 50 d and then spiked with Np(V) to achieve a soil concentration of 10,000 pCi/g. Fescue grass was grown on the soils and harvested 14 and 42 d after planting. The soils were then leached with water, and the leachate was collected after percolation through the soil.

Analysis of variance showed significant differences in plant uptake of ^{235}Np due to soil series and time of harvest. The only difference due to time of harvest was for the Fuquay soil type. There was 1000-fold variation in the soil to plant transfer of ^{235}Np over the five soil series. Plant uptake of ^{235}Np increased with decreasing cation exchange capacity and decreasing organic matter content of the soils. The results from leaching the soils with water paralleled the plant uptake of ^{235}Np by fescue. There was high leachability of ^{235}Np from sandy soils with low cation exchange capacity which was consistent with the high plant uptake on sandy soil. Neptunium (V) in these laboratory studies exhibited a soil-plant relationship consistent with that expected of any simple cation.

Actinide Environmental Chemistry

Association of Trivalent and Tetravalent Actinides with Organic Matter

The association of Cm, Am, and Pu(III+IV) with a high-molecular-weight (nominally 6000 to 10,000) organic fraction in solution (Auerbach et al. 1979) and their subsequent re-release over a longer time period indicate that sorption by algal detrital material plays a major role in the cycling of these elements.

Conversion of insoluble detrital organic matter to lower molecular weight fragments (humic materials) by microbial degradation could explain the observed solubility pattern. One issue that required resolution was the oxidation state of the organically bound plutonium. The qualitative separation of Pu(IV) from Pu(III) using precipitation techniques was previously illustrated (Auerbach et al. 1978). For the evaluation of Pu(III) vs Pu(IV) in Pond 3513 water, Zr phenylarsonate (Zr PA) was precipitated after making the water 0.5 *M* in HCl and adding ^{236}Pu(III). The ^{236}Pu, reduced to the trivalent state with a Jones Reductor, was added to serve as an internal oxidation state "control"; that is, to check the efficiency of the Zr PA precipitation, which should coprecipitate Pu(IV).

The results are presented in Table 2.2. The August 1 results indicated that the amount of ^{239}Pu that precipitated with $BiPO_4$ [Pu(III + IV)] was the same as that precipitated with Zr PA [i.e., Pu(IV) dominates]. Added ^{236}Pu(III) did not significantly carry (18%), thus validating the valence separation. Because the high-molecular-weight "fulvic" material also precipitated with the Zr PA, the ^{239}Pu could have been trivalent, complexed with the organics, and not released upon acidification. To test this, a second sample (August 5) was made millimolar in hydroxylamine, micromolar in Fe(II) at the time of acidification. This reductive treatment (room temperature, 10 min) reduced by about 75% the amount of Zr PA-carriable Pu and completely eliminated the precipitation of the added ^{236}Pu(III). From these data, we conclude that Pu(III) is not a significant component of the organically bound plutonium.

Table 2.2. Pu(III) vs (IV) evaluations on 0.22-μm-filtered water from Pond 3513

	^{239}Pu (pCi/L)			
	III + IV[a]	IV[b]	V + VI[a]	III + V + VI[b]
August 1 1980 added ^{236}Pu(III)	0.72 ± 0.04	0.74 ± 0.06 18%	Lost	0.46 ± 0.03 82%
August 5, 1980 added ^{236}Pu(III) + hydroxylamine, Fe(II)	0.65 ± 0.03	0.17 ± 0.03 <1%	0.49 ± 0.03	0.9 99%

[a]$BiPO_4$ method.
[b]ZrPA method.

Long-Term Changes Expected in Trivalent Actinide Behavior in Pond 3513

Although Pond 3513 currently maintains a sediment-water exchange equilibrium for the actinides, it is clearly only quasi-stable for Pu (significant long-term correlations with time) and for Cm and Am (nonuniformity in sediment-water exchange). The nonuniformity in Am-Cm exchange behavior will eventually resolve itself when either differences in chemical associations or, more likely, depth distribution in sediments are eliminated with time. On a geologic time scale, equilibrium differences in geochemical behavior of Am(III) and Cm(III) must be relatively insignificant because of their similar chemistries. Nonetheless, it is significant that such a difference in observed behavior (25:1 in sediment-water exchange) can occur because of anthropogenic influences over a very short time scale (<10 y). Similar phenomena have been observed for anthropogenic sources of nonradioactive heavy metals and transition elements in sediments.

Under laboratory conditions of pH, ionic strength, and carbonate comparable to Pond 3513 values, Allard and Beall (1979) reported K_d values for ^{241}Am primarily in the range 1 to 10 × 10^3 for over 30 natural minerals (including quartz, gibbsite, biotite, dolomite, calcite, albite, olivine, montmorillonite, kaolinite, muscovite, olivine, chlorite, augite, etc.). The estimated K_d for ^{244}Cm from Pond 3513 was 5.9×10^3, very comparable to the median value of the data above. This observation suggests that the ^{241}Am is physically occluded relative to ^{244}Cm in the surficial sediment layer.

Influence of Bioturbation on Trivalent Actinide Activity Ratios in Solution

Although one could hypothesize that chemical occlusion (produced by waste effluent variations) rather than physical occlusion (caused by differences between the depth distributions of Am and Cm) was responsible for the observed differences in apparent solubility, the latter explanation now appears to be more plausible. Surficial sediment leaching with either 1 *N* HNO_3 or 0.01 *N* HCl indicated no significant differences between Am and Cm solution-sediment exchange (C. T. Garten data). Further, in-situ homogenization of surficial sediments inside plexiglass TM columns inserted into Pond 3513 sediments resulted in lowered ^{244}Cm:^{241}Am activity ratios comparable to those in the entire 0- to 5-cm depth layer.

Because we had previously observed that digestive tracts of benthic-feeding fishes contained significant quantities of sediment with radiological characteristics similar to that of the 0- to 5-cm surficial sediment layer (Auerbach et al. 1978), one could predict that continued bioturbation of surficial sediments by fish alone would eventually resolve the apparent differences observed in Am and Cm solution-sediment exchange. Despite the effects produced by the 1977 algal bloom and by the 1978 accidental spike of ^{244}Cm into Pond 3513 (^{244}Cm:^{241}Am activity ratio in solution raised to 40:1) which tended to obscure the long-term trends, both the absolute concentration of ^{244}Cm and the ^{244}Cm:^{241}Am activity ratio have fallen steadily. By July 1980, the ^{244}Cm concentration in filtered water had fallen to 0.068 Bq/L, approximately twice that of ^{241}Am. The concentration of ^{241}Am was comparable to the values obtained in 1977 before the introduction of fish to Pond 3513. Pond-wide mean values for the ^{244}Cm:^{241}Am ratio in surficial sediment and seston were 1.3 to 1.5 as opposed to activity ratios of 25:1 and 40:1 in the overlying water following the 1977 algal bloom and the 1978 spike, respectively. Thus, these data suggest that in the three years since fish were introduced 60 to 70% of the 0- to 5-cm sediment layer in Pond 3513 has been homogenized by bioturbation, and, coupled with the effects of the 1977 algal bloom, direct biotic effects on the solution chemistry of the trivalent actinides have been more important than physicochemical factors. Plutonium solution chemistry, on the other hand, is complicated by its oxidation state transformations and is apparently more subject to physicochemical perturbations (i.e., redox-pH effects) in the Pond 3513 system.

Origins of Global Fallout-Derived Pu(V + VI) Species

Work by Wahlgren et al. (1977) demonstrated the presence of Pu(V+VI) species in North American lakes. These oxidized Pu species could originate by in situ oxidation (thermodynamically possible) or could be a "memory" of their origin. This latter possibility was particularly intriguing, since most of the globally dispersed Pu originated by pulsed neutron activation of natural uranium reflectors or tampers in thermonuclear weapons [i.e., $^{238}U(n,\gamma)^{239}U \xrightarrow{\beta} {}^{239}Np \xrightarrow{\beta} {}^{239}Pu$.] The Pu measured in fallout was not present during condensation whereas the ^{239}U was. The oxidation state of the U was most likely +6. Experiments were conducted to determine if this oxidation state could be preserved during β^- decay in a solid (no work like this has been done).

Because it is impossible to simulate the sequence of events following a nuclear detonation, it was only possible to activate depleted ^{238}U in various solids (CaO and mixed Ca, Fe, and Al oxides) as well as to precipitate ^{239}Np in solids. Thus, following 1-min activation in the ORR, both ^{239}Np and ^{239}Pu oxidation state determinations were performed after appropriate decay periods by sample dissolution—radiochemical separations. Plutonium-238(IV) was present in several solids before activation to evaluate chemical oxidation during the radiochemical steps. The evidence seems unequivocal that at least part of the ^{239}Pu is oxidized (+5 or

+6) after double beta decay. For example, when Fe and/or Al was present, between 60 and 90% of the ^{239}Pu was oxidized. Several other tests showed very little oxidized Pu, however. It should be noted that β^- decay is the loss of an electron; theoretically this increases the charge on the daughter element, but the matrix environment and daughter chemistry are also important. For the U, Np, Pu decay sequence, the chemical species are so similar that oxidation state preservation is more likely than the case where ^{131}Te decays to ^{131}I.

Dissolution Characteristics of Pu-Contaminated Soils in Synthetic Lung Fluid

Models for Pu retention in the human respiratory tract rely upon distinct Pu solubility classes for inhaled particles. Solubility class Y, represented by oxides and hydroxides, was used by the EPA in the development of a soil screening level. Application of a single solubility class to a dose assessment model for nonoccupational-environmental exposure may not be appropriate because the chemical nature of Pu in contaminated soils may be different from synthetic PuO_2 particles. How does soil Pu vary in "solubility"?

Individual aliquots of five contaminated materials [nuclear (N-NTS) and safety short (S-NTS) soils from the Nevada Test Site, retention and pond sediment from ORNL (ORNL), canal sediment from Mound Laboratory (ML), and surface soil from Rocky Flats (RF)] were continuously equilibrated in synthetic lung fluid (Lovelace Foundation recipe) at 37°C. After a designated equilibration period, the solutions were centrifuged and filtered (0.22 μm) and the dissolved actinides (Pu, Am, U) measured. Another set was successively leached by weekly replacement with fresh solution for seven weeks. The dissolution patterns—Pu in solution vs time—for the continuously equilibrated set indicated that dissolved Pu had reached a maximum within a day of equilibration. The dissolved Pu from the soils was 0.70 (RF), 0.43 (ML), 0.03 (S-NTS), 0.02 (ORNL), and 0.01% (N-NTS). The results of the successive extraction experiments showed that the extracted Pu from RF, ORNL, and ML samples decreased after a few extractions and then remained at concentrations that were less than 10% of the first Pu extractions. This result indicates that a variable amount of soil Pu may be rapidly solubilized but that this leach rate is not representative of the entire soil-associated Pu.

The differences in dissolution characteristics of the contaminated soils indicate that a single solubility class (i.e., Y) is too generic. This is most evident when it is recognized that ML and ORNL represent contamination events involving soluble Pu, while S-NTS and RF contain particulate Pu. It is not clear how this differential solubility should be handled in the International Commission on Radiological Protection type lung models, but clearly single solubility classes may not be environmentally relevant. The most important result, therefore, seems to be that the contamination mode (source term) is not reflected in the solubility data for these real-world soils.

Radionuclides in the Coastal Zone

"Mud Patch" Sedimentation

Continental shelf sediments off the northeastern United States are dominated by sands. Thus, the occurrence of fine-grained sediments under some 80 m of water in an area south of Martha's Vineyard has long been conspicuous. Whether this deposit, called the "mud patch," is a modern feature or a relict deposit remaining from deposition during a period of lowered sea level has not been resolved among geologists. Recent work by U.S. Geological Survey (USGS) scientists (Bothner, in press) implies that the mud patch is either a modern deposit or that the feature is undergoing a dynamic exchange with overlying water. In cooperation with the USGS, we analyzed sediment cores from the mud patch for gamma-emitters.

These cores contain ^{137}Cs to depths of greater than 20 cm but less than 30 cm, indicating that very recent sedimentary material is being mixed downward into the mud patch, presumably by burrowing organisms. Even more rapid mixing is apparent in the upper 5 cm of the sediment column, where 53-d ^{7}Be is found. Because both

^{137}Cs and ^{7}Be in marine sedimentary environments are permanently bound to particles once they become adsorbed, these observations demonstrate the transport of fine-grained particles downward in the sediment column at surprisingly high rates. Persistence of the mud patch among coarser grained sediments despite a highly dynamic particle exchange rate must, therefore, be the result of physical controls related to water circulation, turbulence, and wave action. If the deposit is indeed relict, it is even more surprising that it should persist throughout the changes in physical oceanographic features that presumably accompanied oceanic transgression.

Geochemistry of Long-Lived Radionuclides

Introduction

The reduction of TcO_4^- to less-soluble (mobile) oxidation states occurs within geochemical regimes encountered naturally. A generic model, considering the three-electron reduction of TcO_4^- to TcO_2, was previously suggested (Bondietti and Francis 1979, Allard et al. 1979) as a means for in evaluating migration under breached repository conditions. We have extended our previous work and attempted to experimentally evaluate the generic model. The availability of ΔG_f^0 for hydrated TcO_2, i.e., $Tc(OH)_4$ (Cartledge 1971) reformulates the equilibrium model as the relationship: $\log [TcO_4^-] = (Eh - 0.710 + 0.0788\ pH)/0.0197$ for the reduction of TcO_4^- to $Tc(OH)_4$. We have been interested in evaluating this model experimentally using the Fe(II)-Fe(III) couple as the redox system.

Because sulfides are important in the chemistry of Tc and have geochemical significance, work on Tc-sulfide interactions was initiated, and initial results are presented. In all our experiments, loss of soluble Tc was considered to involve a change in chemical form, usually involving reduction. The actual oxidation states are unknown, although Tc(IV) was assumed because coprecipitation of Tc(IV) by $Fe(OH)_3$ is well recognized.

Pt Electrodes and the Evaluation of Eh

Inert electrodes (Pt, Au) are potentially useful for evaluating redox potentials if exchange currents are high enough, O_2 is excluded, and (ideally) the electrode reaction is known.

In the hydrolyzed Fe(II,III) system and above pH 7.5, the Pt electrode response was noted to approximate 180 mV/pH unit, consistent with electrode couples involving Fe^{2+} and $Fe(OH)_3^0$ and/or $Fe(OH)^+$ and $Fe(OH)_4^-$ (i.e., 3 OH^-). Between pH 6 and 7, the response approximated 120 mv/pH unit, corresponding presumably to the Fe^{2+}-$Fe(OH)_2^+$ couple. In the Fe(II)-Fe(III) system, the redox potential can also be theoretically evaluated if the equilibrium concentration of Fe^{2+} and Fe^{3+} are known. Redox (Eh) measurements obtained at steady state or in decline [due to slow oxidation of Fe(II), particularly at pH values above 8] were combined with measured Fe(II) concentrations to calculate Fe^{3+} concentrations. These values were then normalized for pH using K_{sp} values. Data from FY 1979 experiments showed a calculated $\log K_{sp}$ ($\mu = 0.01$) for $Fe(OH)_3$ of -38.1 ± 0.55 (geometric mean, ± 1 SD), where $N = 14$ and pH ranged between 7.8 and 4.8. The $\log K_{sp}$ values obtained this FY (1980) in the pH range 8 to 9.8 (8 experiments, $N = 20$) were similar: -37.8 ± 0.48. These calculations were performed from the relationship $Eh = 0.771 + 0.0591 \log Fe^{3+}/Fe^{2+}$. The measured redox potentials were judged to be valid since the same (factor of 3) solubility product was calculated when 10^{-6} *M* Fe(II) was present as when 10^{-4} *M* Fe(II) was present. In several experiments where TcO_4^- was added to deaerated solutions containing Fe(II) and where the measured Eh values were slightly higher than the model boundary, a fraction of the TcO_4^- was lost immediately (5 min) but appeared in solution over a period of several hours. However, when the measured Eh's were below the model boundary, added Tc was rapidly lost, loss was continuous in time, and most of the lost Tc did not reappear in soluble form even after several days of aeration. One problem is that results from our transient studies are being compared to an equilibrium model. This is by necessity, but obviously conclusions must be tempered. Also, the model assumes a solid phase of $Tc(OH)_4$, yet the almost identical ionic radii of Fe^{3+} and Tc^{4+} preclude such a phase.

Figure 2.2 summarizes the basic results in very abbreviated form. Two concentrations of Tc were studied (4.2 μM below pH 8, 0.011 μM above). When Eh's were above the model boundaries, TcO_4 was generally not lost from solution (regions N), and in those cases where it was, it was not continuous (M). In every case where experimental potentials were below the boundary, over 90% of the Tc was lost (R). What was derived, therefore, was much more definitive experimental evidence that in the Fe system, TcO_4^- can be reduced and that the Tc(VII)-Tc(IV) model is a valid approximation of the redox potentials where this occurs. A geochemical model, which calculates Fe(II) concentrations during rock weathering, can be used to predict Eh, and thus TcO_4^- stability.

ORNL-DWG 81-3880 ESD

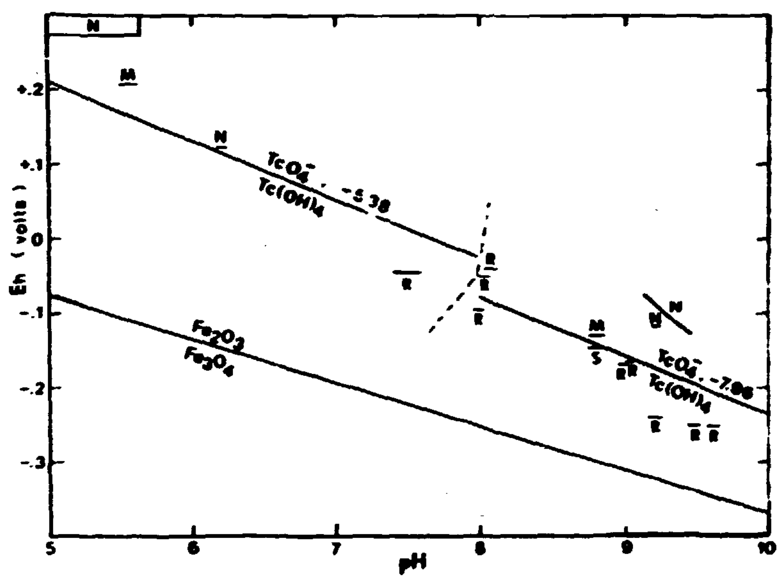

Fig. 2.2. Summary of experimental data obtained to define Eh-pH boundary for TcO_4^- reduction. Equilibrium lines were calculated at log TcO_4 concentrations initially present experimentally.

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3. ENVIRONMENTAL IMPACTS PROGRAM

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Introduction

The Environmental Impacts Program (EIP) prepares environmental analyses relating to federal energy planning and decision-making processes. This effort includes preparation of Environmental Impact Statements (EISs) and Environmental Assessments (EIAs), development of environmental monitoring strategies and protocols, formulation of guidelines and environmental compliance documents, and technical assistance. The Program assists the Department of Energy (DOE) and the Nuclear Regulatory Commission (NRC) in accomplishing their environmental responsibilities under the National Environmental Policy Act (NEPA).

The EIP was formally established in May 1974. During its first few years, the Program's primary responsibility was preparation of EISs on proposed nuclear power plants for the U.S. Nuclear Regulatory Commission (then the Regulatory Division of the U.S. Atomic Energy Commission). In the last few years we have almost eliminated our work on commercial nuclear reactors in order to address advanced energy technologies, initiate assessment and monitoring research, and develop environmental guidance for use by decision-makers.

The EIP is organized around six team activities: Power Stations, Nuclear Fuel Cycle, Geothermal Energy and Fuel Conversions, NEPA Affairs and Fossil Energy, Monitoring Protocols Development, and Solar and Special Projects. Impact statement work is a cooperative effort with the ORNL Energy Division, in which the EIP analyzes issues dealing with terrestrial and aquatic ecology and land and water use.

The primary goal of the Program is to promote the inclusion of scientifically sound and supportable environmental analyses and advice as input into major federal decisions. To implement this goal the EIP engaged in several activities this year which provide guidance, technical assistance, planning, and long-range environmental analyses.

Five types of DOE actions involve decisions affecting the environment: legislative or regulatory actions, programmatic decisions, regulation and permits, construction projects wholly undertaken by the agency, and procurement (funding) of the private sector for development and demonstration projects. All these activities,

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except procurement, have required and have had public participation and environmental (NEPA) documentation. The procurement process occurs after an agency decides to develop a program objective, e.g., demonstrate coal gasification or develop fuels from biomass or geothermal energy. The agency may provide assistance to the private sector by funding for feasibility studies, loan guarantees, and cooperative agreements. Announcements of availability of funds are generally made by publication of a Request for Proposal (RFP) or a Program Opportunity Notice (PON) which solicits proposals for DOE consideration. These announcements include specifications of the types of information (economic, technical, and environmental) to be included in the submitted proposals. Each proposer designates a site and type of process. Much of the information provided to support the proposal is proprietary and therefore cannot be released to public forum as is required by NEPA. Therefore, little if any environmental analysis has traditionally gone into the selection process even though the various proposals could have widely different environmental consequences. Selection of proposals at the procurement stage forecloses many alternatives available to the agency, and therefore the selection process represents a major decision point requiring environmental review under provisions of the new Council on Environmental Quality (CEQ) regulations. Recognizing this, the EIP has been active in finding ways to include scientifically valid environmental analyses in these decisions.

The staff participated in the procurement process to select proposals for strategic petroleum reserve sites and for development of alternative fuels. As part of its technical assistance to DOE's NEPA Affairs Division, the staff developed guidelines for incorporating environmental information into proposals, forming the basis for an environmental impact analysis comparing and environmental consequences among the various proposals. This system has been used successfully in two recent solicitations.

The staff developed other guidance documents which facilitate the inclusion of sound environmental analyses at the earliest point in the decision-making process. These include environmental report and monitoring guidelines. In addition, the staff has given technical assistance to the Environmental Protection Agency (EPA) in evaluation of 316(a, b) demonstrations.

The program continues to develop environmental analyses, impact statements, and assessments in such new areas as conversion of existing oil and natural gas burners to alternative fuels, biomass energy facilities, and alcohol fuel plants.

The staff also contributed to the Oak Ridge National Energy Perspective, which attempts to anticipate the environmental constraints on, and impacts of, the energy-producing sector under a desirable future scenario. Highlights are discussed below.

Procurement

Strategic Petroleum Reserve

The 1973 oil embargo and the resultant effects triggered governmental efforts to reduce the nation's vulnerability to future interruptions. Congress ordered the creation of a Strategic Petroleum Reserve (SPR) in passing the Energy Policy and Conservation Act of 1975. The SPR program calls for storage of oil in man-made underground caverns so that it could be available to reduce the effects of an oil embargo.

Present and planned oil storage sites are within Gulf Coast salt domes, large underground salt deposits up to 1500 m in diameter and 6000 m in depth. Storage caverns are typically developed by injecting freshwater into a well deep in the salt dome. The bore hole enlarges as the water dissolves the salt, eventually forming a cylindrical cavern. The resultant concentrated brine is displaced by the storage of oil. The principal environmental concerns related to SPR projects are deep-well or offshore disposal of brine, construction in wetlands, pipeline routing, brine and or oil spills in sensitive areas, freshwater consumption and its effects on aquatic biota, and atmospheric release of hydrocarbons.

Initial storage sites, developed during SPR Phase I, used existing solution-mined salt caverns and one salt mine with a total capacity of 248 million barrels (30×10^6 m^3)[although to date only 92 million barrels (14.6×10^6 m^3) have been stored]. Phase II of the plan, currently being implemented, will increase the storage capacity by 290 million barrels (46×10^6 m^3).

In November 1978, DOE issued an RFP for industry development of oil storage facilities for the SPR Phase III development (the SPR "Turnkey" program). Staff from EIP served on the Committee on Environment for the SPR Turnkey Source Evaluation Board charged with reviewing and comparing the environmental effects related to industry. After the review, the Secretary of Energy cancelled the SPR Turnkey program prior to awarding contracts because Saudi Arabia threatened to curtail its oil production if the United States maintained its commitment to have one billion barrels (15×10^6 m^3) of oil in storage by 1989. Recent events in the Middle East, however, prompted renewed interest in SPR Phase III expansion. Although the industry Turnkey approach has been abandoned, DOE is now committed to government construction of SPR expansion sites. SPR Phase III will add 212 million barrels (33×10^6 m^3) of oil storage for a total U.S. oil reserve of 750 million barrels (119×10^6 m^3). In assistance with Phase III efforts, EIP staff members are currently working as environmental advisors to the New Orleans SPR Project Management Office.

Alternative Fuels Production

On November 27, 1979, Congress passed the Department of Interior and Related Agencies Appropriations Act for FY 80 (PL 96-126). This act made $2.2 billion available, stimulating commercial production of domestic alternative fuels. Of this total, the first $200 million was allotted for grants for project development feasibility studies and commercial-scale development by cooperative agreement with non-federal entities.

Under an accelerated schedule mandated by Congress, DOE issued RFPs for alternative fuels projects. The resource technology areas included in the solicitation were biomass, coal liquids and gases, shale oil, tar sands, unconventional natural gas, solid waste, lignite, peat, and other minerals or organic materials. DOE had received well over 900 proposals, over two-thirds dealing with biomass resources, the majority of which were fo production of ethyl alcohol for blending with gasoline. Each proposal was reviewed and scored by teams of scientists drawn largely from the national laboratories or from within DOE. Each team evaluated one of the following areas. (1) commercial viability; (2) environmental, health, safety, and socioeconomic factors; (3) business factors; or (4) cost factors in each proposal. The success of this first solicitation prompted Congress to appropriate $300 million in additional funding to be awarded in the near future by the same process.

The experience acquired by EIP personnel in this exercise provided an impetus for two subsequent activities. First, a summary of the existing knowledge on the environmental impacts of alcohol fuel production is being prepared for publication. Second, EIP personnel provide technical expertise for guidance documents to be used as information resources for future solicitations (see NEPA Affairs). These efforts will contribute to increasing the accuracy of proposal evaluation and to improving realization of environmental goals by incorporating such considerations at the earliest possible stages of decision-making.

Guidance and Technical Assistance

Guidance to DOE on NEPA Affairs

The Council on Environmental Quality (CEQ) regulations for implementing procedural provisions of the NEPA have initiated major changes in DOE's NEPA process. The NEPA Affairs Division within DOE is responsible for incorporating the new CEQ procedures into department-wide, decision-making activities and for assuring that appropriate analyses are developed for DOE NEPA documents. As part of the technical support, EIP staff developed a set of environmental guidance documents to be used by applicants for DOE financial assistance in preparing proposals and environmental reports in support of their applications.

The environmental information requirements in RFPs and PONs have traditionally been vague and sketchy in comparison to technical and economic information requirements. Environmental information content of proposals has, as a result, been highly variable in quality and completeness, and meaningful comparison of proposals on environmental grounds has been difficult, if not impossible.

The EIP staff prepared a procurement-level environmental guidance document that can be included in the text of an RFP or a PON. When finalized, the document will be available for use by both personnel who draft the RFPs or PONs and applicants who are preparing the proposals. The EIP document contains guidance for preparing descriptions of existing environmental conditions and for assessing environmental impacts to land, water, air, biotic, and socioeconomic resources. Because the time period available for preparation of proposals is short (generally 60 to 90 d), the guidance assumes that existing information from published sources and the applicant's own studies will form the primary data base for proposals. However, the guidance encourages applicants to include reconnaissance-level field studies for each site.

The new CEQ regulations state that the central focus of a NEPA review should be a rigorous comparison of reasonable alternatives. The rigorous comparison of alternatives by DOE to comply with NEPA is then provided by DOE's comparison of the group of submitted proposals. This NEPA review focuses on the criteria used for selection of proposals and the types and severity of environmental impacts resulting from each project. Ideally, the environmental review at the procurement level will be tiered to NEPA reviews for specific projects at a later stage of project development. The procurement level environmental guidance document thus helps ensure that an adequate environmental comparison of proposals is possible at this important stage in selecting alternatives.

An environmental report (ER), a document providing environmental data on the existing environment, presents the applicant's assessment of environmental impacts and the need for mitigation measures. The ER is used by DOE as a basic source of data in preparing the agency's environmental impact statement (EIS). The ER is developed in consultation with DOE so that adequate information is available on process design, effluents, and onsite conditions.

The EIP staff developed generic environmental guidance for preparing ERs that will be submitted to DOE. The guidance document was written to permit flexibility so that the applicant, in consultation with DOE, can focus on significant issues in detail and provide only general baseline information for issues where no significant impacts are anticipated.

The emphasis of a specific ER is on the applicant's preferred alternative. A brief description of other alternatives considered by the applicant will be included. Assuming an adequate environmental review of alternative projects was conducted at the procurement level, DOE focuses the project-specific EIS on a relatively narrow range of alternatives, including the no-action alternative, alternative sites, designs, pollution abatement systems, and other agency actions which may be available. Although the ER is a major source of information for the DOE impact statement, the agency needs to develop additional data to permit an independent analysis of alternatives and potential impacts.

A set of technology-specific environmental guidance documents is currently under development which will identify specific issues related to major alternative energy technologies. These documents will supplement the gr · ER guidelines.

In addition to the preparation of environmental guidance, EIP is providing technical assistance in two other areas. An inventory was developed of projects throughout DOE, focusing on project identification and NEPA compliance. This inventory will be used by the NEPA Affairs Division to evaluate and advise project offices on compliance requirements (e.g., scoping) and schedules. The EIP staff also provided technical evaluations of NEPA documents prepared by other agencies and submitted to DOE for review. Most of these evaluations were assessments of constraints to energy development (e.g., uranium deposits, oil shale, hydroelectric potential) which would be imposed by designation of wild and scenic rivers. The EIP staff also responds to specific requests for short-term technical assistance to the NEPA Affairs Division on a variety of other projects.

Evaluation and Analysis of 316 (a, b) Demonstration for EPA

The EIP, through an interagency agreement with EPA-Region V, performs reviews, analyses, and evaluations of Section 316 (a, b) material to determine the acceptability of power plant cooling intake and discharge systems in accordance with the Federal Water Pollution Control Act amendments of 1972 (PL 92-500). Federal and state regulations designed to implement the technological standards prescribed by the Act place strict limitations upon the discharge of heat from stream-electric power plants. Even if these standards are being exceeded, a thermal discharge can still comply with the statutes of the Act by demonstrating, under Section 316 (a), that the effluent limitations are unnecessarily stringent. This is accomplished by providing evidence that alternative, less-stringent thermal effluent limitations can still assure "the protection and propagation of a balanced, indigenous community in or on the receiving water body."

EPA contracts with the EIP to provide technical evaluations of validity of the demonstrations. Three evaluations were completed and two are in progress. Studies on the Prairie Island nuclear generating plant (PINGP) on the Mississippi River involved a detailed analysis to assess the ecological impacts of the cooling water intake. Results of our study indicated that the white bass population in the area of PINGP could be reduced by 0.7 to 24% due to entrainment through the present intake system. A significant highlight of this study relates to our recommendation for installation of modified vertical fine-mesh traveling screens as an alternative intake system for Prairie Island. The power company, the Minnesota Pollution Control Agency, and EPA endorsed our recommendation, and the power company plans to install this intake system at Prairie Island to reduce cooling-water-related ecological impacts at an estimated cost of $7 to 10 million.

The analysis and evaluation of the Muskingum River power station [316 (a, b)] was also a major project. The analysis of the 316 (a) data indicated that, except for short periods in the summer when temperatures may limit the distribution of a few fish species, the thermal discharge does not affect the population structure or abundance of fish in the vicinity of the plant. Consideration of the 316 (b) data revealed that the present design, location, and operation of the plant do not serve to minimize entrainment impacts; however, the present location of the intake appears favorable for minimizing impingement-related impacts.

Ongoing efforts under this interagency agreement include determining the status of the Ohio River fish community and a review and critique of the Monroe Power Plant 316 (a, b). Determining the status of the Ohio River fish community will allow the significance of Public Law 92-500 (316 a, b) and the NEPA on the Ohio River to be evaluated. The significance of these acts can be evaluated by comparing the present status of the Ohio River aquatic communities to the communities in the river prior to passage of these acts in the early 1970s. A description of the current status of the fisheries will also serve as a background for the interpretation of site-specific environmental impact statements and 316 (a, b) compliance reports.

Monitoring Protocols Development Project

The purpose of the Monitoring Protocols Development Project is to develop and demonstrate site-specific monitoring protocols for conducting scientifically valid, cost-effective assessments of the nonradiological impacts of energy-production facilities on ecosystems. Our approach is unique in that field monitoring techniques, experimental-perturbation techniques, and analytical techniques derived from ecological theory are integrated and used to identify vulnerable ecosystem components and processes. Monitoring resources can then be optimized, and the information can be used to make the best possible evaluation of ecological impacts.

Preliminary work performed during the first two years of the project consisted in evaluating statutory requirements for ecological monitoring (Sanders et al. 1979), evaluating the usefulness of existing ecological data bases for incorporation in site-specific assessments (Huber et al. 1980), and developing general strategies for measuring and assessing ecological impacts (Sanders et al., 1980). In the last year our focus shifted from the production of review and synthesis reports to the development and demonstration of two components of our integrated approach to site-specific monitoring and assessment: experimental perturbation systems and analytical methodologies. Once this developmental work is completed, funding will be sought to perform a full-scale field test of the methodology at a DOE energy-production facility.

Perturbation experiments performed using field enclosures or mesocosms offer a direct method of investigating the effects of complex effluent mixtures on ecosystems. For such experiments to be useful in site-specific assessments, it must be possible to construct the experimental systems at a reasonable cost and to perform the studies within a reasonably short time. In addition, the results obtained from the experiments must be representative of the actual effects of the effluent on the receiving ecosystem. As a first step in the development of practical experimental systems, we evaluated existing microcosm and enclosure systems with respect to ecological realism, practicality, and cost. An evaluation of terrestrial systems was published (Suter 1980). Evaluations of marine/estuarine and lotic freshwater systems were performed, and draft reports are now in review.

Mathematical models can be used to formulate explicit hypotheses about potential impacts which can be tested using perturbation experiments. Models can also aid in the interpretation of results obtained from both experiments and operational monitoring studies. A detailed, site-specific ecosystem model is, in principle, the ideal tool for predicting impacts. However, practical problems associated with complex models prevented them from being widely used in impact assessment. The objective of this subtask is the development of alternative analytical methodologies that are more practical for monitoring/assessment studies.

We are currently evaluating two candidate methodologies: input/output analysis (Finn 1976, Lettenmaier and Richey 1978) and loop analysis (Levins 1974). Two reports on the derivation of material cycling indices using input/output analysis were prepared and are in review. During the last year we used computer simulation experiments to examine both loop analysis and input/output analysis. Specially designed stochastic simulation models are being used to examine the sensitivity of loop analysis to violations of the steady-state assumption. In addition, we are developing the computer programs necessary for applying input/output analysis to synthetic data generated by an ecosystem simulation model. This simulation experiment will be designed to simulate, as closely as possible, the conditions that would be encountered in an actual field application. Its purposes are to test the reliability of methods used to compute the matrix of flow coefficients used in input/output analysis, to test the ability of input/output models to predict changes in the structure of ecosystems when stress is applied, and to explore the relationships between the cycling indices derived from input/output analysis and more conventional measures of adverse impact (e.g., change in stability and/or species composition).

The EIP concluded an agreement for cooperative research with Dr. Harry Leland of the U.S. Geological Survey. Dr. Leland had performed experimental studies of the effects of low-level copper pollution on stream ecosystems, using an experimental design similar to one that we might propose. Our primary goal is to obtain hands-on experience at using our analytical methodologies to interpret data obtained from perturbation experiments. In addition, we will use the Convict Creek data to evaluate and refine an experimental protocol for artificial streams that we have developed.

Environmental Impact Statement Projects

Fuel Conversions Project

The Fuel Use Act (FUA) project was initiated this past fiscal year to provide technical assistance to the Economic Regulatory Administration's (ERA) Office of Fuels Conversion in its implementation of the Power

Plant and Industrial Fuel Use Act. The primary purpose of the legislation is to further the national policy of minimizing reliance on petroleum and natural gas. The Act prohibits the use of these fuels in new electrical generating facilities and major industrial boilers and provides a vehicle for DOE to order existing utilities and major industrial users which are capable of using coal or an alternate fuel to cease burning oil or natural gas. EIP's involvement in the FUA project centered on the analysis of environmental effects of conversion of existing oil-burning electric utilities in the Northeast to coal or to an alternate fuel.

The environmental review process for the FUA evolved as a prime example of the concept of tiering put forth under the new CEQ regulations. The concept is intended to focus discussion of environmental issues at a scale appropriate with the level of environmental review. Agencies are encouraged to prepare broadly focused EISs for major programs or policy decisions, followed by briefer, more narrowly focused EISs for specific actions under the program. The generic EIS for the FUA legislation focused on the environmental implications, on a national scale, of increased coal utilization resulting from implementation of the Act. Of the 107 existing generating units at 50 stations which ERA has identified as prime candidates for conversion to coal or to an alternate fuel, over 75% are located in the northeastern United States. Consequently, the decision was made to prepare a Northeast Regional EIS to address on an appropriate scale the cumulative impacts of prohibiting these northeastern facilities from burning oil or natural gas.

EIP personnel were instrumental in instituting the tiering of regional and subsequent site-specific EISs and participated in scoping of issues for the regional EIS. The major issues include degradation of air quality, health effects, potential exacerbation of the regional acid rain problem, availability of adequate disposal facilities in the densely populated areas for the increased amounts of ash and scrubber sludge, and adequacy of local rail and barge transportation facilities to handle the coal. The EIS is subdivided into five major task groups: air quality impacts, transportation, health effects, fuel availability, and waste disposal. ORNL is responsible for the first three tasks; Argonne National Laboratory has responsibility for the latter two.

The staff is also preparing EISs for the proposed issuance of prohibition orders for two oil-fueled electric generating units at two stations in metropolitan New York. The units are located at the Arthur Kill facility on Staten Island and the Ravenswood plant in Queens. The fact that the units are located in the most densely populated metropolitan region in the country makes their conversion especially sensitive. Local concern has been expressed over whether the units can be converted to coal without significant degradation of local air quality with possible adverse health effects on the surrounding population. Additionally, there is a dearth of adequate landfills for the increased amounts of ash. The staff is analyzing these and other environmental issues.

Geothermal Project

Technical assistance to DOE's Division of Geothermal Energy accelerated in FY 1981, with the primary emphasis on site-specific environmental analyses of research, development, and demonstration projects and geothermal loan guarantees. Final EIAs were published for direct heat use demonstration and for a hot dry rock research project and a geopressure well test.

As part of loan guaranty project support, a draft EIA was issued for the direct use of geothermal water to provide cooling and process and space heat for a commercial mushroom-growing facility. A draft EIA was also issued for a loan guaranty application to support an electric generating facility, south of the Geyers, in Sonoma County, California.

The EIP staff also participated in a review of a California State Environmental Impact Report for a second phase of activity in the Imperial Valley, South Brawley Project. This activity was initiated in response to the CEQ regulations encouraging joint federal and state environmental reviews and to reduce duplication of effort. The state Environn... al Impact Report was subsequently adopted as an addendum to DOE's Final EIA for the South Brawley Loan Guaranty Application, which had been prepared by ORNL and published in ...

The EIP staff participated in environmental evaluations of two DOE-sponsored demonstrations of commercial-sized geothermal power plants. A final EIS was issued for the 50-MW flash-cyle power plant at the Baca location, New Mexico. The staff prepared an alternative tradeoffs analysis and concluded that the Baca location was not the environmentally preferable alternative. However, based on technical, management, and other program objectives, DOE decided to fund the demonstration project at the Baca site.

An EIA was completed for the 50-MW Heber Binary Cycle Demonstration Power Plant in California's Imperial Valley. A critical issue concerned the potential adverse effects of salt drift from the power plant's cooling towers on adjacent valuable croplands. For most of its operating life, the Heber binary plant will use agricultural return flow in the cooling towers, which will operate with a drift salinity of 20,000 mg/L. The staff analyzed three alternative drift loss rates: 0.1% of circulation water (corresponding to no drift eliminators) and 0.008 and 0.002% (corresponding to use of reasonably achievable and state-of-the-art drift eliminators).

The analysis revealed that some agricultural soils in the project vicinity are currently at, or very near, their maximum leaching capacity. Significant incremental salt as drift could cause moderate to severe salinization of these soils. The staff concluded that a 0.1% drift loss rate could result in salinization of up to 250 ha of cropland, with crops on an additional 150 ha suffering damage from deposition of salt on foliage. With the reasonably achievable loss rate of 0.008%, the staff predicted that less than 25 ha of croplands might be adversely affected by salt from the towers and that if state-of-the-art drift eliminators were used, holding loss to 0.002%, effects would be negligible. Based on the staff's analysis, the commercial partner decided to utilized eliminators capable of reducing drift loss to 0.008% and to institute a monitoring program during the initial years of operation to determine whether the towers should be retrofitted with eliminators which would reduce the loss rate to 0.002%.

Fossil Energy Environmental Project

As participants in the ORNL Fossil Energy Environmental Project (FEEP), EIP staff provided ecological analyses for EISs on six proposed DOE coal conversion demonstration projects. Two of these facilities (SRC-I and SRC-II) are coal liquefaction plants, while the other four (ICGG, Conoco, MLGW, and Grace) are coal gasification projects for producing pipeline or industrial fuel gas. These demonstration plants are critical to the nation's efforts to develop a synthetic fuels industry, and the EISs will receive a high degree of public visibility. The draft EIS on the SRC-II project was released to the public in May 1980 and has received extensive comments from agencies and public interest groups. The preliminary drafts for the other projects are being modified in partial response to comments on the SRC-II document and will be released for public review late in 1980 or early in 1981.

Preparation of the six coal conversion EISs (which are among the first major EISs that DOE has prepared under the new CEQ regulations for implementing the NEPA process) presented the project staff with a number of challenges. A public scoping process in which EIP staff actively participated was held for each of the projects and revealed considerable public concern about siting and potential release of carcinogens.

Because the demonstration projects involve newly developing technologies, the staff had to deal with the particularly difficult problem of assessing environmental impacts for a process with poorly characterized effluents and emissions. DOE determined that the impact statements were to be prepared using a conceptual design because finalization of the design would represent a major commitment of funds and therefore a significant action under NEPA. The staff, therefore, based its analysis on data available from bench-scale and pilot plant research, information from industries using related technologies, and predictions of the nature and amounts of effluents based upon the conceptual design.

In its comments on the SRC-II EIS, EPA objected to preparing an EIS using such preliminary information. As a result of subsequent consultation, DOE and EPA developed a memorandum of understanding which commits DOE to undertake a comprehensive monitoring program and submit information on the final design and the results of the monitoring program to public review at a later time. The monitoring program, which EIP staff is currently developing, will become a critical part of the environmental review process.

The coal conversion projects provided EIP staff with additional experience in preparing analyses needed to meet new or revised regulatory requirements. Since several of these projects would affect floodplains and wetlands, an assessment was needed to satisfy new DOE regulations for complying with executive orders regarding floodplain management and protection of wetlands. Project staff evaluated the potential impacts resulting from the proposed project and alternatives which would avoid or minimize disturbance of such areas.

Consultation with the U.S. Fish and Wildlife Service (USFWS) indicated concern about potential impacts of the SRC-I project to the Indiana bat, an endangered species. To comply with the provisions of the Endangered Species Act, EIP staff helped DOE and the industrial partner assemble a team of experts to conduct field studies. The staff then used the collected data to prepare a biological assessment for submittal to the USFWS. Although Indiana bats were found on the site, the assessment indicated that impacts to the species would be minimal because no critical habitat was present on or in close proximity to the site.

Uranium Fuel Cycle Project

Evaluation of potential environmental impacts is an integral part of the licensing process for uranium fuel cycle facilities. Environmental assessments are required to support NRC licensing decisions on new and continued activities including uranium mining and milling, fuel processing and fabrication, and decommission and site reclamation of inactive uranium recovery facilities. The EIP staff provided technical assistance to the NRC's Office of Nuclear Material Safety and Safeguards by conducting several assessments of uranium fuel cycle operations during this reporting period. The projects (Table 3.1) include open-pit uranium mining, in situ uranium mining, fabrication of uranium fuel rods, and decommissioning a uranium mill complex.

Table 3.1. Nuclear fuel cycle projects reviewed by EIP staff in FY 1980

Project title	Location	Fuel cycle component	Activity completed
Bison Basin	Fremont County, Wyoming	In situ uranium mine	Draft environmental impact statement
Edgemont Uranium Mill Decommissioning	Fall River County, South Dakota	Decommissioning a uranium mill complex	Initiation of ecological analyses
Federal-American Partners	Fremont County, Wyoming	Open-pit uranium mine, uranium mill	Initiation of ecological analyses
Alabama Nuclear Fuel Fabrication Plant	Autauga County, Alabama	Uranium fuel fabrication plant	Preliminary draft environmental impact statement
Sand Rock Mill	Campbell County, Wyoming	Open-pit uranium mine, uranium mill	Acceptance review of ER

Special Projects

The special projects team completed programmatic EISs for the Biomass Energy Systems and the Aquifer Thermal Energy Storage programs during FY 1980. Work in progress includes an EIS for a proposed Defense Waste Processing Facility (DWPF) at the Savannah River Plant, an EIA of mining and retorting Chattanooga oil shale, and an EIA and outreach support for conventional fuel ethanol production for the Office of Alcohol Fuels.

The DOE Biomass Energy Systems Division supports production, conversion, and end use of all forms of biomass and biomass-derived fuels except alcohol. Consequently, the biomass programmatic assessment had a broad scope. Assessment of production and harvesting considered the wood resources of mill wastes, forest residues, noncommercial forest and silvicultural energy farms, the agricultural resources of energy crops, crop residues and livestock wastes, and both freshwater and marine aquaculture. Conversion assessments considered direct combustion, anaerobic digestion, fermentation, and thermochemical conversion (gasification, liquefaction, and pyrolysis). As might be expected from such diverse energy sources, environmental impacts ranged from beneficial to benign to highly detrimental. An example of a beneficial impact would be the conversion of feedlot livestock wastes to methane by anaerobic digestion, thereby ameliorating a waste disposal problem. Among the potentially most serious impacts were those deriving from open-ocean kelp farms. Because of their large size and the fact that very large volumes of cold, deep water would be pumped to the surface to supply nutrients, the climate, biology, and morphometry of coastal areas could be affected.

The Aquifer Thermal Energy Storage program promotes the use of aquifers to store heated or chilled water for later use in space heating or cooling. One example uses the waste heat from an industrial process (aluminum smelting) to provide winter heat to a nearby commercial district. Water is drawn from the aquifer, passed through a heat exchanger where it is warmed, and reinjected upstream in the same aquifer. Heat storage can occur year-round. During the winter, warmed water is withdrawn from the aquifer for space heating. Conversely, spray fields can be used to chill water in winter for storage and retrieval during summer for cooling. No significant impacts to ecosystems were identified during the assessment. Potential degradation to ground-water quality was identified as a major concern, as were effects on aquifer permeability.

In 1950, the U.S. Government set aside 800 km^2 in southwestern South Carolina for the production of nuclear materials for national defense. Since production began, some 76,000 m^3 of high-level radioactive wastes have accumulated in storage tanks on the Savannah River Plant reservation. DOE now wishes to reduce the volume of that waste and package it in a form suitable for eventual permanent disposal. A large industrial facility known as the Defense Waste Processing Facility (DWPF) will be required.

Although the Savannah River Plant was set aside for an industrial purpose, less than 5% of the land area is actually occupied by man-made structures. The remaining area has been planted into pine or allowed to revert to native vegetation, and all is protected from public access. The value of the reservation as an environmental research site was recognized early, first with university contracts to study the biota and later the establishment of the University of Georgia's Savannah River Ecology Laboratory on the reservation. Finally, the U.S. Atomic Energy Commission designated the entire reservation as the first National Environmental Research Park (NERP) in 1972.

There are no serious environmental issues associated with building the DWPF at the Savannah River Plant, because the reservation has already been dedicated to industrial use and the NERP was established as a means to study the effects of industrialization on natural systems. The ecological assessment rather focused upon the alternatives of design and location within the reservation. Issues focused on protection of unique assemblages of flora and fauna and the impact construction and operation of this facility will have on current and future NERP scientific objectives.

The equivalent of 2 to 4 trillion barrels of oil is contained in shales within the United States. By far the majority of the oil is in the Green River formation of Colorado, Wyoming, and Utah. The Green River formation shales produce an average of 0.095 m^3 (25 gal) of oil per ton of rock while the eastern black shales produce only about 0.04 m^3 (10 gal) of oil per ton of rock although their carbon content is essentially equivalent. However, a recently developed high-pressure, hydrogen-atmosphere retort process reportedly produces yields equivalent to the western shales.

The laboratory began an internally funded study of the Chattanooga formation, a Devonian shale of middle Tennessee, southern Kentucky, and parts of northern Alabama and Georgia. This will allow the development of the expertise needed if commercial development of eastern shales does proceed. Issues to be clarified are the feasibility of eastern oils shale development and the identification of areas, process and environmental constraints, and mitigation measures. The EIP is involved in the overall assessment of the impacts of mining, retorting, and waste disposal.

Major issues appear to be impacts on hydrology and water quality, air quality, and stabilization and vegetation of spent shale. Because of the expense associated with removing the overlying Fort Payne dolomite, little surface mining is anticipated. Aboveground disposal of spent, surface-retorted shale is expected and will result in atmospheric loading of particulates, leaching and runoff of acid and metals, and the need to establish a vegetative cover on a material that is essentially an extremely poor plant-growth medium.

Finally, ORNL was designated as the environmental compliance field center for the new DOE Office of Alcohol Fuels. In this capacity, we are responsible for program planning, advice on compliance needs, environmental impact assessments and statements, and outreach. Current activity includes preparation for an environmental compliance workshop for alcohol fuel producers and the preparation of generic environmental health and safety assessments for conventional fuel alcohol plants producing 0.06 to 0.67×10^6 m^3 (15 to 150 million gal/year).

Long-Range Environmental Issues Analysis

Oak Ridge National Energy Perspective

The Oak Ridge National Energy Perspective (ONEP) was designed to provide an independent judgment of the factors that constitute the basis of our national energy problem and to articulate a rational perspective of the nation's energy future to clarify the priorities for allocating the Laboratory's resources during the 1980s. The goal was not to forecast the energy future, but rather to decide on the future that was desired and then to characterize policies that would tend to bring that future into being. The two questions which were to be answered were (1) what is the energy crisis and (2) what is a reasonable strategy for dealing with it. To provide resource information for the steering group performing the analysis, individuals and groups within ORNL were asked to prepare background papers covering different aspects of energy supply and demand. The staff prepared working papers on three topics: (1) environmental implications of current energy systems, (2) environmental implications of unconventional energy systems, and (3) environmental implications of different emission standards for combustion devices. The thrust of these evaluations was an iterative, interactive analysis to set likely limits of environmentally acceptable and attainable levels of development for each of the conventional and novel technologies.

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4. ECOSYSTEM STUDIES PROGRAM

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Introduction

The Ecosystem Studies Program consists of National Science Foundation-supported research designed to increase our understanding of both aquatic and terrestrial ecosystem function and Department of Energy-supported research which addresses issues associated with successful utilization of fuels from biomass. National Science Foundation activities currently include work in systems analysis, spiralling of nutrients in stream ecosystems, and global carbon inventories and cycling. Fuels from biomass activities deal with production and harvest of wood for fuel and environmental constraints associated with utilizing agricultural and forest residues for fuel. Strong emphasis is placed on interaction and collaboration with outside institutions as evidenced by the number of universities and federal agencies involved in our efforts. Educational aspects of the program include support of undergraduate and pre- and postdoctoral candidates who are actively involved in one of our five major research areas.

Research activities in the extending systems analysis in ecology project were initiated on March 1, 1978, for a three-year period. The primary objectives of this project are (1) to provide analytical approaches and solutions to ecosystem-level problems that are important to continued progress of the self-discipline of systems ecology, (2) to develop and apply new analytical systems ecology methodologies which aid in advancing our basic

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understanding of ecological phenomena, and (3) to apply systems analysis techniques from other disciplines to ecological problems of current concern. Major areas of research effort include forest dynamics, error analysis, and community dynamics. Significant accomplishments this year include development of seven new dynamic simulators for temperate, tropical, and managed forests. These models are being utilized in increasing our understanding of forest dynamics and evaluating the impact of pollutants on these systems. Our error analysis work concentrated on uncertainties resulting from model structure, uncertainties due to natural variability of the system being modeled, and uncertainties associated with estimation of model parameters. Community dynamics work focused primarily on evaluation of positive feedback systems and on the recognition that recent developments in matrices mathematics are uniquely suited to analysis of these systems.

The material spiralling and stream ecosystems project was initiated on May 1, 1978, for a three-year period, to test the hypothesis that the ability of a stream community to retain and reutilize material such as nutrients and carbon is an important systems-level process that alters stability properties at the total stream system. Experimental studies in this project are designed for utilization of tracers in natural and artificial streams to determine spiralling indices and for manipulating stream systems defining their stability properties. The work is divided into three major areas: measurement of spiralling in stream systems, detailed investigations of spiralling mechanisms, and field manipulation of streams to test the length-stability hypotheses. Third-year efforts concentrated on deriving methods of estimating spiralling lengths from data on downstream flux of an element and the rate at which the element is removed from the water column, and on partitioning of the spiralling length into (1) an uptake length associated with transport in the water column, (2) a particulate turnover length associated with seston transport, and (3) a consumer turnover length due to invertebrate drift. On the basis of our field experiments, we concluded that spiralling of phosphorus, for example, can be observed in field data utilizing radiotracers. In quantifying pathways of nutrient spiralling, we observed in laboratory experiments with particulate matter from Walker Branch that most of the uptake of PO_4-P is biotic and that the uptake length of phosphorus appears to vary seasonally.

The global CO_2 research in the Division is directed toward clarifying the role of terrestrial biota in the global carbon cycle and developing methods for assessing the effects of climatic change that might be induced by increases in CO_2. We are also concerned with how these climatic changes might influence the distribution of terrestrial vegetation. The Global CO_2 Project, which was initiated in October 1978 for a six-year period, is developing mathematical models of global carbon cycling based on newly developed inventories of carbon distribution in world ecosystems and incorporating ocean representations developed elsewhere. Current research is aimed at improving our understanding the role of terrestrial ecosystems in the global biogeochemical cycle of carbon with primary attention on time scales of 100 to 200 years. We concentrated on studies which aggregate across geography, climate, and types of ecosystems to develop inventories for total terrestrial carbon storage and its historical change, as well as models for carbon cycling in the collection of terrestrial ecosystems which have been integrated into the total global cycle representation. Climate reconstruction activities in this project continue to address the development of reliable southeastern tree-ring chronologies and simulation of vegetation reconstruction over the last 16,000-year period utilizing pollen records and forest succession models. Results to date indicate that we can identify and separate the roles of climate and biotic interaction in determining changes in species composition reflected by pollen chronologies.

Fuels from biomass activities increased during the past year with the Division taking on a larger responsibility in the Fuels and Chemicals from Woody Biomass Program, which is DOE's national program for basic research in species screening, stand establishment, advanced management strategies, and harvesting techniques. In addition to our management responsibilities for the 4.4 million dollar, 24-contractor program, we further developed our in-house research on regionalization of our contractor results and accompanying evaluation of environmental impacts of intensive silviculture and on site-specific research on the Oak Ridge Reservation designed to evaluate specific ecosystem effects of intensive silviculture. We are now into our second year of research on the Environmental Effects of Whole-Tree Harvesting Project, which consists of research sites in Oak Ridge and at seven other institutions around the United States. Each of the watersheds in this five-year study have now been harvested after a full one-year accumulation of baseline data, and near-term impacts associated with immediate erosion should soon become evident. Our agricultural residue removal project, Fertility and Tilth Effects of Fuel Crop Residue Removal, is continuing into its second year of funding and is concerned primarily with erosion and nutrient depletion as a rate of residue removal and tillage level. The research being carried out at USDA-SEA Laboratories is beginning to yield information on soil and nutrient loss in both corn and wheat experiments. Modeling is being pursued as a means of extrapolating and interpolating our limited field data and ultimately yielding simple equations that can be used in determining residue removal rates.

Systems Ecology

The Extending Systems Analysis in Ecology project is funded by the National Science Foundation's Ecosystem Studies Program. The major objectives of this project are (1) to provide analytical approaches and solutions to ecosystem-level problems that are important to continued progress of the subdiscipline of systems ecology, (2) to develop and apply new analytical systems ecology methodologies which aid in advancing our basic understanding of ecological phenomena, and (3) to apply systems analysis techniques from other disciplines to ecological problems of current concern. Three major themes pervade this project: forest dynamics, error analysis, and spatial studies; each contains elements of our three major program objectives.

Forest Dynamics

The FORET model was the basis for a considerable part of our work. The original documentation (Shugart and West 1977) described the validation procedure using the demise of American chestnut as the focal point. The following discussion highlights the products from this area of systems.

A stand model for upland forests in Arkansas (FORAR) considers 33 tree species typical of the upland forests of southern Arkansas. It was validated using historical accounts, density-diameter distribution curves, and USDA-Forest Service Continuous Forest Inventory species composition data.

A stochastic stand simulator for loblolly pine plantations simulates planted pine using a wide variation of planting densities and site-index values. The output was validated by simulations employing published values (density and site index) from actual plantations of various ages. The results showed a significant change in overall stand growth and biomass production depending on fire, cutting practices, and variations in density and site.

A model of the Mississippi River floodplain forest includes 33 species dominating the Mississippi River floodplain forest and simulates forest growth and development with variations in flooding and drought. Results indicate that drought conditions are a significant environmental factor in the dynamics of a floodplain forest.

A model of Eucalyptus forests along a montane gradient in the Australian Alps (BRIND; Noble et al., in press) simulates the dynamics of forests along a 2000-m altitudinal gradient with various frequencies of wildfire. The model was validated against independent field data on the growth and yield of Alpine ash forests (*E. delegatensis*) and against known patterns of successional dynamics in these forests.

A model of Complex Notophyll vine forest (subtropical rainforest) in Australia (KIAMBRAM; Shugart et al., in press) simulates the dynamics of 125 species of trees in forests found in the Tweed Range near the New South Wales Queensland border. The model was tested on its ability to reproduce successional patterns of rainforest and was used to assess the impact of current forestry practice.

A model of deer browse effects (FORCAT) is being used to determine the reciprocal effects of deer browsing stand dynamics. The model will be used to develop cutting schedules to optimize deer habitat on the Catoosa Wildlife Management area on the Cumberland Plateau in Tennessee.

A stand dynamics model of a Puerto Rican rainforest (FORICO) was developed for the Tabauoco forest in Puerto Rico. The model was validated on its ability to independently predict diameter frequency distributions in forests of different ages. The model will be used to test the effect of hurricanes on the diversity of this rainforest type.

We plan to collaborate in the development of a Boreal succession model with the Fire Science Centre, University of New Brunswick, and the Forest Science Laboratory, Oregon State University, and in the development of a simulator for coniferous forests of the Pacific Northwest. Such collaborations are a desirable adjunct, and we expect to continue to build models either by visits of our staff to research centers (as was done with Shugart in developing two models for Australian forests), or by visits of staff from other institutions to Oak Ridge.

Error Analysis

In summarizing the results for the present funding period, we highlight major conclusions under three categories: (1) uncertainties resulting from the structure of the model, (2) uncertainties due to natural variability of the system being modeled, and (3) uncertainties associated with the estimation of model parameters.

Prediction uncertainty is a function of the mathematical formulation chosen to represent processes in the system. Six nonlinear models were calibrated to the same data and their prediction uncertainty was compared. Differences in mathematical formulations caused major differences in prediction uncertainty among the models. Parameters associated with loss terms affect primarily one state variable and the simpler the term the less the error. However, terms describing relationships between state variables can play a dominant role in total errors, and greater complexity is desirable

Amplification of parameter errors can be the most important factor in deciding among model structures. Model variance may dominate the total sum of squares for a model and be more important than estimation bias (deviation of model from "truth") in determining the uncertainties of model predictions, yet most models are developed and parameterized to minimize estimation bias.

Ignoring natural system variability in a deterministic model always results in prediction error. The prediction of a deterministic model using the mean values of each parameter is not equal to mean behavior of the system when the parameters are allowed to vary around their means (O'Neill and Gardner 1979). The systematic bias introduced can lead to serious error in some circumstances.

Natural environmental constraints place boundaries on model error. Natural processes, such as seasonal changes in light and temperature, place upper and lower boundaries on what is biologically possible. Models which consider these constraints explicitly also show bounds on their error terms.

Environmental variability must be considered in designing field validation experiments. Discrimination between models can be done most effectively with data collected during periods when conditions are optimal and system components are changing most rapidly.

Parameter means and variances must be estimated with specific model objectives in mind. In our study of a marsh model (Gardner et al., submitted), variance on one parameter was estimated a priori from knowledge about how this parameter varies across marshes. Although this parameter was relatively unimportant to model mechanisms, its variance dominated total prediction uncertainty. When its variance was reduced to the variability that would be expected within any specific marsh, its importance dropped to reasonable levels.

Simultaneous measurement of parameters can be as important as increased accuracy in individual measurements. Simultaneous measurement of model parameters permits estimation of correlations. Including these correlations in the analysis results in a reduction in prediction uncertainty equivalent to reducing the variance on individual parameters (O'Neill et al. 1980).

Sensitivity analysis can lead to erroneous results. Sensitivity analysis is the most common approach used to decide which parameters of a model should be measured most accurately. The assumptions of the sensitivity approach are seriously violated in many ecosystem studies. In our analysis of a marsh model, we were able to show that sensitivity analysis directed the researchers' attention to the wrong parameters.

Community Dynamics

During the past two years our group studied positive feedback systems from the analytic point of view, as well as researched phenomena in which such processes occur. The first important result of this work was the recognition that recent developments in the mathematics of matrices (namely the theory of M-matrices and Morishima matrices) were uniquely suited to the analysis of systems characterized by positive feedback loops involving many different system components. In particular, it was possible to evaluate the stability of a large system (linear or nonlinear) by simply calculating the principal minors (determinants of the principal submatrices) of the system matrix. Criteria for stability (and hence indirectly threshold criteria for persistence and population irruptions) could be provided in algebraic form, even for very large system models.

Our first application of these methods was to ecological community models involving mutualism and competition among members of the community (Travis and Post 1979). To give a simple example, let us consider a system composed of three species, A, B, and C, where A and B compete and B and C compete, but where A and C are mutualistic. This is a positive feedback system, and analytic conditions are easily found for its stability or for the ability of one of the species, initially absent, to successfully invade. Much more complex systems are also manageable. The stability criteria were extended to nonlinear models (Travis and Post 1979) and to models with delays (Post and Travis 1979).

A second application of our methods was suggested by our work on problems of the persistence of tree or other plant species in dissected (patchy) environments, such as areas of forest islands, which constitute much of the landscape of the eastern United States (DeAngelis et al. 1979). Species initially relatively rare in continuous forest cover may not be maintained on individual islands for very long because of random extinctions. Once gone from a particular island, such species would not reappear if there were no interisland seed dispersal, and eventually the species would disappear from the whole landscape. However, if dispersal of seeds by wind or by animals takes place, the populations on any given island could be regenerated periodically so they could persist indefinitely in the whole system. Models of this system, with species populations on each island being the variables, are positive feedback systems.

Problems of disease and pest outbreaks in regions with patchily distributed hosts are similar in abstract form to the forest island problem. In any given small patch, the cluster of hosts may be too small for the rate of transmission to exceed the threshold needed for an epibiotic to become established. If, however, there are many such patches and there is migration of hosts and pests or pathogen vectors among the patches, the rate of contact between infecteds and noninfecteds may be high enough to lead to an outbreak. We derived conditions under which this can occur.

We also adapted the positive feedback matrix criteria to discrete-time systems such as Leslie matrices and their generalization to interacting species populations. In particular, we considered a Leslie matrix model of competing fish populations where the competition coefficients, as well as survival and fecundity, are age-specific. We showed that it is relatively simple to obtain conditions for the stability of communities of mutually coexisting, competitive, age-structured species and that the presence of age structure can lead to significant differences from models that do not consider it.

Material Spiralling in Stream Ecosystems

Nutrient cycling in a stream is coupled with downstream transport, so that one can think of the path traveled by a nutrient atom as a spiral. Our study combines theoretical and experimental approaches to explore the spiralling concept and its potential as a framework for synthesizing stream ecosystem analysis. Theoretical analysis of stream dynamics yields a measurable index of spiralling which we call the spiralling length. Spiralling length can be derived in two ways: (1) for a steady-state system, spiralling length is the total downstream flux of a nutrient divided by the rate at which the nutrient is taken out of the water column by organic matter, substrates, and organisms; and (2) more generally, it is the average downstream velocity of all components of nutrient transport times the cycling turnover time (i.e., the time required to complete one cycle). Spiralling length can be partitioned into (1) an uptake length associated with transport in the water column, (2) a particulate turnover length associated with seston transport, and (3) a consumer turnover length due to invertebrate drift (Fig. 4.1).

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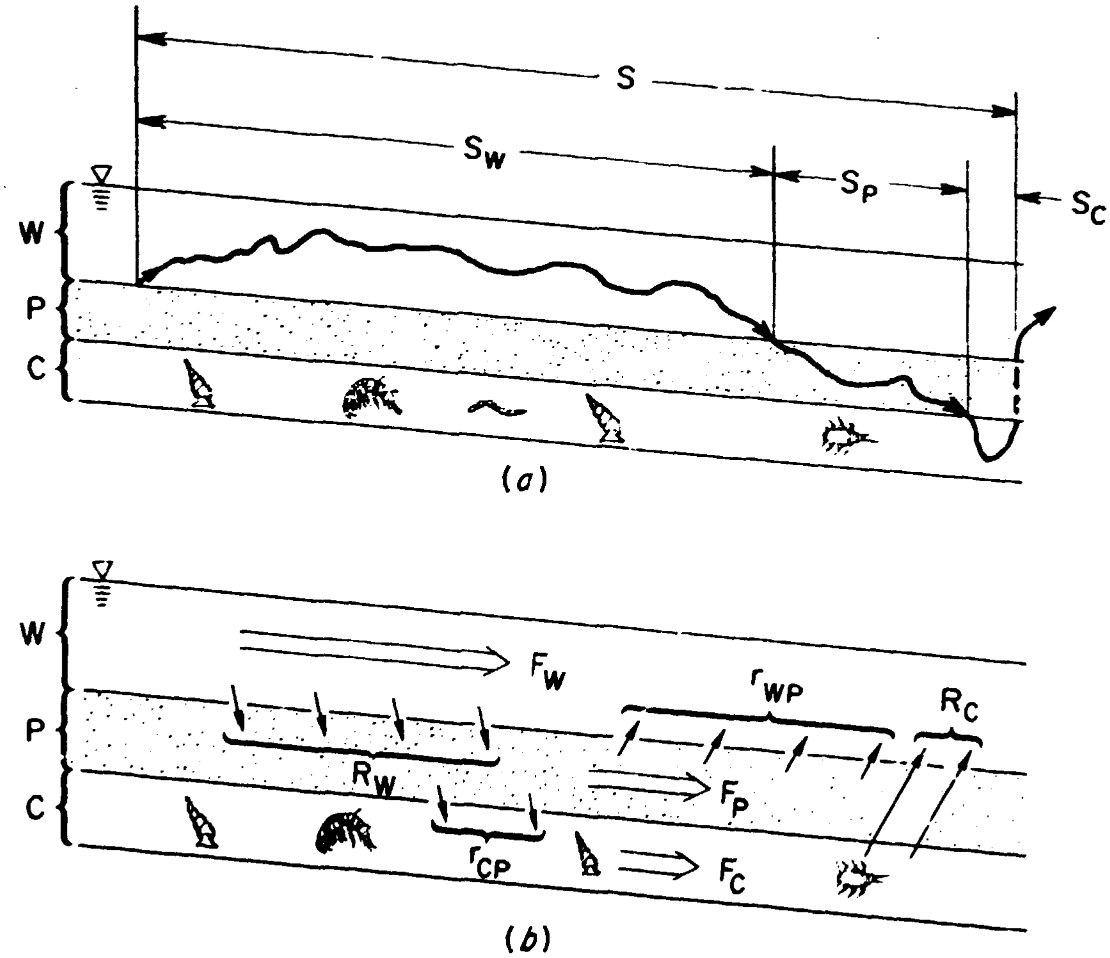

Fig. 4.1. Nutrient spiralling in a stream ecosystem. (*a*) The three components of spiralling length, S. The nutrient atom travels an average longitudinal distance, S_W, dissolved in the water compartment, W, plus an average distance, S_P, in the particulate compartment, P, plus an average distance, S_C, in the invertebrate consumer compartment, C, before returning to the water. (*b*) Downstream nutrient fluxes, F (g s), and exchange fluxes, R (g s^{-1} m^{-1}), of nutrients between compartments. The total release from the particulate compartment, R_P, consists of the sum of the release to the water, r_{WP}, and the uptake by consumers, r_{CP}.

To subject this concept to field testing, we conducted an experimental release of ^{32}P in Walker Branch, a small woodland stream in Tennessee. Measurements were made of ^{32}P in water, seston, coarse particulate organic matter (CPOM), fine particulate organic matter (FPOM), grazers, collectors, filter-feeders, and predators over a six-week period. Analysis of the data was accomplished with a partial differential equation model of stream ecosystem dynamics. This combination of data and model permits an extensive analysis of the components of phosphorus cycling in the stream ecosystem. The radiotracer was initially taken up primarily onto particulates. The CPOM accounted for 60% and FPOM for 35% of the ^{32}P taken up. Analysis of FPOM data indicates both a fast and a slow turnover component. The phosphorus subsequently moved up the foodchain, but only about 3% of the total ^{32}P released found its way into the invertebrates by the end of the sampling period. Transport of particulates was dominated by FPOM, which constituted over 98% of the total by weight. Most of the remaining 2% was composed of CPOM. Over the measurement period, about one-half of the ^{32}P originally taken up by fine particulates was exported as suspended FPOM. Expected travel distance for FPOM was calculated to be 37 m for the fast turnover fraction and 6.7 m for the slow turnover seston. Both aufwuchs and CPOM clearly showed the effects of spiralling. At downstream sampling stations, these components reutilized ^{32}P which had been released from upstream portions of the system.

Uptake into invertebrates was dominated by the snail *Goniobasis clavaeformes*, which also dominated the standing crop of consumers. By the end of the measurement period a significant portion of the ^{32}P remaining in the experimental reach was in consumers, indicating a potentially important role in retention of nutrient within the ecosystem. There was little upstream-downstream difference in ^{32}P concentrations in food sources. Initially, upstream concentrations of ^{32}P food compartments were nearly double the downstream concentrations, but these differences diminished as ^{32}P was released upstream and reutilized in food compartments downstream.

The stream ecosystem model was used to estimate the total stable phosphorus dynamics by running the model to equilibrium with hypothetical inputs. This calculation indicates that only about 20% of the organic particulate pools are exchangeable. Estimates of exchangeable phosphorus for the majority of invertebrates were between 81 and 93%. Calculations of total phosphorus fluxes permitted estimation of all three components of spiralling length. Uptake length (i.e., average distance traveled by a nutrient atom in water) was 164 m. Particulate turnover length was 23 m, and consumer turnover length was 0.0023 m.

On the basis of these results, we concluded that spiralling of phosphorus can be observed in field data utilizing radiotracers. Although our original explorations of the concept involved extensive sampling, spiralling length can be reasonably estimated by short-term measurement of ^{32}P in water samples and seston, combined with laboratory estimates of equilibrium ^{32}P concentration in FPOM. Spiralling length appears, therefore, to be a reasonable index, measurable in the field, which synthesizes transport-dependent and transport-independent phenomena in stream ecosystems.

In addition to quantifying pathways of nutrient spiralling in stream ecosystems based on components of spiralling length, we have investigated mechanisms underlying nutrient spiralling and how spiralling varies seasonally. Nutrient uptake onto stream sediments occurs via two primary mechanisms: abiotic surface adsorption and absorption by attached living microorganisms. Results of laboratory experiments using sterile and nonsterile fine particulate matter and inorganic substrates from Walker Branch, Tennessee, indicated that most of the uptake of PO_4-P is biotic. The uptake length of phosphorus appears to vary seasonally, ranging from approximately 6 m in late fall after leaf drop to over 180 m in summer. Thus, uptake length is shortest in late autumn, when the standing crop of detritus and surface area for microbial colonization are at their annual maximum. If the major site of nutrient uptake is microbes associated with stream sediments, then uptake length will be a function of microbial biomass which, in turn, is a function of the surface area that can be colonized.

Another mechanism of increasing productivity and stabilizing the nutrient availability in stream ecosystems is to store nutrients in sites that are less vulnerable to downstream transport. The greater retention time of phosphorus in Walker Branch in late autumn compared to that during summer and early fall suggests that the turnover of phosphorus sorbed by substrates on the stream bottom is much slower during the late fall period. Phosphorus associated with leaf detritus collected following a November release of $^{32}PO_4$ appears to exhibit an asymptotic decline in activity, with approximately 70% of the ^{32}P having a turnover time of 15 d. However, there appears to be little or no turnover of the remaining 30%, implying that a substantial fraction of the phosphorus is sequestered by microbes into storage sites with a very slow turnover rate. Leaf detritus collected after the ^{32}P release in July, however, did not exhibit this slow turnover compartment. Slow turnover rates in late fall may be a result of the increased nutrient supply from leaf detritus. If this sequestered phosphorus is available to microbes, it could provide an important stabilizing factor during a later period when the demand is high but the supply is reduced.

Global Carbon Dioxide

The NSF-supported Global Carbon Project, initiated October 1, 1978, was developed (1) to determine whether forests and woodlands which comprise the bulk of terrestrial carbon storage are a net source or sink for atmospheric carbon dioxide and (2) to establish a means by which it is possible to predict how the carbon balance might be changed, especially by climatic shifts associated with credible changes in atmospheric carbon dioxide. Our six-year approach in addressing these two objectives includes a series of six subtasks. These are (1) evaluation of major geographic and geochemical carbon pools, (2) determination of land-use shifts as they effect trends in carbon pools, (3) utilization of this information in an overall terrestrial carbon submodel for global exchanges, (4) evaluation of production and loss rates of carbon for the main classes of ecosystems that dominate the terrestrial environment, (5) comparison of the climatic control of present geographic patterns to real climatic fluctuation in post-glacial times, and (6) utilization of all this information for a beginning assessment of how the carbon cycle itself could be modified by future climatic changes which now seem likely to arise if atmospheric carbon dioxide increases substantially.

Carbon Cycling

The carbon cycling activity is aimed at improving our understanding of the role of terrestrial ecosystems in the global biogeochemical cycle of carbon. Our primary attention is directed to time scales of 100 to 200 years and the dependence of the terrestrial component of the carbon cycle on climate. We concentrated on studies which aggregate across geography, climate, and types of ecosystems to develop inventories for total terrestrial carbon storage and its historical change, as well as models for carbon cycling in the collection of terrestrial ecosystems which were then integrated into total carbon cycle representations. Although our emphasis was on globally aggregated models and data, we continue to move toward more detailed representations. Our approach includes three major areas: (1) Distribution of Terrestrial Ecosystems, Associated Carbon Storage, and Their Dependence on Climate; (2) Models for Carbon Cycling in Terrestrial Ecosystems; and (3) Total Carbon Cycle Integration and Modeling.

Recently, Olson prepared his estimates of vegetation distribution in computerized form using the data organization system developed by Hummel and Reck (1979). A vegetation classification is assigned to each 0.5-latitude by 0.5-longitude cell on the earth's land surface. The resulting map forms a much improved basis for constructing models of the terrestrial component of the carbon cycle, allowing treatment of each type of ecosystem and their geographical distribution.

In addition to this ongoing effort at a global terrestrial carbon inventory, the historical changes in carbon at the regional level were analyzed in detail for areas where data are available and our group has first-hand experience. Delcourt and Harris (1980) reconstructed the standing crop of carbon in forests of the southeastern United States from 1750 to the present and clearly established a shift from net source to net sink with respect to the atmosphere. We found a similar trend for the Georgia Piedmont area. In very recent work, Y. H. Chan is completing an analysis of carbon change in Malaysia. He estimates an annual net release of CO_2 from this region of approximately 0.25 Pg.

The largest actively exchanging pool in the terrestrial component of the carbon cycle is in the soil. In collaboration with Paul Zinke at the University of California-Berkeley, this project expanded the data base for estimating the standing crop of carbon in soil. Approximately 2100 profiles for soil carbon were assembled in a computer-readable form. These profiles were initially sorted according to major types of ecosystems and climate conditions to provide preliminary estimates of average soil carbon density for each ecosystem type.

Many studies of the global carbon cycle report that the terrestrial component of the cycle must be treated as a net sink for carbon from the atmosphere in order to balance with models for the ocean. This conclusion depends on the assumed initial concentration of CO_2 in the atmosphere as well as the values for other model parameters. These assumptions and a general approach to including explicit treatment of the less abundant carbon isotopes, ^{13}C and ^{14}C, in models for terrestrial carbon circulation are given in Emanuel et al. (1980a). In a companion paper (Emanuel et al. 1980b), a detailed derivation of relationships for representing isotope fractionation in our model for terrestrial carbon cycling was presented along with further comparison of model response with data which reflect the dynamic characteristics of the total carbon cycle.

Investigations of the exchange of CO_2 between the atmosphere and terrestrial plants on a global scale cannot ignore the complementary role played by the ocean in the world carbon cycle. This principle guided the component of our modeling program that is concerned with dynamics of the total carbon cycle.

The rate of evasion of CO_2 from the ocean to the atmosphere is assumed to be proportional to the (globally averaged) partial pressure, P_m, of CO_2 in the surface waters. Keeling (1973) emphasized the importance of treating the dependence of P_m on the surface water temperature, T. The effect is such that warming of the surface waters or increases in inorganic carbon as a result of uptake from the atmosphere decreases the ocean's capacity for additional CO_2. Using a logistic scenario that would ultimately release about 3000 Pg of carbon to the atmosphere, Killough (1980) carried out long-term simulations to contrast the case of explicit treatment of the dependence of the evasion flux on temperature with the temperature-independent assumption. The predicted maximum in atmospheric CO_2 is 1200 ppmv in the first case and 896 ppmv in the second. A comparison was also made of the result of allowing the temperature to rise 3 K for each doubling of CO_2. In these cases the maximum predicted CO_2 levels were 1200 and 1150 ppmv, respectively.

Killough and Emanuel (1980) compared the response characteristics of five models of carbon turnover in the ocean. Four of the models were prototypes that correspond structurally to models proposed by several investigators. The five were calib[illegible] the same carbon-mass distribution of natural ^{14}C activity, insofar as the individual structures permit, an[illegible]re subjected to the same assumed secular trend in atmospheric CO_2 from 1860 to 1975. The resultant net [illegible] of carbon ranged from 24 to 66 Pg. Correspondingly, the complementary components of carbon that did not remain airborne suggested quite different modes of behavior for the terrestrial biosphere, ranging from a net sink for carbon throughout the simulated history at one extreme to a pattern of alternation between sink and source at the other.

Bioclimatology

Climatic changes due to CO_2 increases in the atmosphere would affect the growth of forest species directly by reducing or enhancing annual productivity and indirectly by controlling competitive interactions among species. The competitive interactions are a function of immigration of new species to areas where climatic conditions have become more favorable for their growth. The separate and combined effects of climatic change and species immigration on forest composition were examined, using a forest stand succession model (FORET; Shugart and West 1977) in concert with a continuous record of fossil pollen data in eastern Tennessee. The pollen record reflects vegetation changes over the last 16,000 years, near full-glacial plant refugia and at least 400 km south of the maximum extent of continental ice sheets. The pollen record should therefore record effects of climatic change with minimal effects of irregular invasions by individual forest species.

Four separate simulation conditions were considered: (1) all species available, climate constant; (2) all species available, climate variable; (3) species sequentially available, climate constant; and (4) species sequentially available, climate variable. Species availability and climatic variability were defined by the pollen record, based on the reasoning that if these factors determined the pollen record, then their use in valid simulations should produce a simulated vegetation record similar to that obtained from the pollen data. If those factors do not determine the vegetation record reflected by the pollen record, or if the model is invalid, then the simulation record would not duplicate the pollen record.

The majority of covariance between pollen and simulation records occurred under climate-variable simulations. In addition, patterns of community response to expansion into empty niches (under species-variable simulations) were characteristically different from community response to species expansion under climate-variable simulations. Both of these patterns can be identified in other pollen records such as Rogers Lake, Connecticut (Davis 1969), Moulton Pond, Maine (Davis et al. 1975) or Yellow Dog Pond, in northern Michigan (Brubaker 1975).

These results demonstrate that we are now capable of identifying the separate roles of climate and biotic interactions in determining the changes in species composition reflected by pollen chronologies. Thus, we can select chronologies which reflect primarily climatic variations for use in reconstructing past biotic analogs to future vegetation shifts which may occur under a CO_2-induced climatic warming. Results from these simulations may then be utilized in estimating world carbon pools under future scenario conditions.

Fuels and Chemicals from Woody Biomass

During 1980, we increased our activities in the Fuels and Chemicals from Woody Biomass Program a program originating with the DOE-Division of Biomass Energy Systems. The purpose of the program is to investigate increasing or improving wood supplies for energy and includes areas of research in species screening; forest stand establishment; new or altered forest management strategies; harvest, collection, transport, and storage of wood fuels; and environmental effects of producing wood for energy. The involvement of the Environmental Sciences Division focused on technical monitoring of the program for DOE and in-house research concerning environmental effects of wood energy development.

The program is now funded at a level of $4.4 million and consists of 24 contracts, primarily with universities. These projects reflect the recent consolidation of DOE-related, wood-energy production projects around the country into one program at ESD. Concomitant with the monitoring activities of site visits, reporting results to DOE, and assistance to DOE in program planning, the Division has taken a more active role in coordination of research and issue identification in wood-energy production around the country and world.

The Fuels and Chemicals from Woody Biomass Program focused primarily on the viability of wood-energy plantations and species screening for biomass and energy production. Results to date showed that wood-energy plantations can be a viable source of supplemental energy in some locations ($22–25 dry ton), that production of 12 to 25 dry metric tons biomass ha^{-1} $year^{-1}$ (5–10 tons $acre^{-1}$ $year^{-1}$) can usually be achieved on good sites in the East, Midwest, Pacific Northwest, and South, and that genetic improvement and species screening can raise this figure 25% or more in the first or second generation of selection efforts. The Southeast has the greatest potential for sustained wood-energy production, and surprising results occurred with semi-arid shrubs of the Southwest (35 metric tons ha^{-1} $year^{-1}$ with irrigation). Spacing and rotation length studies on short-rotation plantations in the East indicate that (1) spacing trees closer than about 2 × 2 m for eight-year rotations is a waste of effort and that (2) harvesting more often than about once every eight years causes the average periodic increment to decline.

Closer spacings with shorter rotations are being evaluated to determine economic possibilities for the small landowner. Utilization of forest slash for fuel (i.e., its collection and transport) received attention both in making collection more economical and making handling more feasible (development of a slash baler). Energy balance studies led to efforts to reduce the use of man-made fertilizers, wood drying by artificial means, and irrigation, all of which consume considerable energy to produce wood energy.

Division activities involving wood-energy development and related to program management for DOE included sponsoring technical workshops for wood-energy production researchers to identify needs for future research, guiding international forest energy tours, reviewing proposals, participating in the International Energy Agency, and speaking about wood energy in the United States at scientific meetings and to public groups.

Research in the Division related to or evolving from program management activities in the Fuels and Chemicals from Woody Biomass Program continued to develop. Included are programs in Environmental Effects of Whole-Tree Removal, Tilth and Fertility Effects of Crop Residue Removal for Energy, and in-house regional studies concerning the potentials and environmental effects of wood-energy development in the Southeast and the country. Future plans include continued program management and increased efforts in environmental research and regional studies with DOE and the USDA-Forest Service.

Environmental Effects of Whole-Tree Harvesting

To investigate the additional environmental effects of residue removal and whole-tree utilization beyond those caused by contemporary harvesting techniques, sites were selected in northern hardwood, oak-hickory, northwestern coniferous, and southern pine forests (Table 4.1). The selected sites have large data bases of nutrient cycling in undisturbed systems providing a reference point for possible nutrient depletion and erosion. In addition, a slash pine experimental forest near Macon, Georgia, was selected for study to evaluate the long-term effects of repeated plantation harvest on productivity. Questions to be answered as a result of this research are: (1) What are the effects of total aboveground woody biomass removal on erosion and nutrient loss and subsequent changes in water quality? (2) What are the changes in nutrient supply? (3) What will these changes mean in terms of subsequent biomass productivity under whole-tree or residue removal harvesting rotations?

Table 4.1. Residue Removal and Whole-Tree Harvesting Research Sites

Location	Forest Type
Gainesville, Florida	Slash pine
Macon, Georgia[a]	Slash pine
Clemson, South Carolina	Loblolly pine
Coweeta, North Carolina	Mixed upland hardwood
Oak Ridge, Tennessee	Mixed upland hardwood
Hubbard Brook, New Hampshire	Mixed northern hardwood, spruce-fir
Thompson, Washington	Douglas-fir, red alder

[a]Research at this site is limited to evaluation of changes in nutrient pools under different rotation periods.

Following the selection of sites, a research framework was agreed upon which would maximize integration of results among the different forest types being studied. Although sites differ both in suitability for certain types of data collection and in available expertise and funding, all sites have certain elements in common, including some form of monitoring of nutrient status, leaching, and productivity.

In addition to the research progress and results described below, a comprehensive data base of species nutrient pools for the sites was compiled to provide estimates of nutrients exported during harvesting. Included in this data base are nutrient concentrations and total nutrient contents of the species of trees occurring on the sites by age-class and tree parts and similar data on many other species.

Harvesting is complete at Hubbard Brook, Clemson, and Coweeta; underway at Thompson; and will be completed at Oak Ridge and Gainesville by the end of 1980. Preliminary data on biomass, nutrient input and loss, and nutrient totals are available from most sites. In addition, instrumentation was installed and permanent sampling plots for growth measurements and system process monitoring were established.

Because the significant adverse effects may be realized immediately after harvesting, indications of the initial difference in environmental effect between total biomass removal and conventional harvesting should be evident by the end of 1981. As an example of information obtained with this study, analysis of data at Oak Ridge indicates that both conventional and whole-tree harvesting will have the greatest impact upon the direct removal of calcium. Removal of total aboveground vegetation with one harvest cycle will deplete 56% of the available calcium content of the ecosystem. We will continue to monitor nutrient dynamics through leaching and erosion processes and, periodically, through inventory vegetation for species composition and biomass. Current plans call for continuation of this study for at least five years, a time span which other studies indicate is sufficient for stabilization of mineral cycling processes.

Fertility and Tilth Effects of Fuel Crops Residue Removal

The fertility and tilth project is a cooperative effort between the Department of Energy and the Department of Agriculture to determine means of maximizing crop residue removal for energy without unacceptable declines in the productive capability of agricultural soils. We are managing the work for the Department of Energy. The research is organized around erosion and nutrient depletion as a function of rate of residue removal and level of tillage. Small plots planted in corn or wheat provide most of the data, while a modeling effort seeks to extrapolate the results to the rest of the country.

Corn and wheat were chosen as our focus because together they account for approximately 57% of all crop residues produced in the United States. Soybeans are the next largest crop with less than 10% of the residues produced nationally. Because soybean residues decompose too rapidly to have an excess for energy production, they were not included in our research design.

Modeling is being pursued as a means of extrapolating our limited field data to areas of the country where we do not have study sites. Ultimately, we expect the modeling effort to yield simple equations that a county agricultural extension agent can use to advise a farmer on residue harvest from a specific field.

Data were collected for only one year, so conclusions are premature. In fact, growing conditions during the past year were anything but typical. Nature seemed to conspire against the wheat plots. Winter wheat was planted in October without the usual preemergence herbicide treatment because of insufficient soil moisture to activate the chemical. Winter rains produced such heavy weed growth that the plots were killed out with herbicide in April and replanted in spring wheat. The eruption of Mt. St. Helens buried the plots in volcanic ash in May, and the unusually cool, wet summer which followed led to a severe leaf rust infestation and >50% yield reduction. Treatment effects on yield, erosion, and loss of nitrogen, phosphorus, and organic matter were not clear due to the confounding variables.

The corn plots yielded interesting results in an atypical year. The early growing season was dry, with insufficient storm intensity to produce erosion. Sediment yield was actually lower on the tilled plots than on the untilled plots due to the water storage capacity of the rough surface. Because storms of sufficient intensity to produce erosion did not occur until after the crop had formed a closed canopy, no differences were seen between tillage levels or residue cover treatments.

The modeling effort is in the model construction phase. Early emphasis is on soil organic matter dynamics and soil moisture dynamics. Existing models were evaluated for their applicability to this program in terms of

data needed to run them and the kinds of information they yield. Two soil carbon models were selected, one which deals with short-term changes (about a year) and one which deals with long-term soil carbon balances. The two models are being adapted for programmatic needs and are being linked together so that output from the short-term model serves as input to the long-term model. A water balance model was selected on the basis of its ability to interface with the organic matter models and yield information on the relative importance of phenomena observed in the field. Ultimately, both models will need to be simplified before they can be of general use.

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5. LOW-LEVEL WASTE RESEARCH AND DEVELOPMENT PROGRAM

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Introduction

Solid wastes generated by laboratory and industrial activities involving radionuclides are frequently contaminated with low-level radioactivity. Where contamination levels are relatively low, it is cost effective to dispose of these wastes by shallow land burial. Some disposal sites have been used for over 30 years while others have been newly opened. During this time period, changes in burial techniques and in situ monitoring practices have been made to keep pace with increased awareness of and concern for environmental radioactive contamination. Corrective action may be required where inadequate containment of radionuclides at older burial sites causes contamination of the biosphere.

This project provides for the development and implementation of new methodologies in environmental monitoring, updating of existing procedures, and standardization of monitoring criteria for all present and future burial facilities. These guidelines, with appropriate modifications, may be extended to encompass alternative disposal options to shallow land burial, such as deep disposal in geologic formations.

The most significant mechanism for transport of radionuclides from shallow land burial sites in the eastern United States is ground-water flow. Water flowing laterally into buried waste or percolating downward from the surface leaches radionuclides from the waste and flows onward, spreading the contamination. Several radionuclides, especially ^{90}Sr, are found in solution in ground water flowing from older burial sites. Methods for immobilization of such radionuclides or for their collection and removal are badly needed. Furthermore, the continued development and implementation of improved shallow land burial practices is necessary.

The overall goal of this work is to develop the necessary technology to ensure the safe, economical, and environmentally and socially acceptable disposal of solid low-level radioactive wastes. Specific objectives include studies of the mechanisms whereby radionuclides are mobilized and transported (or, conversely, retained) at shallow land burial sites, development and evaluation of measures for prevention of mobilization, and development and evaluation of measures for correction of radionuclide dispersion problems at older sites.

Low-level waste storage areas at Oak Ridge National Laboratory (ORNL) are used as a testing and proving ground for monitoring and modeling techniques. Because of the range in age of the ORNL waste storage areas and the similarity of hydrologic and topographic conditions to much of those of the eastern United States, these

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areas provide an excellent setting for real-world assessment of methods. Therefore, where advanced methods are evaluated, the various disposal trenches, pits, and shallow land burial grounds at ORNL have been used. For the most part these areas are contained within the White Oak Creek watershed.

Geological Investigation of the Cambrian Conasauga Group in the Vicinity of the Oak Ridge Department of Energy Reservation, Tennessee

A new research effort was initiated this fiscal year to provide a detailed comprehensive understanding of the stratigraphy, petrology, and geochemistry of the Cambrian Conasauga Group in the vicinity of Oak Ridge, Tennessee. Conasauga Group sediments exhibit very complex lithostratigraphic and geochemical facies variation in this area, and previous research results do not provide adequate detail into the spatial distribution and complex nature of this lithology.

Research began with verification and synthesis of the reported results of previously undertaken geological research. Existing literature, as well as drill cores and geophysical logs from boreholes within the Oak Ridge DOE Reservation, was examined. Drill core was relogged and samples were taken from the drill core for laboratory analysis by standard mineralogical, petrological, and geochemical techniques.

From examination of extensive drill core material from the White Oak thrust sheet in Bear Creek Valley (obtained from Exxon Nuclear), six constituent formations of the Conasauga Group (the Pumpkin Valley Shale, Rutledge Limestone, Rogersville Shale, Maryville Limestone, Nolichucky Shale, and Maynardville Limestone) were delineated. Less complete core data from the Copper Creek thrust sheet in Melton Valley suggest that all six formations are also developed and that they are stratigraphically and lithologically quite similar to the material in Bear Creek Valley. ORNL geophysical borehole logs and a recently obtained U.S. Geological Survey (USGS) log identify at least the lowermost four formations throughout much of Melton Valley. These data suggest that the Conasauga Group from the Oak Ridge vicinity is in the transition zone between the clastic-rich, carbonate-poor "Northwest" facies and the clastic-poorer, carbonate-rich "Central" facies of Valley and Ridge Conasauga Group lithologies (Rodgers, 1953). The data also indicate that the Conasauga Group in the Oak Ridge area has much greater affinity to "Central" facies lithologies than previously had been thought.

X-ray diffraction and petrographic thin-section analysis indicates that all formations within the Conasauga Group are lithologically heterogeneous. Silt- and sand-rich formations may contain significant amounts of carbonate, both calcite and dolomite, typically as cements in subarkosic submature siltstones. Carbonate-rich portions are typically argillaceous or arenaceous interclastic micrites (lime muds) to poorly washed sparse biosparites (fossil-bearing coarse-grained limestones). Such lithologies account for between 30 to 60% of the total thickness of Conasauga in both thrust sheets. Argillaceous portions exhibit a complete gradation from massive, poorly bedded mudstones to fissile shales. Complex color and mineralogical variations are noted reflecting differing modal amounts of kaolinite, chlorite, illite, smectite, mixed-layer illite-smectite, quartz, K-feldspar, glauconite, hematite, pyrite, chalcocite, and organic material; significant amounts of carbonate may be contained as well. Formation contacts are readily recognizable by changes in bedding character and abrupt mineralogical changes, but the general complexity of the group as a whole makes characterization of the Conasauga Group by "average" mineralogical compositions or cation exchange values futile.

Preliminary structural analyses show much evidence of internal deformation throughout the Conasauga Group in both Bear Creek and Melton valleys. Numerous small-scale folds and faults are observed both in drill core and in outcrop. Argillaceous portions typically are slickensided, indicating substantial bedding plane slip has occurred. Such slippage and most of the folding were contemporaneous with a major regional thrusting event. The Conasauga is also highly jointed and locally fractured. Most jointing is synthrusting and some joints have been subsequently filled with calcite; many others, however, still remain unfilled. Fractures are syn- and post-thrusting and typically exhibit evidence of having sustained substantial fluid flow (e.g., vein fillings and wall-rock alteration).

Research is continuing to establish a detailed lithostratigraphic map of the Conasauga Group in the Oak Ridge vicinity. Sedimentological, mineralogical, and petrological analyses are planned to document spatial and temporal variations in the Conasauga depositional environment and the subsequent diagenetic and deformational events responsible for the presently observed lithological and geochemical variability of the Conasauga Group at this locality.

Appraisal of Present Monitoring System

The monitoring practices for waters in the waste management areas at ORNL have been reviewed. Although surface waters are routinely monitored at several locations within and downstream of the waste disposal areas, no ground-water monitoring has been employed. Furthermore, the data available on burial grounds have been deemed "inadequate for the design of reliable monitoring programs" (Dames and Moore 1978).

During FY 1980 this subtask was devoted to the design of a preliminary ground-water monitoring plan. Since definition of geohydrologic conditions at the ORNL site is the primary function of the ongoing USGS project at the site and results from that effort have not been available, a design has been constructed without detailed knowledge of ground-water flows. To approximate the extent and range of present ground-water contamination with radionuclides, a quarterly ground-water sampling and analysis effort was conducted. The preliminary monitoring design is based primarily on information from that sampling effort.

A system for recording and storing radionuclide analyses results in computer-retrievable format was developed and implemented to aid in providing information on the distribution of radionuclides in shallow-land disposal sites. The required information and the format for recording results on punched cards are described in the SORA computer program documentation (Huff 1980). The required information includes data on site location, elevation, and past history, as well as results of radiochemical analyses, identification of laboratory log and report numbers for each sample, type of sample, and primary investigator. Where appropriate, observations such as well-water level may be included.

At present, nearly 2000 individual records have been stored in an interactive data base management system, and these data are available for access on demand. With the system, it is possible to select all records available for a user-specified area, sort them, and prepare a record by site, date, and radionuclide. Alternatively, it is possible to select an area and request all observations greater than a specified value for a given radionuclide. Where data are available and have been entered into the system, each of the above tasks can be completed in less than 5 min, including report generation. We still need to incorporate more of the extant radionuclide data into the system; however, current priorities will prevent this in the near future.

In cooperation with the USGS, water-level observations for wells in Solid Waste Disposal Areas 3, 4, and 6 have been loaded into the data base management system. A total of 8155 records that cover the period from April 1975 through September 1979 are available. With the computer software that has been developed, graphs such as that shown in Fig. 5.1 may be generated. The locations of the 278 wells represented in the data base may also be plotted to allow examination of the distribution of the present monitoring system. Data for observation wells in SWDA 5 will be supplied by the USGS in the future, but it is anticipated that support for the data system will not be available to load those results into the system or to continue to make existing results available.

Transport Controls

Transport of radionuclides from eastern U.S. disposal areas by water dominates all modes of contaminant dispersal. Detailed understanding of the movements of water and of its interactions with disposed waste is

ORNL-DWG 81-3881 ESD

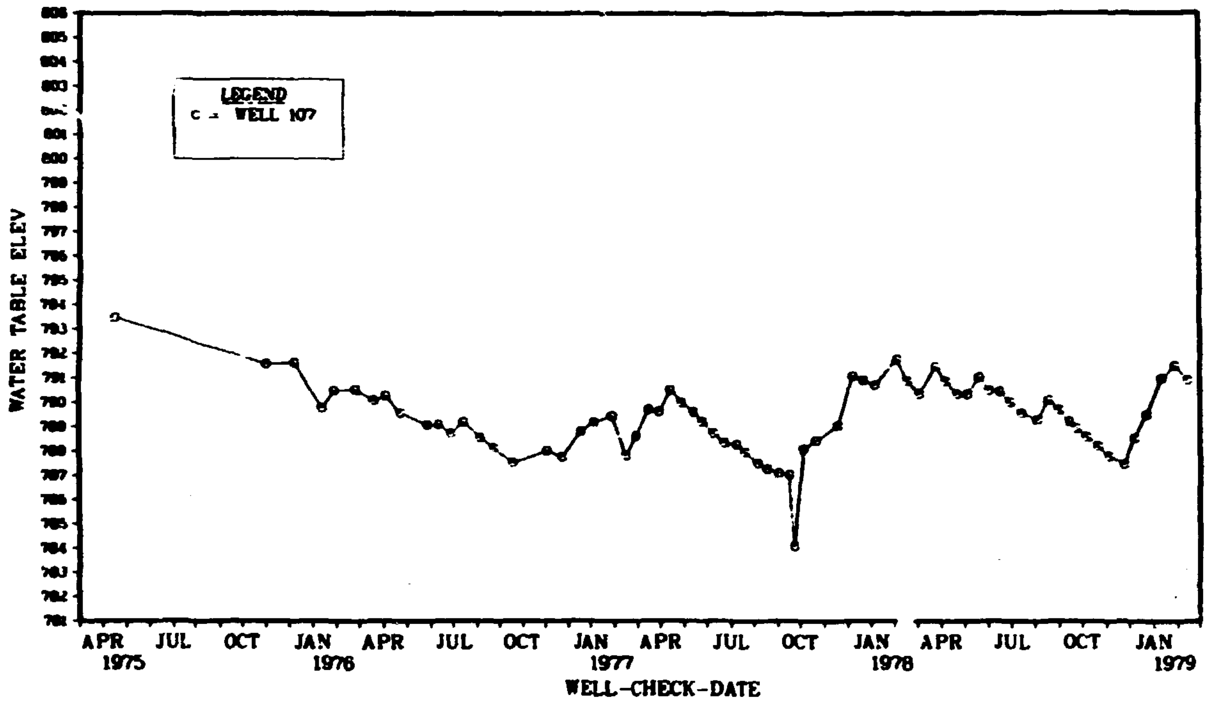

Fig. 5.1. Well 107 area 6 water table elevation vs check date.

essential for the adequate design of remedial measures and for the prevention of future contamination resulting from current disposal.

Solid Waste Disposal Area 4 Case Study

As a case study, ground- and surface-water transport of ^{90}Sr in Solid Waste Disposal Area 4 (SWDA 4) has been determined in order to evaluate the relative importance of these two modes of transport and to suggest effective remedial actions to reduce or eliminate ^{90}Sr migration from the area. Sampling stations for the study were established as noted in Fig. 5.2. In the early part of the study, data on flow rate and ^{90}Sr concentration were collected simultaneously to establish a relationship between flow rate and total ^{90}Sr flux. This relationship can be used as a control or baseline in future work to evaluate remedial actions.

Subsequent work has dealt with characterizing distribution and transport of ^{90}Sr during storms and during low-flow conditions. Figure 5.3 shows the increase in ^{90}Sr concentration downstream along the SWDA 4 tributary both for low- and storm-flow conditions. The major inputs are located primarily between TMS-1 and TMS-3. This area also corresponds to the zone of highest ^{90}Sr levels in ground water and the point where the surface diversion channels empty runoff from north of SWDA 4 into the tributary.

We find a strong association among ground-water contamination, ^{90}Sr flux in storm runoff and base flow, and the discharge points for the surface diversion channels. Our results indicate that the remedial action that would be most likely to be successful would have to focus on dealing with surface runoff that originates north of Lagoon Road. The runoff must be collected and conveyed directly to White Oak Creek, preventing recharge of the contaminated ground-water zone in the region between TMS-1 and TMS-3.

ORNL-DWG 80-16965 ESD

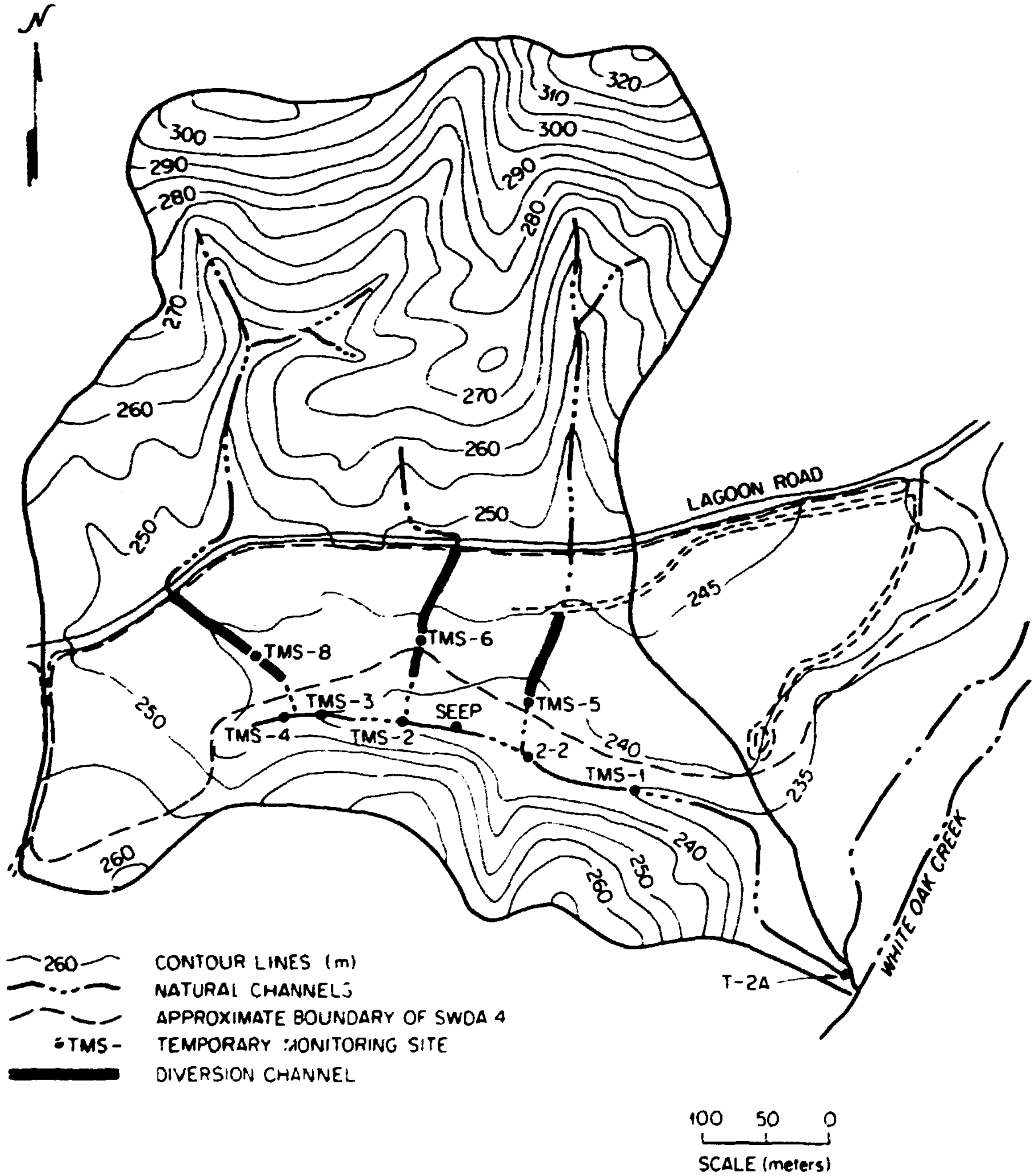

Fig. 5.2. Surface topography in the vicinity of SWDA-4.

Infiltration Study

Spatial variability and chemical modification of drainage through a weathered shale subsoil were evaluated at a site near the area used for shallow land burial of low-level radioactive waste at ORNL. Double-ring infiltrometers were installed at 48 locations on a 2 × 2 m grid after the removal of 1 to 2 m of soil (Litz-Sequoia Association, typic hapludults). Drainage rates were measured before and 20 and 259 days after treatment with

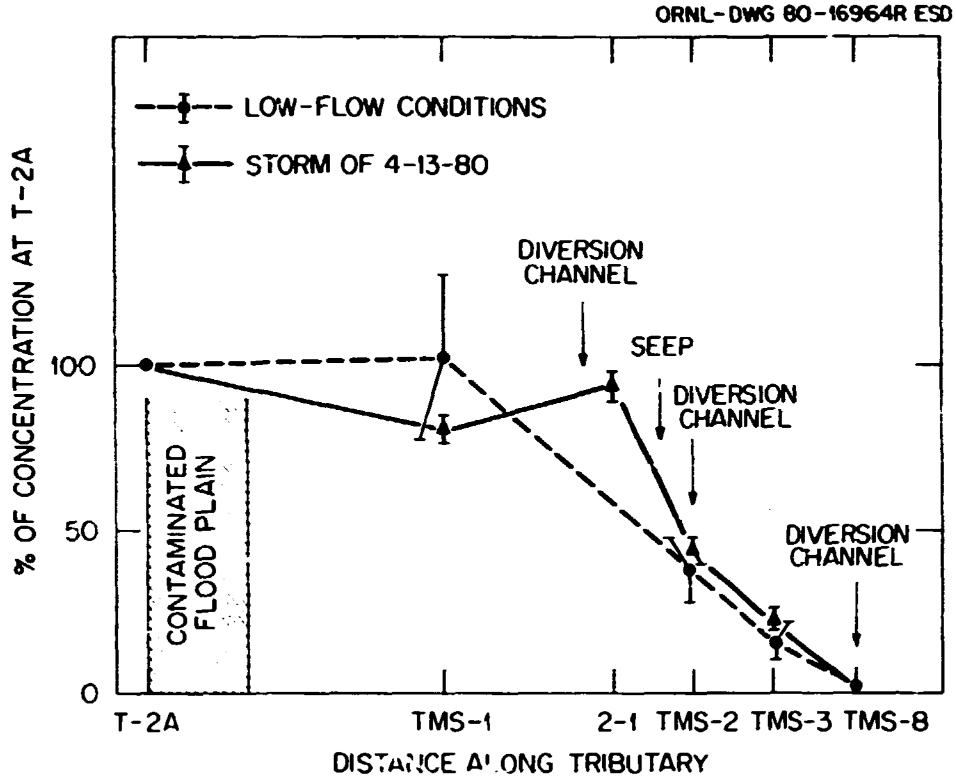

Fig. 5.3. Concentrations of ^{90}Sr in surface water along southside of SWDA-4. Flow is from right to left. The reach of greatest ^{90}Sr input lies between TMS-3 and TMS-1.

solutions of NaOH, KOH, NaF, $NaAlO_2$, and Na_2SiO_3 at rates of 151 equivalents per square meter. None of these chemical treatments significantly altered drainage rate, indicating that chemical modification of soil may be achieved without inducing hydrologic disturbance in these subsoils. A semivariogram analysis of drainage data showed that areal variability was random and, therefore, that any spatial patterning must occur at a smaller scale than the 2 × 2 m grid. The frequency distribution of drainage rate fitted a lognormal model with a geometric mean of 2 cm/d and a coefficient of determination of 130%.

Soil Block Study at Trench 7

Soil water retention characteristics (relationship between water content and water potential) were determined for the horizons of a Sequoia silt loam profile from calibrated neutron probe and tensiometer measurements taken during drainage of the field soil. These field data were compared with laboratory measurements made in soil cores taken in the vicinity of the field study. Changes in the shape of the laboratory-determined retention curves suggested that a significant reduction in the frequency of pores in the 0.005- to 0.01-cm diam range occurred during soil core sampling. Hydraulic characteristics determined on soil cores cannot be used to represent the field properties of Sequoia silt loam. The field retention data may be used in hydrologic transport model applications to the low-level solid waste management areas.

Mechanisms of Mobilization

Stream-bed gravels in White Oak Creek watershed often have substantial dark coatings of iron and manganese hydrous oxides. These coatings have been found to be strong absorbents for ^{60}Co from stream water.

Radioactivity determinations of gravel samples from throughout White Oak Creek watershed have delineated the areal extent of radionuclide contamination. Two reports on this work have been prepared; one has been issued (Spalding and Cerling 1979) and the other is in press.

Rates of formation of hydrous oxide coatings and the relationship between their rates of formation and the rates of uptake of heavy metals and radionuclides have been only recently quantified (Means et al. 1978). Like ferromanganese crusts and concretions found in lakes, these coatings appear to be ephemeral in streams. Rates of destruction and fate of heavy metals and radionuclides sequestered in coatings undergoing destruction are unknown.

The kinetic aspects of this problem required a method of periodically resampling the same stream substrate over an extended period of time. Tethered containers with screen mesh (1-mm opening) sides and partially filled with gravel (1 to 2 mm size) of known starting composition were used to meet these requirements. Rates of formation of coatings and uptake of ^{60}Co were determined by placing gravels uncontaminated with ^{60}Co at sites on White Oak Creek (WOC) known to be contaminated with ^{60}Co and following changes in Fe, Mn, and ^{60}Co content over a 250-d period. Rates of destruction of coatings and loss of ^{60}Co were determined by placing ^{60}Co-contaminated gravel at uncontaminated sites on WOC. One "destruction site" was chosen, on the basis of its low redox potential, to provide favorable conditions for dissolution of the ferromanganese coatings. Concurrent studies also involved ^{137}Cs and ^{90}Sr.

Although oxidizing conditions are required for precipitation of manganese oxides, the coatings can accumulate only if dissolved iron and manganese in stream water exceed about 50 μg/L. Below this concentration, coatings are lost by abrasion as fast as, or faster than, the growth by precipitation. At one site with average stream-water concentrations of manganese of 276 μg/L, and characterized by oxidizing conditions, the rate of manganese accumulation was 9.2 g d^{-1} g^{-1} of sample gravels. BET surface areas of about 30 m^2/g were measured for these gravels.

Previous work at ORNL (Spalding and Cerling 1979) and elsewhere (Jenne and Wahlberg 1965, Carpenter and Hayes 1980) has established an association between manganese and ^{60}Co in hydrous oxide coatings. However, net growth of these coatings does not appear to be necessary for cobalt to be incorporated into the coatings. Cobalt-60 accumulated rapidly (50 Bq g^{-1} d^{-1}) at one site where dissolved ^{60}Co averaged 8 Bq/L, but manganese content of the gravel was stable or slightly decreasing with time. Contaminated gravels placed in uncontaminated and well-aerated stream reaches did not lose ^{60}Co over a 250-d period. In contrast, where an oxide coating containing ^{60}Co was being dissolved (at rates between 10 and 25 g of manganese per gram of coating per day) because of local reducing conditions, ^{60}Co was lost in direct proportion to the loss of manganese.

The rate of natural decontamination of a stream environment after cessation of contaminant input is expected to depend on both the rates of downstream transport and dilution of contaminated substrate material, and on the new equilibria established between the clean aqueous phase and the residual contaminated solid phase. The results presented here suggest that contaminated substrates in well-aerated streams will lose ^{60}Co very slowly. In contrast, local reducing conditions occurring in organic debris dams and stream-bank alluvium will greatly accelerate the loss of ^{60}Co from contaminated substrate contained therein. Subsequent alternating cycles of exposure of substrate to oxidizing and reducing conditions result in a "leap frog" pattern of downstream transport of ^{60}Co and manganese.

The behaviors of ^{137}Cs and ^{90}Sr in the stream environment contrast considerably with that of ^{60}Co. Cesium is irreversibly adsorbed to stream substrate, and once adsorbed, its downstream transport depends entirely on physical processes. Strontium is reversibly adsorbed to substrate largely in a readily exchangeable form and thus is rapidly desorbed when aqueous concentrations are decreased.

This work also suggested the value of simple tethered substrates as monitors of radioactivity in the stream environment. The gravels used here were quite sensitive both to low levels of activity and to spikes in activity in the aqueous phase. They may be useful in estimating natural rates of decontamination of the stream environment.

Chemical Treatments to Control Radionuclide Transport

Treating soil with caustic soda increases both the capacity and selectivity for radiostrontium adsorption. A report on the fundamental chemistry of this soil reaction has been published (Spalding 1980). A field-scale demonstration of sodium hydroxide treatment of a burial trench was initiated, but results to date have been inconclusive; the initial treatment did not reach the entire trench volume, necessitating repeated hydroxide treatments during the year. The entire trench now appears to have been influenced by the hydroxide, and monitoring of the surrounding area will continue through the wet winter months to demonstrate the effectiveness of the treatment.

Several other chemical treatments of soil which precipitate radiostrontium and or calcium have been investigated. The precipitated phases are formed in soil by percolating solutions through columns of soil and can result in up to a 65% reduction in the leachability of radiostrontium. Of the various precipitating anions tested with several soils the leachability of radiostrontium in the resulting soil followed the order carbonate < phosphate < fluoride < silicate < aluminate < hydroxide. A report on this work has been queued for publication in the Journal of Environmental Quality.

All these proposed chemical treatments were found to have no effect on the in situ hydraulic conductivity of a typical subsoil used for waste burial at ORNL. This was a little surprising since most of these strongly alkaline reagents are excellent soil-dispersing agents; such dispersion would result in very large decreases in soil profile hydraulic conductivities. If these chemical treatments had decreased the hydraulic conductivities, their use would have inflicted a major perturbation in the ground-water flow pattern; such effects would have had to be carefully assessed before their use could be recommended. Apparently the soil interparticle binding in weathered Conasauga shale soils is strong enough to withstand these chemical dispersing forces, and alteration of conductivity is insignificant.

Permeable Barriers for Retarding Radionuclide Movement

Low-level waste literature indicates that zeolite minerals are potentially suitable for construction of water-permeable barriers composed of radionuclide-sorbing materials. In particular, clinotilolite has played a prominent role in waste management for over 20 years. This mineral has a high cation exchange capacity and therefore was considered to be a prime candidate material to be used as a sorptive barrier for ^{90}Sr and ^{137}Cs at shallow land burial sites. Five zeolite-rich samples were obtained from industrial vendors. To determine distribution coefficients for ^{90}Sr each sample was crushed and sieved into three size fractions: 80 to 100 mesh (180 to 160 μm), 100 to 200 mesh (160 to 75 μm), and 200 mesh (<75 μm). Ground water from SWDA 5 and ^{85}Sr were added to each sample, which was then shaken and centrifuged. An aliquot of the transparent supernatant liquid was extracted and counted for ^{85}Sr on a scintillation spectrometer. The data (corrected for background) were then used to calculate K_d values for each size fraction of each sample. The results of these experiments were quite variable but also quite promising (Table 5.1). The <75-μm size fraction for two of the samples (CZ1, Z5) yielded very high distribution coefficients, $\sim 10^4$. Further studies are continuing on these samples. Preliminary results from column studies indicate that all size fractions, which are in the coarse- to fine-sand range, are quite permeable to water flow. Field testing of these materials at a known radioactive surface seep in Burial Ground 6 is planned.

Electromigration Experiments

Most radionuclides transported by water are in an ionic chemical form and are, therefore, susceptible to alteration of movement by electric potential gradients. This subtask has investigated the feasibility of practical application of electric fields for control of ionic radionuclide transport. An electromigration field test was carried

Table 5.1. Distribution coefficients (K_d) for strontium obtained using various size fractions of zeolite-rich samples

Sample	K_d for grain sizes:		
	160-180 μm	75-160 μm	<75 μm
CZ1	5.900	7.500	10.400
CZ2	4.800	6.200	
CZ3			2.500
CZ4	3.900	3.600	
CZ5	6.400	7.900	9.800

out of the experimental floodplain below Burial Ground 4. A cathode consisting of a 61-cm (24-in.) section of standard 16-cm (2-in.) stainless steel pipe was used. A series of holes along one side allowed circulation of water between the interior and exterior of the pipe. The pipe was wrapped in blotting paper and placed into an open drill hole. Although the hole was initially full of water, during the unusually dry summer the water level declined and eventually became completely dry. The anode consisted of a row of stainless steel rods driven into the ground approximately 8 m from the cathode.

Nearly all the voltage drop took place near the electrodes. This resulted from the relatively small cross-sectional area of the soil through which the current passed near the electrode surfaces. Since cross-sectional area increases rapidly with increasing distance from the electrodes, the current density and voltage gradient are very small away from the electrodes.

Results of the field test are given in Table 5.2. Initially the ^{90}Sr content, the pH, and the electrical conductivity of the water in the cathode hole increased. These results were expected because of the migration of cations to the cathode and the generation of OH^- ions by the reaction $2H_2O + 2e^- \rightarrow 2OH^- + H_2(g)$. The highest ^{90}Sr concentration and electrical conductivity, however, were observed after only three days of operation. The next sample, taken after a power interruption, showed values lower than that of the water before electrolysis. After the current was started the ^{90}Sr concentration increased temporarily and then fell to an even lower level. The electrical cost per unit of ^{90}Sr removed will be inversely proportional to the ratio of ^{90}Sr to the total exchangeable mineral content of the soil. Thus, this cost will decline as the level of contamination increases and will also decline as the total exchangeable mineral content of the soil declines. The floodplain soil is a poor soil for

Table 5.2. Log of electromigration field test

Elapsed time (h)	Conductivity (μs/cm)	Current (C)	pH	^{90}Sr (Bq/m³)
0	685	0	7.4	1083
5	2[illegible]	1.3 × 10[illegible]	11.5	2017
53	1200	1.4 × 10[illegible]	11.4	1983
76	6000	2.0 × 10[illegible]	12.0	7683
193	220	3.5 × 10[illegible]	9.6	317
396		4.5 × 10[illegible]	12.7	3250
718		1.04 × 10[illegible]	12.7	67
834		1.17 × 10[illegible]	12.7	67
1054		1.4 × 10[illegible]		No water
1678		1.7 × 10[illegible]		No water

The power was found to have been turned off by an automatic relay at the time sample 5 was taken.

the application of this process. A well-leached soil would be better. The electrical power consumed per unit of decontamination is directly proportional to the voltage at which the process is operated. The rate of decontamination is also most directly proportional to the voltage when other things are equal

Hydrologic Modeling

Environmental release of radionuclides may occur in subsurface aquifers, surface water regimes, oceans estuaries, the atmosphere, or even directly to biota. However, following the release, there will be redistribution of the wastes into all media. The possible important pathways of the radionuclides from source of release to man are shown in Fig. 5.4. Accordingly, for a complete systematic approach, flow dynamic, waste transport, biological transfer, and dose models are needed to cover the entire biosphere. Flow dynamic models are required to simulate the flows of the carrier fluid; waste transport models are necessary for predicting the concentration distribution; biological transfer models are needed to simulate the uptake and release between the biota and physical environment. Dose models must be provided to compute radiation dose and its effect on man through external exposure and the inhalation, ingestion, immersion, submersion and other internal exposures.

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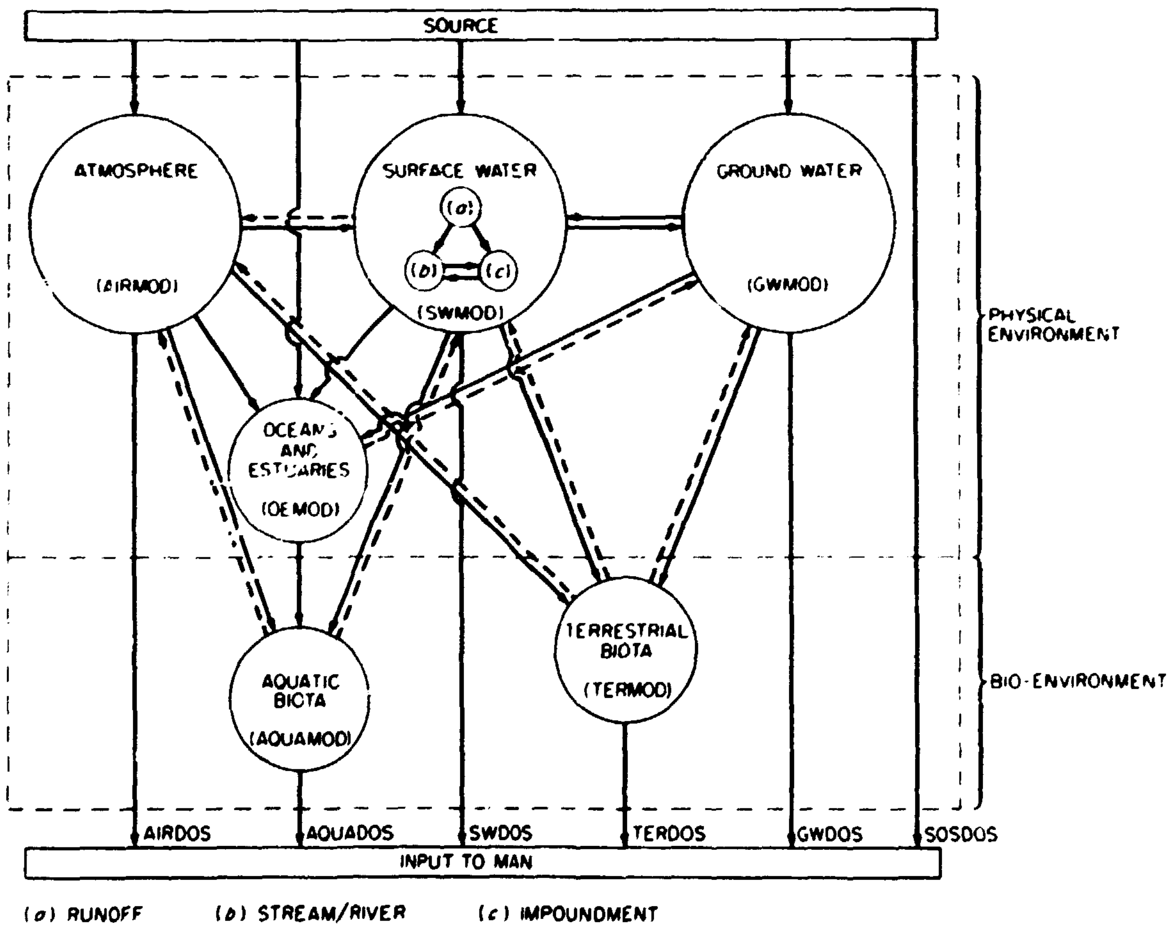

Fig. 5.4. Environmental compartments and associated simulation models.

Computer codes of biological transfer models (AQUAMOD and TERMOD) and dose models (AIRDOS, SWDOS, GWDOS, AQUADOS, TERDOS, and SOSDOS) have been routinely used for several years to assess the radiological impact of environmental release of radionuclides (Booth et al. 1971, Moore 1975, Halfon and Bargmann, 1975). Many of the environmental transfer coefficients and other pertinent data required for a given simulation are already available. Hence, in the past year, we were primarily concerned with the implementation and adaptation of flow dynamics and waste transport models in subsurface aquifers, surface water regimes, estuaries/oceans, and the atmosphere.

To predict the concentration distribution of radwastes in the physical environment, we have envisioned at least 36 types of models (Table 5.3), that must be documented for practical applications. These include steady one-dimensional to transient three-dimensional models of flow dynamics and waste transport in subsurface aquifers, surface water regimes, estuaries/oceans, and the atmosphere. Most of these models are available (Owen et al. 1979); but for a systematic approach, they must be adapted, modified, and documented in a unique format so that the flexibility and utility of combining the models can be achieved. They can then be used separately to deal with site-specific problems or in combination to handle a large-scale generic study. If a combination of models is employed, iterations must be used to obtain interface parameters for the media when feedback between media is strong. When the feedback between media is weak, the output from one medium may be used as input to the subsequent medium and iterations may be ignored.

Because of problems that result from unsound management practices based on poor assessments, each of the models listed in Table 5.3 must yield valid results when applied to any management proposal. To achieve this goal, each model must satisfy the following minimum requirements: (1) the problem must be logically formulated and expressed in mathematical equations to include as many processes as possible; (2) up-to-date and efficient computational algorithms must be devised and analyzed; (3) the model must be validated by comparing the model results with well-known analytical solutions, other types of numerical simulations, laboratory experiments, and/or field measurements; and (4) demonstrative applications must be made.

The processes governing radwaste transport within a medium may include mainly the advection of carrier fluid, hydrodynamic dispersion, radioactive decay and medium-dependent processes. For example, adsorption by the soil matrix will occur in the subsurface aquifer. The adsorption and desorption by sediments, which are transported along with the radionuclide by the fluid, can occur in the surface water regimes and the estuaries/oceans. Cloud scavenging and precipitation washout may take place in the atmosphere. On the other hand, transfer across media interfaces may be induced by various kinds of processes such as deposition, resuspension, aeration, seepage, infiltration, volatilization, evaporation, and transpiration. All these processes must be transformed into equations. Computational algorithms range from simple analytical and empirical methods to realistic sophisticated numerical techniques including finite-difference, finite-element, and Monte Carlo simulations. Analytical and empirical models are best utilized for analyzing the response of the media to the variation of model parameters. Insensitive parameters are then excluded from the sophisticated numerical based models.

Eight models (6 to 13), each representing an example of model types 1, 2, 3, 4, 12, 13, 17, and 18 in Table 5.3, have been completed according to the minimum requirements described above. Each model has been documented by an ORNL report (Yeh, 1980a; Yeh, 1980b; Yeh and Ward, 1980a; Yeh and Ward, 1980b).

Modeling of Geologic Controls on Hydrology

One important aspect of radionuclide migration from solid waste disposal areas is the direction and rate of ground-water movement. Because shales in the Conasauga Group at ORNL are highly fractured, the fracture porosity and permeability are highly significant in assessing ground-water flow and thus radionuclide migration.

Table 5.3. Dynamic transport models required for a systematic modeling approach[a]

		Model No.	Flow						Radionuclides						Sediments					
			S	T	1-D	2-D X-Y	2-D X-Z	3-D	S	T	1-D	2-D X-Y	2-D X-Z	3-D	S	T	1-D	2-D X-Y	2-D X-Z	3-D
Subsurface Aquifer (GWMOD)	Unsat-Sat.	1		X			X													
		2								X			X							
		3		X				X												
		4								X				X						
	Sat.	5		X		X														
		6								X		X								
	Unsat.	7		X	X															
		8								X	X									
Surface Water Regimes (SWMOD)	Runoff	9		X		X														
		10								X		X				X		X		
	Streams/Rivers	11	X		X															
		12		X	X															
		13								X	X					X	X			
		14	X				X													
		15		X			X													
		16								X			X			X			X	
	Surface Impoundment	17	X			X														
		18		X		X														
		19								X		X				X		X		
		20	X					X												
		21		X				X												
		22								X				X		X				X
Oceans & Estuaries (OEMOD)		24		X	X															
		25								X	X					X	X			
		26		X		X														
		27								X		X				X		X		
		28		X			X													
		29								X			X			X			X	
		30		X				X												
		31								X				X		X				X
Atmosphere (ATMOD)		32	X		X															
		33	X			X														
		34		X				X												
		35							X					X						
		36								X				X						

[a]S = steady-state simulation, T = transient simulation, 1-D = one-dimensional simulation, 2-D X-Y = two-dimensional simulation in the X-Y plane, 2-D X-Z = two-dimensional simulation in the X-Z plane, 3-D = three-dimensional simulation.

Joint orientations, spacing, length, and gap-size data were collected for the shale and siltstone beds of the Conasauga Group from outcrop exposures and drill core specimens for the ORNL Reservation. Joint length, spacing, and orientation data were subjected to computer analysis to determine dominant trends. In the siltstone beds, joint length varied from 2 to 76 cm with a range of 6 to 45 joints per meter. Shale beds contained a nearly constant joint length of 12 cm with a frequency of 12 to 28 joints per meter. Based on the findings, a computer model of the Conasauga formation was developed. The model allows prediction of joint orientation, fracture porosity, and fracture permeability for a wide range of locations in the ORNL area as a function of depth at a site. Results are limited by availability of suitable geologic core data. The model does provide the basic framework for building a comprehensive coverage of the ORNL area and should prove very useful in future studies of radionuclide migration in highly fractured formations. It is believed to be most applicable to near-surface conditions. A detailed description of the study and the computer model has been published (Sledz 1980).

Radiologic Modeling

Primary efforts during the year focused on two tasks. The first was to develop an assessment methodology for the calculation of water-borne radiological doses, and the second concerned the organization of an interagency workshop to discuss modeling applications to low-level waste management.

The assessment methodology is intended to provide users having no dosimetric training, such as hydrologic modelers, with a means of calculating radiological doses given a radionuclide concentration in water. A user-oriented handbook and later an interactive computer code were to have been written to specify the important assumptions in such calculations and to append the necessary dose conversion factors and other data for the various water pathways to human populations. This work is not yet completed.

C. A. Little has been serving as scientific secretary of the interagency workshop planned for December 1 to 4, 1980. The meeting is sponsored by the Interagency Low-Level Waste Modeling Committee and will include representatives of DOE, the Environmental Protection Agency (EPA), the Nuclear Regulatory Commission (NRC), and USGS. Modelers and model users from each of these agencies will be brought together to discuss each agency's needs for modeling of low-level waste management. Workshops on release mechanisms, environmental transport pathways and parameters, overall system modeling, and model verification validation will be conducted to discuss topics in those specific areas. Approximately 20 formal papers will be presented by both model users and modelers. A proceedings of both the papers and the workshop summaries will be published.

Development and Testing of New Ground-Water Tracers

The objective of this subtask is to define the physical and chemical parameters which influence the migration of organic molecules in groundwater in order to identify tracer species capable of not only indicating the direction and velocity of ground water, but also the ability of a particular burial site to retard the passage of contaminants (chemical and radioactive) once they reach the saturated zone. Previous efforts have demonstrated that a particular class of organic compounds, chlorofluorocarbons, have unique advantages over more conventional tracers such as salts and dyes in determining ground-water direction and velocity.

At present, efforts are directed at quantifying the mechanisms by which tracers are sorbed on heterogeneous natural media. By use of experimental techniques adapted from the related field of adsorption chromatography and a mathematical model which can describe multisite, heterogeneous surfaces, it has been shown that chlorofluorocarbons interact with a wide variety of minerals only through weak, nonspecific, electronic dispersion-type forces. Furthermore, it is apparent that the strength of these interactions is dependent primarily on the size of the molecule.

The ability to quantitatively describe solute-surface interactions has several implications for tracer studies. First, it is possible, using a multiple set of chemically related tracers (a "homologous series"), to determine whether significant sorption has occurred and the extent to which this sorption will retard the migration of compounds in the saturated zone. Second, ground-water velocities can in theory be calculated even when all the members of a tracer series are sorbed to some extent. Finally, comparisons between sorption studies of field cores and corresponding field migration profiles can indicate the in situ character of the hydrologic system.

Sorption studies also indicate distinct differences in surface properties between mineral classes. Naturally occurring silica, in contrast to synthetic silica gels, appears to have an essentially nonpolar surface and consequently interacts relatively strongly with nonpolar organic compounds. Carbonates and silicates, on the other hand, have adsorptive surfaces dominated by large, complex anions. Similar studies of shale obtained from the Engineering Test Facility (ETF), located in SWDA 6 at ORNL, indicate that the surface of the shale member of the Conasauga Group is similar to the silica surface, being essentially nonpolar. Further studies are indicated to determine whether this is a result of a high silica content or the presence of large amounts of organic debris.

A one-dimensional, multiple-chlorofluorocarbon tracer test was conducted in the Burial Ground 4 area under an artificially induced hydraulic gradient. Tracer migration was observed in a direction parallel to the general bedding plane in the Melton Valley. Results clearly indicate multiple pathways with no detectable sorption of tracers, consistent with the assumption of fluid flow in wide-aperture strike joints and faults. Two-dimensional studies of tracer migration are presently under way at the ETF site.

Demonstration and Implementation

In the ETF (formerly the demonstration burial ground) an array of 10 wells was drilled in a semicircular pattern for tracer tests. These tests were performed by investigators from the University of Arizona and Indiana University. Fluorobenzoic acids, yeast, and standard chemical tracers were used by the University of Arizona investigators, while a homologous series of chlorofluorocarbons was employed by the investigators from Indiana University. Test results are being interpreted; preliminary scrutiny indicates that the tracer travel is dominated by preferred pathways. Initial hydraulic tests performed by the University of Arizona researchers indicate that the Conasauga Group in the ETF has hydraulic conductivities ranging from 0.05 to 0.41 m^2 d; transmissivity of 0.05 m^2 d; and a storage coefficient of 0.005. More extensive hydraulic tests are planned to verify the numbers. In addition to the ten tracer array wells the E and W wells were also drilled. The N and S wells are still being considered for multiple piezometer array. Rock core was recovered from 7 of the 12 wells drilled. The cores were logged, and samples for thin sections have been obtained for petrographic analysis. Study of the cores shows a complex interbedding of shale and limestone, with limestone being the more abundant rock type. Numerous fractures in the cores were noted; some fractures were calcite-filled and some open, indicating water had at one time flowed through the rock. More work is planned on correlating the cores as well as introducing thin-section information into the interpretation.

Weekly measurements of water levels are made at the 12 new wells in addition to the original 4 observation wells. Continuous water-level monitoring is expected to begin soon. A rain gauge was installed to monitor the rainfall in the ETF. Sites for the flumes, which provide the surface water data, were prepared, and monitoring of the surface water will begin upon completion of flume emplacement. Geophysical surveys (resistivity and seismic) of the area will be performed in addition to installing tensiometers and continuing the monitoring efforts.

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6. NATIONAL LOW-LEVEL WASTE PROGRAM MANAGEMENT

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Introduction

Early in FY 1979 Oak Ridge National Laboratory was assigned the associate lead role in the Department of Energy (DOE) National Low-Level Waste Mangement Program (NLLWMP). This role is carried out under the overall management of the DOE Program Manager, the lead contractor, EG&G Idaho at the Idaho National Engineering Laboratory, and DOE's Oak Ridge Operations Office.

The overall objective of the NLLWMP is to develop and promote environmentally sound techniques for safely and efficiently managing all types of low-level wastes (LLW). These are all the radioactive wastes that contain less than 10 nCi of transuranic contaminants per gram of material and contain potentially hazardous quantities of radionuclides. They result from such activities as energy production, manufacturing, and the use of radioisotopes in medical and other fields. Some specific activities included in the program are the development of waste treatment and packaging technology; optimization of shallow land burial; establishment of remedial measures for stabilizing and improving performance of existing burial grounds; evaluation of methods for storage and disposal that are alternatives to shallow land burial; and development of guidelines or standards for waste characterization, disposal, and monitoring. In addition, the program includes assistance in developing a national plan for handling and disposing of such wastes and in the public and governmental interface activities necessary to prepare for the implementation of programmatic developments.

In its associate lead role ORNL has the responsibility to manage a delegated part of the national effort. Although the Laboratory will generally assist EG&G Idaho in the total program, emphasis at ORNL is on the overall management of research, development and demonstrations for technical areas involving waste generation, waste handling and treatment, environmental technology, and waste disposal facilities. During this year the ORNL office of the NLLWMP drafted technical program plans; prioritized FY 1981 and 1982 zero-based budgets aimed at implementing these programs within DOE financial constraints; provided guidance to the participating DOE site programs; and initiated cooperative efforts with waste disposal programs within DOE, in other federal agencies, in the state of Tennessee, with the Federal Republic of Germany, and with the International Atomic Energy Agency(IAEA).

Figure 6.1 shows the work breakdown structure for the NLLWM program and identifies the areas of direct ORNL responsibility (WBS 3.5.0) The total program budget this year was about $9.3 million, and that for the portion managed by ORNL was about $6.5 million.

Management Activities

Some of the more important accomplishments in the ORNL management activity for the NLLWM Program are briefly described in the following paragraphs.

Technical Planning

In cooperation with the lead laboratory, EG&G Idaho, the NLLWM technical program was reevaluated in June and focused on eight major program milestones (Table 6.1). On the basis of these a detailed set of supporting milestones and program logic diagrams was developed to guide the execution of the program. The principal

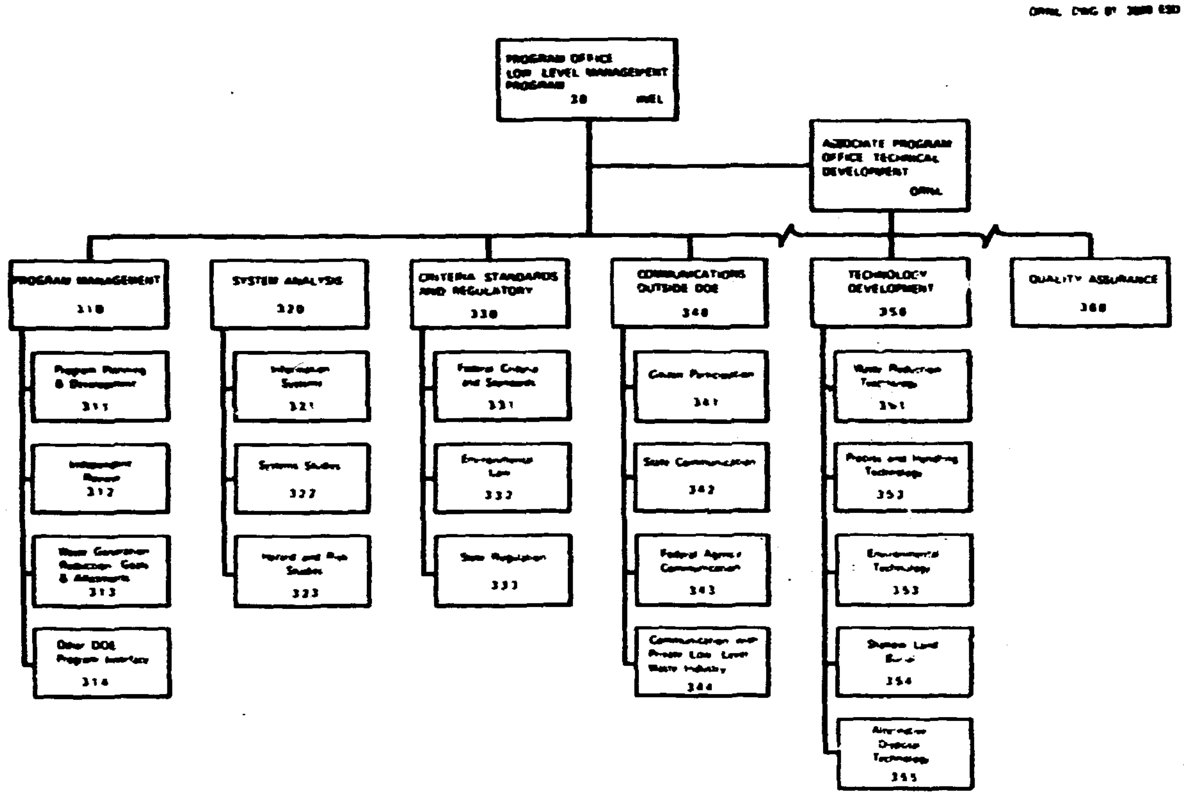

Fig. 6.1. Work breakdown structure (WBS) for WLLWM Program and identification of ORNL responsibilities (WBS 3.5.0).

Table 6.1. Major technology program milestones of the NLLWMP

Date	Activity
4/84	Provide a Waste Generation Reduction Handbook
12/83	Document waste treatment and solidification systems meeting shallow land burial (SLB) site operating criteria
3/84	Document all procedures and information required to support locating an SLB site in eastern United States
12/84	Provide a manual of proven and recommended remedial actions for SLB sites
3/86	Document all procedures and information required to establish a facility that provides greater isolation from the environment
6/81	Provide a waste classification system
9/85	Provide waste treatment methods for greater isolation
6/81	Provide information required for use in establishing interim engineered storage facilities

technical goal of the program is to provide the information needed to support opening a new improved shallow land burial facility at a humid site in 1985. The other milestones and program efforts support this goal, provide for longer term, nonshallow land burial disposal options, or address remedies to currently existing problems in shallow land burial.

Seven state-of-the-art review reports were issued during this year documenting information developed in support of program planning. These reports covered waste treatment processes, models and monitoring for disposal sites, shallow land burial of LLW, and alternative approaches.

Several areas were identified where insufficient effort was currently under way to meet the needs of the national program. To remedy this deficiency, a procedure for obtaining competitively awarded work from DOE contractors was developed in conjunction with the program lead site and our respective DOE Operations Offices. Responses in four technical areas resulted in 49 proposals from 16 organizations. After technical review and evaluation, several proposals were selected for FY 1981 funding.

Program Implementation

One of the more important activities carried out by the ORNL office of the NLLWM program is the review and guidance of technology dvelopment and demonstration programs being carried out at all DOE sites participating in the NLLWMP. Site visits were made for this purpose during 1980. During these visits, site programs and program proposals were reviewed and guidance was furnished relative to program goals, funding and organization. In parallel with these visits, budget priorities were developed for the program zero-based budget analyses used for FY 1981 and FY 1982 budget actions by DOE.

Program Coordination

Information exchange and program coordination with other DOE and federal waste programs continued. The first annual DOE NLLWMP Information Meeting was held in December 1979, a DOE Modeling Workshop was held in July 1980, and arrangements were finalized for an Interagency Modeling Meeting for early FY 1981. Foreign program cooperation efforts were limited to initiating a cooperative program with the Federal Republic of Germany in the area of low-level waste fixation and technical assistance to the IAEA in the fields of waste treatment and disposal facility siting.

Citizen Participation

At the request of Tennessee Governor Alexander, a plan for management of low-level radioactive wastes in Tennessee is being prepared jointly by the DOE NLLWM Offices and the Tennessee Department of Public Health. After several developmental meetings with the Governor's staff, the Tennessee Department of Public Health, and the Tennessee Valley Authority, the first draft of the plan was given to the Tennessee Department of Public Health in August 1980. The Governor is to receive the final report by January 1981. The plan lists sources of low-level radioactive wastes, projects the quantities for future years, and discusses short- and long-term management options. The national LLWMP office at ORNL is responsible for determining the quantities and sources of the waste, identifying alternatives for managing the waste, and assessing the environmental impacts.

PART II. ENVIRONMENTAL SCIENCES DIVISION SECTIONS

7. AQUATIC ECOLOGY

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Introduction

The Aquatic Ecology Section is involved in basic and applied research focusing on environmental problems and on gaining a better understanding of the structure and function of aquatic ecosystems. The continuing objectives of the section are to develop and maintain a position of excellence in disciplinary areas of aquatic ecology, to provide technical expertise to achieve the goals of the various Division programs, and to anticipate future disciplinary and programmatic directions of research in aquatic ecology. In addition to interacting with the programs and other sections of the Division, the Aquatic Ecology Section interacts with several other ORNL divisions (e.g., Analytical Chemistry, Energy, Health and Safety Research, and Information), with the Computer Sciences Division (UCCND), and with several outside research

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organizations in the Southeast [e.g., Tennessee Valley Authority (TVA), University of Tennessee, Tennessee Technological University, and the National Reservoir Research Program of the U.S. Fish and Wildlife Service]. Research in the section is funded by the Department of Energy (36%), the National Science Foundation (22%), the Nuclear Regulatory Commission (20%), the Environmental Protection Agency (19%), and the Electric Power Research Institute (3%).

There are two major projects in the section. The Reservoir Studies Project involves research on ecological issues related to small-scale hydroelectric development. Studies on forage species and their interactions with predators involve defining the role of the Kingston Steam Plant as a "predator" in Watts Bar Reservoir and determining an intake design that will minimize fish impingement in southeastern reservoirs. These studies also focus on the more basic questions of assessing the effect of low temperatures on mortality of threadfin shad and of identifying the resiliency mechanisms operable within the threadfin shad population of Watts Bar Reservoir. Studies of trophic dynamics of reservoir benthos focus on determining the direct and indirect effects of the Kingston Steam Plant on mayflies and the Asiatic clam, *Corbicula*. Studies of habitat selection by predators involve investigating the role of physical factors, particularly temperature, in determining habitats selected by major predatory fish species and investigating the relationship of selected habitat to prey utilization and physiological performance. During FY 1980, work in the small-scale hydro project focused on analyzing the potential environmental impacts associated with dredging, with water level fluctuations, and with fish passage both upriver and downriver.

The second major project in the section involves analysis and modeling of aquatic populations and ecosystems. A variety of useful quantitative methodologies were developed and applied in an effort to assess the impacts of entrainment and impingement of fish by power plants along the Hudson River in New York. The resultant methodologies are proving to have applicability to a variety of other systems and populations, with particular emphasis on evaluating the effects of toxic materials at both the population and community levels.

Research on impacts associated with power plants continues to be prominent. Our study of toxicant formation in condenser cooling systems is directed toward determining optimum chlorination procedures at power plants. Current research focuses on bioaccumulation of chlorinated organic compounds by the Asiatic clam and toxicity of free residual chlorine. Pathogenic microorganisms in artificially heated waters is a growing area of concern. Our research is focused on determining the extent of distribution of pathogenic amoeba and bacteria, such as the Legionnaires' Disease Bacterium, and on defining the conditions promoting their proliferation.

A new and expanding project in the section is "Multimedia Environmental Transport Modeling," funded by the U.S. Environmental Protection Agency, Office of Toxic Substances. Efforts to date have been concentrated in the areas of formulation of physicochemical processes; operation of the Unified Transport Model; and development, verification, and validation work on atmospheric, terrestrial, and aquatic transport models.

Reservoir Studies Project

The primary goals for the Reservoir Studies Project over the next several years are to further develop a strength in comparative reservoir research and to continue our research and assessment activities related to small-scale hydroelectric development. We present accomplishments during this reporting period for research on ecological processes in southeastern aquatic systems and for analyses of environmental issues of concern when small existing dams are retrofitted to produce hydroelectricity.

Ecological Processes in Southeastern Aquatic Systems

Effects of Forage Loss on Predatory Fish in Watts Bar Reservoir

Research on forage species and their interaction with predators was focused on threadfin shad and young-of-the-year gizzard shad (forage) and on sauger (predator) in Watts Bar Reservoir. Mass mortalities of threadfin and young-of-the-year gizzard shad in many southeastern reservoirs result from impingement at electrical generating stations and low water temperatures in the winter. Shad provide the principal forage for numerous game fish and other top carnivores. The impact on predators of the loss of this forage has never been quantified. The goals of this research were (1) to develop a bioenergetics approach to quantify effects of forage loss on predators and (2) to determine the applicability of this method to two major predators with contrasting feeding strategies, largemouth bass and sauger.

Sauger were collected biweekly from October 1979 through April 1980, and largemouth bass were collected monthly from May 1979 through September 1980. Data for these sauger were combined with sauger data collected for two 7-month periods, October through April 1976–78, and for a 12-month period, October 1978 through September 1979. Fish length, stomach contents, and weight of the total fish, fat, and gonads were recorded for each fish of both species. Short-term effects of loss of prey were determined by comparing changes in caloric intake to changes in caloric value of the two predators. Partitioning of intake energy into the body components of muscle, fat, and gonads was quantified. Long-term effects were determined by measuring growth each year. A bioenergetics model, based on a balanced energy equation, was used to compare predicted growth of sauger with that measured in the field for one year (1979). For largemouth bass, a bioenergetics simulation model is currently being developed and parameterized with laboratory and field data (1) to determine the usefulness of the model in predicting important aspects of predator dynamics (such as growth); (2) to indicate, through sensitivity analysis, areas of predator-prey dynamics which require detailed study; and (3) to investigate the potential application of the model for use as a tool in resource management and regulation.

The growth of sauger in Watts Bar Reservoir during the four-year study was higher than that reported in northern lakes and compared favorably with other southern reservoirs. Sauger minimized the effects of prey fluctuations through several mechanisms. These included (1) utilization of prey which are stressed at cold temperatures, prior to a large decline in the prey population, (2) partitioning of excess energy into fat stores and gonad tissue, and (3) utilization of alternate cold-tolerant prey. Shad consistently comprised the dominant portion of the sauger diet, but shad were especially important in the cold months. For example, in the winter of 1979–80, over 75% of the food consumed was shad, which resulted in a major energy surplus for sauger for the spring spawning season. The bioenergetics model predicts that if this surplus had not been gained, 17% more food would have had to be eaten during the summer months to produce the observed growth. Nonshad prey buffered the diet during periods of low shad abundance, but predation on schools of spawning shad produced the only peak in consumption during nonwinter months.

Largemouth bass are warm-water predators, but their feeding strategy allows them to maintain high growth in a system where preferred prey are most abundant in the early winter. Bass do not take advantage of this increased prey availability. In fact, the total energy intake of bass in winter is less than 50% of that in summer-fall. However, in late winter, when threadfin and young-of-the-year shad populations greatly decline, bass of all age classes except the 0–1 age class are able to feed on large gizzard shad (≥20 cm). Although bass do not store large amounts of energy in the form of fat as do sauger, the lowered metabolic rate in winter, coupled with the ability to utilize large, high-energy prey, explains the good condition of bass in the spring. During the summer months when sauger may be spatially separated from prey due to high temperatures, sauger condition declines. In contrast, largemouth have an increased feeding rate during summer months and maintain their condition due to high temperature preferences that parallel those of their prey.

In summary, sauger and largemouth bass are examples of predators which deal with the problem of a fluctuating prey base in different ways. Sauger increase consumption in winter and store energy which is then used during periods of low prey availability. Low prey availability may be due to mass mortality in winter or to spatial segregation caused by high temperatures in summer. Largemouth bass do not store large amounts of energy but satisfy their energy needs by switching to large prey when the populations of small forage decline and by feeding on warmwater prey during the summer months.

Trophic Dynamics of Reservoir Benthos

Our research on trophic dynamics of reservoir benthos continued to focus on the Asiatic clam (*Corbicula*) and the burrowing mayfly (*Hexagenia bilineata*). As the Asiatic clam, *Corbicula*, migrated to all major U.S. drainage basins below latitude 40° N, reports of fouling of raw water systems (including power plants) increased. Our initial research thus emphasized control of fouling by using heated water or heated water in combination with chlorine. However, the clams have become a major component of benthic communities in many areas. Thus, the research focus shifted to defining temperature limits and effects of temperature on growth and filtration. Research on this species during the past year emphasized their potential function in the Watts Bar Reservoir ecosystem.

Corbicula populations have a high potential for interaction with predator populations. In the well-irrigated substrates in which clams occur, mean density in 60 samples collected using a modified Venturi suction sampler in several representative coves was 70 clams/m^2 and in areas below Melton Hill Dam averaged 825 clams/m^2 over an area at least 1.2 km in length. Conversion of these two densities to biomass standing crops (wet tissue weights) yields values of 390 and 10,000 kg/ha, respectively. In contrast, standing crop biomass of forage fish in 23 southern reservoirs has been reported by other investigators to range from 7.3 to 180 kg/ha. Thus, even if areas populated by *Corbicula* represent only a small percentage of total benthic surface area for the reservoir, the potential for contribution of *Corbicula* to predator-carrying capacities in Watts Bar Reservoir appears substantial.

During late February and March, *Corbicula* populations in Watts Bar Reservoir suffer massive die-offs due to low water temperatures. This mortality coincides with reduction to yearly lows of threadfin shad and young-of-the-year gizzard shad populations, which provide the major forage base for predatory fish in Watts Bar Reservoir. We examined the hypothesis that the coincidence of these two events has a stabilizing effect on populations of predatory fish. Weight change of catfish that were starved, fed minnows, or fed clams was measured over a five-week period to determine whether clam consumption could contribute to maintenance of catfish condition. Studies were conducted in the laboratory at 10°C, the approximate reservoir temperature in March. Fish of 120 mm initial standard length (SL) were fed twice a day (except weekends) and uneaten food was removed after 10 min.

Results were somewhat equivocal. In one replicate (n = 5 for each treatment), catfish that were fed clams gained an average of 0.14 g, while those that were fed minnows lost 1.32 g and those that were starved lost 1.68 g. In the other replicate, all groups lost weight: 1.14 g (clams), 2.14 g (minnows), and 1.82 g (starved). Food consumption paralleled the weight changes. In each replicate the fish that were fed clams fared better than those given other treatments. These preliminary results indicate that catfish will consume clams and suggest that this consumption does help in maintaining condition. Field studies indicate that *Corbicula* are more prevalent in catfish stomachs during the late February–March period when shad populations are low, suggesting that catfish do take advantage of this available food resource.

Our research on the effects of the Kingston Steam Plant on *Hexagenia* populations in Watts Bar Reservoir involved both field and laboratory tasks. Our emphasis during this reporting period was on laboratory investigations to determine the effect of sex, initial size, and temperature on growth rates, adult size, and size at large-wing-pad stage. We found that female mayfly nymphs grew faster and reached larger sizes than males; growth at the constant temperature of 15°C was significantly less than at 22.5°C. Nymphs reared at 15°C were unable to successfully complete metamorphosis into the adult stage even though development and adult tissue maturation appeared normal. Comparison of nymph length at the large-wing-pad stage indicated that temperature/initial size interactions were significant, with the largest nymphs resulting from the 15°C and 17-mm initial size group and the smallest resulting from the 30°C and 9-mm initial size group. In general, all nymphs reared at 30°C were smaller than nymphs reared at 22.5 and 15°C within the same initial size groups. Emergence from the 13.5- and 17-mm initial size classes at both 22.5 and 30°C was nearly synchonous. The lag in emergence of the 9-mm initial size class at both temperatures and the extended period of emergence of the 9-mm group at 22.5°C indicate that a size-dependent threshold for adult tissue maturation occurs between 9 and 13.5 mm. For nymphs above the size threshold, adult tissue maturation was probably synchronized by the simultaneous transfer of nymphs from holding temperatures of 15°C to experimental temperatures of 22.5 and 30°C. The existence of a specific temperature threshold for emergence between 15 and 22.5°C also seems probable, because nymphs reared at 15°C were unsuccessful at metamorphosis.

In summary, our laboratory data indicate that *H. bilineata* generally conform to the expected responses to a suboptimal temperature treatment as proposed by the thermal equilibrium hypothesis of Vannote and Sweeney (1980). In particular, adult size and fecundity and nymph survival were all reduced at 30°C, which is a much higher temperature than would normally be encountered in natural *H. bilineata* habitats. The 15°C treatment appeared to be optimal for the nymphs when judged by the nymphal size attained, but adult metamorphosis was mostly unsuccessful. We hypothesize that the "optimal" constant temperature regime for maximizing size and survival of *H. bilineata* is between 15 and 22.5°C, but a seasonally fluctuating regime with summer temperatures above 19°C and a yearly mean of 15°C may provide nearly optimal conditions.

Habitat Selection by Predators

Research on habitat selection by predators in southeastern reservoirs focused on (1) temperature selection by juvenile striped bass (*Morone saxatilis*) in the laboratory and field, (2) distribution and movements of adult striped bass in Watts Bar Reservoir in relation to water temperature, and (3) growth rate and thermal tolerance of juvenile striped bass held in fluctuating temperature regimes. Results from each of these tasks are summarized below.

Juvenile striped bass are known to occupy nearshore zones of reservoirs and estuaries in summer where active feeding and growth occurs. Temperatures there are relatively high, often exceeding 25°C. Our previous laboratory studies of juvenile growth rates identified optimum growth temperatures near 24 to 25°C. Temperature preferences in the laboratory were suggested to be near 25°C in exploratory studies by others. Our field telemetry studies with subadults and adults, however, indicated lower temperature preferences (near 22 and 20°C, respectively). A size-dependent change in thermal niche was suspected, which necessitated more thorough study of juvenile temperature preferences using a variety of laboratory and field methods.

We tested juvenile striped bass in the spring and summer of 1980, near their first anniversary in a longitudinal thermal gradient trough, in an electronic shuttle box, and in the field following attachment of miniature ultrasonic temperature transmitters. Each method estimated temperature preference to be in the 24 to 27°C range, which was clearly above the preferences of larger fish. We found no size effects among subsets of this age group for which size differences had been accentuated by rearing at growth-stimulating and inhibitory temperatures (total size range was 82–222 mm). We did not find elevated thermal preference in a group which consisted of survivors of lethal critical thermal maximum tests. This elevation suggests a genetic range for thermal preference/tolerance which could have application for breeding stocks of this species that are better adapted to high water temperatures. Tests conducted in late summer and early fall suggested a seasonal decrease in temperature preference, an observation which requires further study.

Thermal niche information was developed for adult striped bass in our previous research in Cherokee Reservoir and in quarry lakes on DOE's Oak Ridge Reservation. This information was tested by following the distribution and movements of similar fish tagged with ultrasonic transmitters in Watts Bar Reservoir. The work was conducted in cooperation with the Tennessee Wildlife Resources Agency and the Department of Interior's Cooperative Fishery Research Unit at Tennessee Technological University. We hypothesized an annual pattern of movement between the lower reservoir (which reaches 25–26°C in summer) and the tributary arms which are generally cooler in summer. The Clinch River tributary rarely exceeds 20°C, while the Tennessee River reaches 25°C briefly in late summer. The movement was expected to be induced by springtime attraction to spawning temperatures in the tributaries and later by avoidance of high temperatures in the lower reservoir. Over 60 fish were tagged.

Results generally supported temperature-oriented movements. Tagged fish showed great mobility throughout the reservoir in months other than June–October, with many fish moving more than 50 km. A June concentration of fish in the Clinch River arm coincided with temperatures generally associated with spawning. There was a second concentration of fish in the Clinch River and in cool zones of the Tennessee River arm in July-September when lower reservoir temperatures were warmest. No tagged fish were found in the lower reservoir when temperatures exceeded about 26°C. Late summer congregations of striped bass in the Clinch River were concentrated between Gallaher Bridge and Grub Island, which is the reach to be occupied by the Clinch River Breeder Reactor Plant. Conflicts may occur between needs of striped bass for cool summer refuges and water uses by the reactor facility.

Previous studies of the effects of fluctuating temperatures on responses of juvenile striped bass indicate that these fish do not respond to the mean temperature, but to some value between the mean and maximum. Studies of other species (e.g. rainbow and cutthroat trout) substantiate this pattern of response. Because fish normally occur in fluctuating field temperatures, predictions of thermal tolerance, growth rates, and bioenergetic efficiency should not be based on the assumption that fish will respond as though they were being held at the average temperature. We sought to determine experimentally the role of amplitude of temperature change in a 24-h fluctuation on growth rates and thermal tolerance of striped bass and to formulate a model for predicting their thermal acclimation state in known fluctuating temperature conditions.

Striped bass were held for three-week growth periods at constant temperatures of 17, 22, 27, and 32°C and in temperature regimes which fluctuated +1, +2, +3, +4, and +5°C around means of 17 and 27°C. Mean growth rates and critical thermal maximum (CTM) values were determined. The trend in the data was generally consistent with the phenomena demonstrated in earlier studies. Growth rates and thermal tolerance of juvenile striped bass held in the fluctuating temperature regimes generally fell between the values for constant temperatures equivalent to the mean and the maximum of the fluctuation. Growth rates and CTM values were not always proportional to amplitude of fluctuation. This result may be due to imprecision in controlling the amplitude or to variations among the test groups of fish. The development of a reliable predictive model is as yet impractical without further experimentation.

Analysis of Environmental Issues Related to Small-Scale Hydroelectric Development

The Environmental Sciences Division continued to implement the Environmental Subprogram Plan for the Department of Energy Division of Hydroelectric Resources Development (Assistant Secretary for Resource Applications). We present below a summary analysis of two environmental issues (upstream fish passage, water level fluctuation) that may be of concern when existing dams are retrofitted to produce hydroelectricity.

The possible requirement (by state and/or federal agencies) of facilities to move migrating fish upstream around dams may be a significant factor in determining the economic feasibility of retrofitting existing dams for hydroelectric generation. Three types of facilities are appropriate to move fish upstream around dams: (1) fishways, (2) fish locks, and (3) fish lifts (also called fish elevators). In a fishway, fish swim up a series of pools, each of which is elevated above the preceding pool. In a fish lock, fish are crowded into a lock chamber, raised above the dam by filling the chamber with water, and released over the dam. A fish lift works similarly to a fish lock, except a water-filled mechanical hopper raises the fish above the dam.

If fish passage facilities are planned for a small hydroelectric site, there are important design considerations that must be evaluated to ensure the device will perform at the level required. The swimming ability of the target fish species requiring passage is one of the most important aspects of design. Swimming ability dictates attraction water velocities to entrance areas, water velocities required in resting areas, and the number and size of pools in a fishway. All environmental parameters that affect fish swimming ability (fish size, temperature, dissolved oxygen, presence of contaminants) must be known and evaluated on a site-specific basis. Fish behavior (including reaction to flows, restricted openings, and light), schooling behavior, and jumping behavior also can affect design features. Regardless of the type of passage system used, attraction water must be supplied to encourage fish to leave the normal flow and enter the device. Exit positions of fishways should be in low-velocity quiet areas. Small hydroelectric developers should obtain the advice and consultation of the U. S. Fish and Wildlife Service and the National Marine Fisheries Service to ensure that these types of complex and site-specific design considerations are properly incorporated into fish passage plans.

Small-scale hydroelectric sites retrofitted to operate in a store-and-release mode will cause water level fluctuations both above and below the dam. Potential impacts on physical and chemical characteristics in reservoirs resulting from water level fluctuation include resuspension and redistribution of bank and bed sediment, leaching of soluble organic matter from sediment in the littoral zone, and changes in water quality resulting from changes in sediment and nutrient trap efficiency. Potential impacts on reservoir biota as a result of water level fluctuation include habitat destruction and the resulting partial or total loss of aquatic species; changes in habitat quality, which result in reduced standing crop and production of aquatic biota; and possible shifts in species diversity.

The potential physical effects of water level fluctuation on downstream systems below dams are (1) streambed and bank erosion and (2) water quality problems related to resuspension and redistribution of these materials. Potential biological impacts of water level fluctuation on downstream systems below dams result from changes in current velocity, habitat reduction, and alteration in food supply. These alterations, either singly or in combination, can adversely affect aquatic populations below dams.

Assessing the potential significance of the above potential impacts due to water level fluctuation to the development of small-scale hydroelectric technology is difficult, due to the site-specific nature and complexity of the impacts. It appears that many existing dams that can be retrofitted to produce hydroelectricity would be operated in a run-of-the-river mode. Water level fluctuation may occur at such sites, but not to the same degree as at store-and-release plants. However, where feasible, store-and-release hydroelectric facilities can produce high value "peaking" power. Developers interested in peaking plants must carefully evaluate adverse impacts of water level fluctuation. Mitigation of water level fluctuation impacts is generally not feasible.

Modeling and Analysis of Aquatic Populations and Ecosystems

The Modeling and Analysis of Aquatic Populations and Ecosystems Group is concerned with the development and application of quantitative methodologies for predicting the consequences of mortality imposed on aquatic populations by man's activities. Historically, our research has focused on the effects of entrainment and impingement at power plants on fish populations. In response to changing regulatory needs, we are now reorienting our efforts toward the development of methods for assessing effects of other kinds of stresses, such as toxic substances and acid precipitation, on both populations and ecosystems.

Four lines of research are described in this section. Three are extensions of entrainment/impingement work that are applicable to any kind of stress. The fourth (Comparison of Estimation Procedures for the von Bertalanffy Growth Equation) is related to our current efforts to develop bioenergetic population models that incorporate the growth of organisms as well as their birth and death.

Stock-Recruitment Analysis

We are examining the statistical dependence of recruitment level upon stock size and selected environmental factors for three fish stocks: California striped bass (*Morone saxatilis*), Atlantic menhaden (*Brevoortia tyrannus*), and American shad (*Alosa sapidissima*) in the Connecticut River. The analysis involves (1) simple and multiple linear regressions of recruitment against stock size and environmental variables, (2) nonlinear regressions of recruitment against stock size using Ricker and Beverton-Holt stock-recruitment models, and (3) nonlinear regressions using Ricker and Beverton-Holt models modified to include environmental effects. We assess relative effectiveness of linear and nonlinear models in describing variation in recruitment level of the three fish stocks by comparing residual mean square (RMS) values and also by determining whether or not the regression models reduce to simpler forms (due to parameter estimates not differing significantly from 0.0) after being fitted to data.

Preliminary results indicated that no single class of models (linear, simple stock-recruitment, modified stock-recruitment) was consistently superior to the others in explaining variation in recruitment for all three fish stocks. The analysis for striped bass showed that environmental (water transport) variables were statistically more important to recruitment than was stock size, with linear regression models providing the most accurate descriptions of the data. In contrast, preliminary analysis of American shad data indicated that stock size was much more important to recruitment than were environmental variables, and modified Ricker and Beverton-Holt models appeared to best fit the data.

The results of such statistical analyses must be interpreted in the context of the data they are based on and of the specific analytical procedures employed. However, general features such as the strong dependence of California striped bass recruitment on environmental factors can be recognized and should be considered in studies of this species in different areas (e.g., in the Hudson River). Our results also may indicate which type of model (linear or nonlinear) would be worth elaborating in future studies of these fish stocks or applying in studies of other stocks of these species.

Detection of Reductions in Year-Class Strength

Fisheries managers and other decisionmakers frequently must predict the likely reduction in the size of a fish stock or in the strength of year classes prior to the imposition of a new or additional impact on the population. Although it may not be possible to address the problem directly with the degree of certainty desirable, it is possible to estimate what reductions could be detected using standard statistical techniques if a historical time series of stock sizes or year-class strengths is available.

White perch is one of the dominant fish species in the Hudson River. It has been the subject of intense study since 1972 with respect to potential population-level effects of entrainment and impingement mortality at power plants. As part of U.S. Environmental Protection Agency hearings, we performed a detailed evaluation of impingement losses of white perch at five power plants on the Hudson River. In this evaluation we used impingement rate of young-of-the-year white perch, especially at the large downriver power plants in winter where most young-of-the-year overwinter, as an approximate index of year-class strength. We concluded, based on regression analyses of impingement rate of young-of-the-year white perch versus year, that there was no statistically significant change in year-class strength during the period 1972 through 1977. Thus, we used impingement rates for 1972 through 1977 at these five power plants as baseline data to provide a measure of "natural" variability in year-class strength.

The two questions we addressed were: (1) Based on a given number of years of additional impingement data (starting in 1978), what is the minimum fractional reduction in mean year-class strength of white perch in the Hudson River that one could expect to detect? (2) Given that we want to be able to detect a specified fractional reduction in mean year-class strength (e.g., a 25 or 50% reduction), how many additional years of impingement data (starting in 1978) would be required?

Our results were not encouraging. They indicated that the variability in the existing baseline time series of impingement rates is so great that (1) 10 additional years of indices of year-class strength are not likely to provide a very powerful data set for detecting even substantial, actual reductions in mean year-class strength; and (2) a number of years of additional data greater than the expected lifetime of the power plants involved (e.g., 40 years) would be required to detect an actual 50% reduction in the mean index of year-class strength, even if one is willing to accept a Type II error of 50%.

Our methodology is applicable whenever a time series of indices of year-class strength is available. Because fluctuations in year-class strength of the Hudson River white perch population are not unusually great compared to those for other fish populations, it seems likely that similar results would be obtained for other species, even if the historical time series already available is appreciably longer. Thus, our analysis of the minimum detectable reduction in year-class strength of the Hudson River white perch population highlights a generic prediction problem which is already well recognized but seldom quantified in environmental impact analyses. Our methodology offers a generic tool for establishing bounds on minimum detectable reductions in fish stocks (or other populations) and on the number of additional years of data required to be able to detect a specified reduction.

Multipopulation Modeling

Ecologists recognize that in many cases studies of the impacts of stresses on single populations are not sufficient because they cannot account for indirect impacts that are mediated by other populations. These indirect effects, related to increases or decreases in the abundance of food organisms, competitors, and or predators, can either magnify or offset the direct effects of stress on a population.

We used a method of multipopulation modeling known as loop analysis to investigate the direct and indirect effects of entrainment and impingement at power plants on the Hudson River white perch population. Our goal was to discover how interactions with other populations affect the response of the white perch population to power plant impacts.

We have studied four models thus far:

1. A simple three-compartment food chain consisting of white perch, macroinvertebrates (the primary prey of both juvenile and adult white perch), and organic detritus (the primary source of energy for the biota of the Hudson and the sink to which entrained and impinged organisms are returned).
2. A four-compartment model in which another fish competes with white perch.
3. A four-compartment model in which another fish preys on white perch.
4. A five-compartment model that includes both a competitor and a predator.

Our analysis showed that in simple food chain models (i.e., no competitors present) the entrainment and impingement of white perch may not necessarily lead to a reduction in the long-term abundance of white perch.

If a competitor is present, then direct mortality to white perch invariably decreases the abundance of white perch, irrespective of whether predators are present. This decrease is invariably accompanied by a complementary increase in the abundance of the competitor.

Because the invertebrate prey of white perch is also preyed on by other fish species, it is clear that competitors with white perch are present in the Hudson River estuary. Our preliminary conclusion, therefore, is that interactions with other populations cannot offset the direct impact of power plant mortality on the Hudson River white perch population. Moreover, if this mortality does cause a decrease in the abundance of white perch, then one or more fish species with similar diets should increase in abundance.

We extended our analyses to models in which the white perch population is subdivided into lifestages, some of which are vulnerable to power plant mortality and some of which are not. We also used numerical simulation modeling to complement the work with loop analysis. Using numerical simulation, we can investigate the sensitivity of inferences drawn from loop analysis to violations of the assumptions employed in the analysis. Two especially important subjects for study are the effects of environmental fluctuations and of nonlinear feeding/assimilation functions.

Comparison of Estimation Procedures for the von Bertalanffy Growth Equation

The von Bertalanffy growth equation is popular with fisheries scientists because it can be fitted to most growth data and incorporated into stock assessment models. The von Bertalanffy equation is often presented in the form

$$l_t = L_\infty\{1 - \exp[-k(t - t_0)]\} \ ,$$

where l_t is the fish length at age t and L_∞, k and t_0 are coefficients characteristic of the fish stock. L_∞ represents the average maximum length, k is the rate at which L_∞ is approached, and t_0 is the age at which l_t equals zero.

The von Bertalanffy growth equation is nonlinear, and in the past it has been difficult to estimate its parameters. Traditionally, population length-age data have been manipulated so that simple linear regression techniques could be applied. The availability of digital computers, however, makes parameter estimation in nonlinear equations a trivial task. This study used Monte Carlo simulations of fish populations to compare linear and nonlinear methods for estimating parameters of the von Bertalanffy growth equation. The methods examined in this study were (1) the Ford-Walford linear method, (2) Bayley's linear method, and (3) an iterative, nonlinear regression computer program.

Monte Carlo simulations of fish populations (individual fish age, length and weight) were generated on an IBM 3033 computer using the von Bertalanffy growth equation [Eq. (1)] and the standard allometric equation. Multiplicative error, to simulate natural variability, was entered into both of these equations. Base conditions were set, and then five parameters were varied: (1) standard error of fish length, (2) total sample size, (3) sampling time interval, (4) the von Bertalanffy growth rate (k), and (5) annual adult survival. Each of the 20 simulated populations was replicated 100 times, with parameter estimates obtained for each replicate using the three estimation methods. The biases in estimates of L_∞, k, and t_0 for each replicate were calculated, and then the mean and standard errors of the biases from the 100 replicates were calculated for each simulated population. The mean of the bias is a measure of the accuracy of the estimate, while the standard error of the bias is a measure of the precision of the estimate.

The results were clear. The nonlinear procedure produced the most accurate parameter estimates in 55 out of 60 cases and the most precise estimates in 56 out of 60 cases. The nonlinear method, in general, also places the fewest constraints on data collection and provides asymptotic confidence intervals. It is also the easiest to use. The results of our study suggest that linear solutions to the von Bertalanffy growth equation should be abandoned.

Toxicant Formation in Condenser Cooling Systems

Potentially toxic products formed during chlorination of freshwaters include free residual chlorine (hypochlorous acid and hypochlorite ion), combined residual chlorine (chloramines - NH_2Cl, $NHCl_2$, NCl_3), and chlorinated organic compounds (chlorophenols, trihalomethanes, etc.). Research during the past year focused on bioaccumulation of chlorinated organic compounds by the Asiatic clam, *Corbicula fluminea*, and toxicity of free residual chlorine. Staff on the project also provided the major impetus for organizing the Third Conference on Water Chlorination and for publication of the proceedings.

Bioaccumulation of Chlorinated Organic Compounds by the Asiatic Clam

Several chlorinated organic compounds have been tentatively identified in Asiatic clams, *Corbicula fluminea*, collected in areas influenced by chlorinated effluents from power plants. Following evaluation of previously developed analytical methodology for extraction and identification of lipophilic chlorinated organics in animal tissues, samples of clams were collected from the discharge area of the Kingston Steam Plant and from a "control" population below Melton Hill Dam, a few miles away. Several halogenated organics were tentatively identified in the test populations (3,4-dichlorobenzoic acid, 1-chloro-tetradecane, 1-chloro-heptadec-6-yne, 3-bromodecane, 11-bromoundecanoic acid), which were not found in controls. Protocol for sampling and for publication of results is currently being established with responsible individuals in the Tennessee Valley Authority. A subsequent collection of *Corbicula* and water samples has been made at the John Sevier Plant and both are currently being analyzed.

Toxicity of Free Residual Chlorine

The term "free residual chlorine" (FRC), which includes hypochlorous acid (HOCl) and hypochlorite ion (OCl^-), was coined by chemists, because analytical techniques could not separate the acid and ionic forms, but FRC appears to be an invalid term with respect to toxicity. Last year we reported results of research examining the relative toxicity of HOCl and OCl^- by exposing *Gambusia affinis*, for 1 h, to predominantly FRC at six levels of pH. LC50 values, in terms of total residual chlorine (TRC), increased with increasing pH, ranging from 0.41 mg/L at pH 6.04 to 1.28 mg/L at pH 8.42. Because of the influence of hydrogen ion concentration on dissociation of HOCl, the percent of FRC which would be present as HOCl is about 97 and 11%, respectively, at the low and high pH. We have subsequently examined toxicity of monochloramine (NH_2Cl) and dichloramine ($NHCl_2$), each of which were $\leqslant 12\%$ of the TRC at each pH. No mortalities were observed after exposure to NH_2Cl at concentrations about four times or to $NHCl_2$ about two times the maximum concentrations present in any of the tests. We therefore assumed that the contribution of these two forms to toxicity was negligible and examined the fit of the FRC concentrations at the LC_{50} for each pH, with predictions based on a theoretically derived model. The model is

$$LC_{FRC} = LC_{HOCl} \left[\frac{1 + \frac{K_{HOCl}}{[H^+]}}{1 + \frac{LC_{OCl^-}}{LC_{HOCl}} \times \frac{K_{HOCl}}{[H^+]}} \right] ,$$

where LC = LC_{50} (mg/L) for each component of FRC, K_{HOCl} = the dissociation constant for HOCl, and $[H^+]$ = hydrogen ion concentration (moles/L). This model assumes that the toxic effects of HOCl and OCl^- are additive. Unknowns are LC_{HOCl} and/or (LC_{OCl^-}/LC_{HOCl}). A nonlinear least-squares regression of LC_{FRC} on pH ($= -\log_{10} [H^+]$) indicated that 99% of the total variability in LC_{FRC} was accounted for by the model, supporting the additivity assumption. Toxicity of HOCl is about four times that of OCl^-, indicating that FRC is not an accurate measure of toxicity.

Knowledge of [illegible]city of chlorine to sensitive life stages of organisms is important for assessing the impacts of chlorinated power plant discharges. We determined the toxicity of 1-h exposures of chlorine (92% free residual) at pH 8.3 (range ± 0.1) to eggs, larvae, and young (through 416 days of age) of common carp, *Cyprinus carpio*. Effects on eggs were assessed as percent hatch (~3 d post-fertilization), while effects on other stages were assessed 24 h after exposure. Probit transformation of percent mortality and log transformation of concentration were used for calculation of LC50 values. Eggs were the least sensitive of all life stages (Fig. 7.1). Larval LC50s were about 1/100 that of eggs. Median lethal concentrations (LC50) of young fish (27–40 d post-fertilization) increased rapidly to about double that of larvae and remained constant for 10- to ~100-mg fish. Then, in a period of less than 7 d the fish grew from about 100 to 300 mg body weight, and LC50 values more than tripled. Toxicity was constant from 47 to 416 d post-fertilization even though body weight increased by more than 15 times. Sensitivity of common carp from egg to 416-d-old fish appears to be characterized by a series of plateaus related to life stage and not body size, with rapid shifts in toxicity between plateaus. Relation of these plateaus to morphological or physiological changes occurring during these transition periods may be helpful in determining the mechanism(s) of chlorine toxicity. At least for common carp, effluent limits based on toxicity to larvae would protect other life stages.

Third Conference on Water Chlorination

The Third Conference on Water Chlorination: Environmental Impact and Health Effects was held in Colorado Springs, Colorado, October 28–November 2, 1979. The conference, co-sponsored by the U.S. Environmental Protection Agency, Department of Energy, Nuclear Regulatory Commission, National Cancer Institute, Tennessee Valley Authority, and Oak Ridge National Laboratory, was attended by over 300 scientists in biological, chemical, engineering, environmental, and related fields. One hundred technical papers were presented in 15 sessions. The proceedings, edited by R. L. Jolley, W. A. Brungs, and R. B. Cumming, was published by Ann Arbor Science Publishers, Inc. The conference and proceedings represent a major contribution to collecting and disseminating the known information and current research results concerning water chlorination and associated environmental effects.

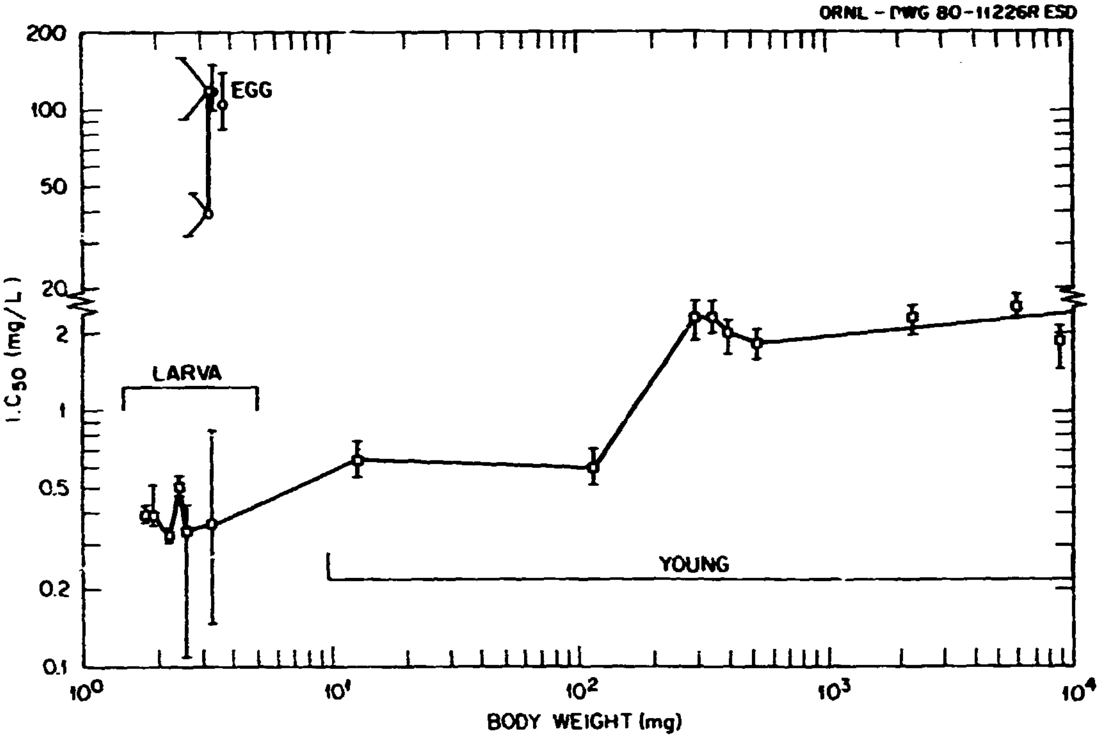

Fig. 7.1. Median lethal concentrations (LC50) and 95% C.L. for common carp (*Cyprinus carpio*) exposed for 1 h to free residual chlorine as a function of weight. Life stages are indicated.

Association of Legionnaire's Disease Bacterium with Cooling Towers

Legionnaire's Disease attained international attention as a "new" disease in 1976 when it caused a number of fatalities in Philadelphia. The causative Legionnaire's Disease Bacterium (LDB) has subsequently been identified at other disease outbreaks in hotels, hospitals, a university center, and in the New York garment district. Thus far, four major serogroups have accounted for the majority of diagnosed cases. Studies of the source of infection have at times implicated cooling towers associated with air conditioning systems as the dispersal vehicle for LDB. To compare the distribution and levels of LDB in air conditioning cooling towers versus the larger industrial-type towers, we surveyed both types of towers from various areas of the continental United States. The towers varied in size, type, and construction material. Some were treated only sporadically with biocides, while others were treated thrice weekly with a variety of biocides. The levels of LDB and the predominant serotype in the tower basin waters and control source waters were determined microscopically by the fluorescent antibody technique. Infectivity of LDB populations was determined by inoculation of guinea pigs and subsequent isolation of the bacterium on agar. The most striking result of the study was the ubiquity of LDB in both cooling towers and ambient control waters. Also the individuality of each tower regarding LDB levels and serotypes of LDB was apparent. Most of 70 test towers contained in excess of 1×10^4 LDB/L of water, as did many of the control waters that served as the source water for the towers. Levels of LDB in the cooling tower water ranged from no increase over source water to several thousandfold increases relative to source water. In general, the LDB populations did not depend on whether the tower was of the air conditioning type or the larger industrial type. Likewise, some towers receiving minimal biocide treatment had low levels of LDB (10^5/L), whereas some receiving extensive biocide treatment had higher concentrations of LDB (10^8/L). In addition, towers of similar size, type, and biocide treatment and receiving the same source water may have LDB populations which vary greatly in numbers, predominating serotype, and infectivity. Treatment with chromate biocide does, however, correlate with low concentrations of LDB.

Multimedia Environmental Transport Modeling

In early 1979, the Environmental Protection Agency (EPA) asked ORNL to further develop and implement ORNL's Unified Transport Model (UTM) for use by EPA in fulfilling the Toxic Substances Control Act of 1976 (TSCA). The UTM was developed in the early 1970s under National Science Foundation sponsorship as a multiple-media (air, land, water) package of linked computer models for tracing the movement of inorganic, trace contaminants through the environment. Under TSCA, EPA must evaluate the environmental hazard of new chemicals, of existing chemicals with new uses, and of existing chemicals that have been designated as priority toxic pollutants. Many of the chemicals are organics. A first step in evaluating hazard is determination of environmental concentrations of the chemicals following dispersal from sites of manufacturing, transportation, and use. The ORNL model package seemed well suited to this need.

In general, major goals of the project in its first year have been to update the UTM and to expand it to incorporate chemical transport mechanisms that are characteristic of organic substances. These mechanisms include volatilization, photolysis, hydrolysis, and chemical/biological degradation. Improved modeling of sediment transport in water and evaluation of deposition routes and rates from air to the surface terrain were important goals. Terrestrial hydrological models were modified to make them more applicable to agricultural lands and to soils with discrete percolation channels ("macropores"). The ability of the UTM to handle multiple-release scenarios was broadened, and model output formats were adapted to graphical displays.

Because the UTM requires stipulation of many environmental variables (e.g. terrain, rainfall, soil types, vegetation cover), the regional assessment staff has sought to characterize discrete environmental regions of the United States. These regions can then be used as "standard environments" for generic evaluation of chemical transport and fate. The regionalization of available data in computer-searchable data bases also provides a resource for input information for initial site-specific analyses.

At the end of the first year, ORNL provided EPA with a working tape of the main UTM model package and 12 backup reports in draft form. We anticipate continuation of the project with further model development and assistance to EPA in applying the transport models to regulatory assessments.

Formulations of the Physicochemical Processes

The UTM developed by ORNL to simulate the movement of heavy metals in the environment is being modified to address the fate of organic compounds in the environment. The resultant new model, the Multimedia Model (MMM), consequently must account for transport, partitioning, and transformation processes of relevance to organics. At the moment, algorithms have been incorporated to represent the various processes only as they occur in the terrestrial and aquatic compartments. Atmospheric processes will be considered in the next developmental phase. The current MMM represents the first phase of the introduction of the above processes into the model. Thus the descriptions of individual processes do not necessarily represent the ultimate level of sophistication intended.

The physicochemical processes represented in the MMM include adsorption-desorption, volatilization, biodegradation, hydrolysis, and photolysis. Wherever possible, rate processes have been presented as first-order or pseudo-first-order expressions. Adsorption-desorption in terrestrial and aquatic systems is given by a simple distribution coefficient, K_d:

$$K_d = \frac{x/m}{C} ,$$

where x/m is the amount of chemical sorbed per unit mass of sorbent and C is the equilibrium concentration of chemical in solution. Chemical degradation and biodegradation processes in terrestrial systems are treated by a single first-order equation utilizing an aggregated first-order constant:

$$-\frac{dC}{dt} = KC ,$$

where C is the concentration of chemical in the soil, and K is the aggregated rate constant. For a given soil, this rate constant is dependent on the temperature and soil moisture content.

In contrast, in aquatic systems, the degradation processes are readily separable into hydrolytic, photolytic, and biodegradation contributions. The hydrolysis rate is given by

$$-\frac{dC}{dt} = K_h C = (k_A[H^+] + k_B[OH^-] + k_N[H_2O])C ,$$

where K_h is the overall hydrolysis constant; k_A, k_B, and k_N are second-order acid, alkaline, and neutral rate constants, respectively; and C is the concentration of chemical in solution. The rate constant is thus dependent upon pH, and in addition upon temperature, in accordance with the Arrhenius equation. The photolytic rate expression is

$$-\frac{dC}{dt} = K_a \phi C ,$$

where C is the concentration of chemical in solution; ϕ is the quantum yield; and K_a is the rate constant (which is further detailed below):

$$K_a = \frac{2.303}{J} \Sigma E_\lambda I_\lambda ,$$

where E is the molar extinction coefficient of the chemical at wavelength λ; I_λ is the "light" intensity at wavelength λ; and J is a conversion factor. The biodegradation rate expression is

$$-\frac{dC}{dt} = KBC ,$$

where K is a second-order rate constant; B is the number of viable bacteria per unit volume, and C is the concentration of the chemical in solution. This equation is derived from the more complicated Monod-type expression at low concentrations of chemical.

Volatilizations of organics from aquatic and terrestrial systems are treated differently. In the latter instance, the expressions depend upon the location of the chemical in the soil profile. Where the chemical is at the soil surface, the flux, F, from volatilization is described by

$$F = C \times V \times EVC/M^{1/2} ,$$

where C is a calibration factor related to watershed characteristics, V is wind velocity, EVC is the equilibrium vapor concentration, and M is the molecular weight of the chemical compound. Where the chemical is deeper in the soil profile and movement of the chemical is diffusion controlled, then the flux, F, is given by

$$F = DC_0/(\pi Dt)^{1/2} \ ,$$

where D is the diffusion coefficient of the chemical in the soil, C_0 is the initial concentration of chemical in the soil, and t is the time elapsed. D is a function of the soil moisture content, porosity, and temperature. In aquatic systems, the expression for volatilization is

$$-\frac{dC}{dt} = K_L(C - P/H)/L \ ,$$

where C is the concentration of chemical in solution, P is the ambient vapor pressure of the chemical, H is Henry's Law constant for the chemical, L is the depth of mixing, and K_L is the overall mass transfer coefficient. K_L is a function of the mass transfer coefficients in the water and air films at the air-water interface, the temperature, turbulence in the air and water, the gas constant, and H. When P is negligible, the above expression reduces to

$$-\frac{dC}{dt} = \frac{K_L}{L}(C) \ .$$

This is a first-order expression under constant environmental conditions.

In the next developmental stage, anticipated alterations to the MMM will include (1) the incorporation of atmospheric chemistry; (2) in a few instances, substitution of new algorithms for ones already present; and (3) for the most part, the addition of new algorithms which represent the influence of assorted environmental conditions on the primary coefficients included in the basic algorithms that are already installed in the model.

Operation of the Model

During October 1979 the UTM was reactivated after a dormancy period of over three years. The model was put in operation again very quickly, and a restudy of the model was begun to make the modifications required by the Environmental Protection Agency. Simultaneously, a series of training sessions were held with the multimedia modeling group, most of whom had not worked with the UTM.

Early and systematic collaboration was begun, aimed at setting the appropriate scale and resolution for the new processes. Volatility from the soil was selected as the first candidate from the processes to be included in the model. Volatilization from the stream channel flow, degradation in the soil, degradation in the stream, and photolysis have now been added to the model, and examples of each have been successfully executed. These secondary sources need to be coupled back to the atmospheric transport portion of the model to establish their fate.

Considerable work has gone into refining the methods by which the results of the model are presented to potential users. Comments by EPA staff indicated that concentrations in the environmental compartments would be of great interest in assessing exposure, so these variables were extracted and displayed in appropriate formats. The display modes now include tabular display of selected data, tabular display of statistical summaries, print plots, CRT displays of selected data (primarily used in debugging operations), and line plots made with pen and ink or other devices.

The capabilities of the UTM have been used to address six release scenarios proposed by the EPA. These scenarios include direct release to air and/or water in both urban and rural sites. The model in its present form is capable of handling each of the proposed scenarios, but it will be modified slightly to accommodate some of these in a more direct manner. Considerable development of the UTM during the coming year can be anticipated to yield an enhanced environmental transport model with greater scope and more utility to the user.

Atmospheric Transport

An updated version of the Atmospheric Transport Model (ATM) (Culkowstic and Patterson 1976) was developed as part of the Multimedia Modeling Project and was delivered to EPA. The ATM is a Gaussian plume-type dispersion model capable of calculating dispersion from point, line, and area sources emitting into the atmosphere. The main features added were a facility to include a vertical wind profile, a mixing height facility, provision for chemical decoy, and an additional atmosphere stability classification scheme.

Models and observations of atmospheric removal processes for toxic chemicals were reviewed. It was discovered that very few field observations of wet and dry removal of toxic chemicals are available. One study showed that the major input of PCBs to the Great Lakes is through atmospheric removal. The recommendation is made that dry deposition speed and washout ratio for new chemicals be set equal to the values observed for known chemicals with similar characteristics. In this way, extensive deposition data for SO_2, CO, iodine, and a few other well-known chemicals can be used.

Verification and validation work has also been undertaken for ATM. The model results were compared with an ^{85}Kr data base from the Savannah River Laboratory. These data covered a 30-month period and contained information on release rates and observed concentrations at 13 locations at distances from 40 to 140 km from the release site. In almost all cases the concentrations calculated using ATM were within a factor of 10 of the measured values, with about one-half of the calculated values being within a factor of 2. The agreement is probably as good as can be expected for such a model.

Terrestrial Transport

Models representative of three levels of resolution were developed or modified to meet EPA assessment needs in pollutant transport, particularly for organic materials. (1) The Wisconsin Hydrologic Transport Model was modified to include organic chemical processes (above). (2) The Terrestrial Ecosystem Hydrology Model (TEHM) was modified for agricultural applications with the inclusion of algorithms for flood and sprinkler irrigation and changes in soil water dynamics to allow macropore channeling flow through the profile. The original algorithm for variable subsurface flow (interflow) in TEHM was also changed to provide variable contributing area flow during storm events. This change provided much more realistic hydrologic behavior in test case applications made for grassland watersheds than was obtained with the original model structure. Several additional modifications were made to the handling of input data to increase flexibility in using either detailed hourly inputs or having the model derive average daily data for periods when no data are available. This agricultural version, called AGTEHM, is being applied to three crop studies (one for corn and two for soybeans) for testing of the new algorithms. (3) The third modeling development involved a finite-element code for two-dimensional transport of contaminants in porous media.

The three levels of model development allow a range of possible application scenarios required for EPA assessment needs. These range from large watersheds (100 km^2) to small watersheds (100 ha) down to small land units (1000 m^2) facilitating applications to regional as well as detailed site specific (e.g., landfill) pollutant transport problems.

Aquatic Transport

First, to predict the processes involving flow dynamics and transport of matters (chemicals, radioactive or nonradioactive wastes) and heat in the physical environment of the hydrosphere, lithosphere, and atmosphere, one is normally faced with the problem of solving a set of elliptic, parabolic, and or hyperbolic differential equations, in which appear both first and second derivatives of dependent variables, usually with nonconstant coefficients. One is further confronted with the problem of analyzing those processes in a region consisting of compound media enclosed by very complex geometrics. Analytical solutions for such complex problems are not possible with the present state-of-the-art of applied mathematics. Numerical methods must therefore be selected to approximate the governing differential equations and to best represent the region of interest.

A powerful numerical method - an integrated compartment method (ICM), proposed last year for the numerical solution of Navier-Stokes equations (Yeh 1980*a*), has been extended to handle any type of partial differential equations that may be carved into the combinations of gradient, divergence, and some functionals of the dependent variables (Yeh 1980*b*). The extension includes among other things the easy handling of nonisotropic media and the adoption of implicit time-marching schemes. The method has been applied to the simulation of flow dynamic problems in a stream river network (Yeh et al., in press). Results indicate that the ICM can definitely simulate the behavior of the hydrodynamic variables that are required for the chemical transport and transformation in the stream river system. It has also been applied to the anisotropic porous media for the multidimensional modeling of the chemical fate and pathway under nonisothermal conditions (Crooks et al. 1980).

The most serious deficiency encountered in the ICM is that the interpolated interface value is only the representative one. The value cannot be identified with a definite point on the interface. Continuing effort should be made to circumvent this problem. One possible way to overcome the problem is to first interpolate the value of the corner points of the interface in terms of the node values whose compartments join at the corner and then interpolate the value at any point on the interface in terms of the values at the corner points. This two-step interpolation procedure would greatly complicate the problem; however, it is worth pursuing for further improvement of the ICM.

Second, to study the transport and fate of dissolved constitutents in a subsurface flow system, the Darcian velocity field therein must first be determined. The finite-element modeling technique is normally used to simulate the pressure distribution in the aquifer system. The flow field is then computed with Darcy's law by taking the derivatives of the calculated pressure field (Pinder 1973, Duguid and Reeves 1975, Gupta et al. 1976, Segol 1976). Inherent in that approach, however, is the resulting discontinuity in the velocity at nodal points and element boundaries, which unfortunately leads to a violation of the conservation of mass in a local sense. Inputting this discontinuity flow field into the contaminant transport computation could conceivably produce erratic error. Therefore, we have proposed to solve Darcy's law for the velocity field at nodal points using the finite-element technique rather than simply taking the derivatives of the computed pressure field. With this approach, we have removed the discontinuity in the velocity field (Yeh et al. in press). To illustrate the case, Figs. 7.2 and 7.3 depict the velocity distribution resulting from a seepage pond

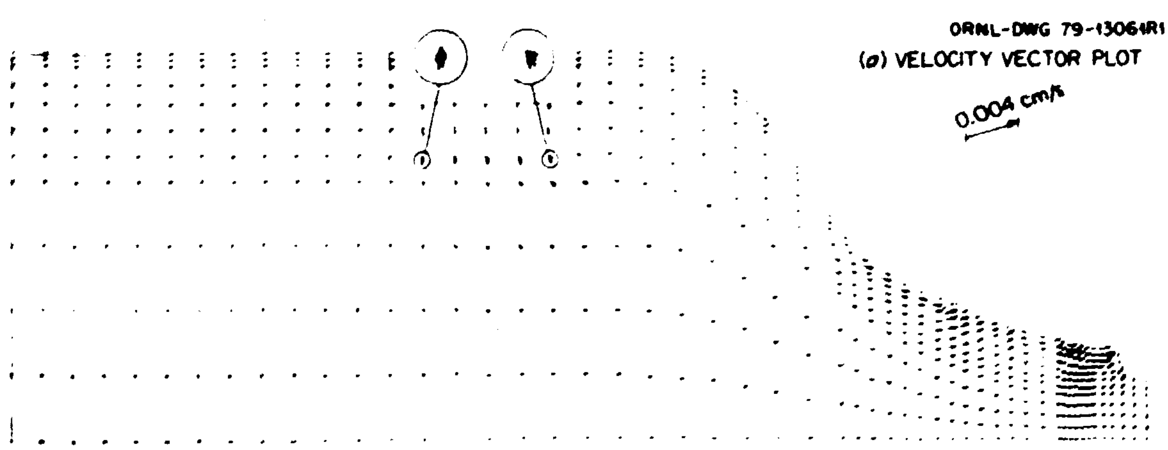

Fig. 7.2. Flow pattern in the ground-water system simulated by the conventional approach

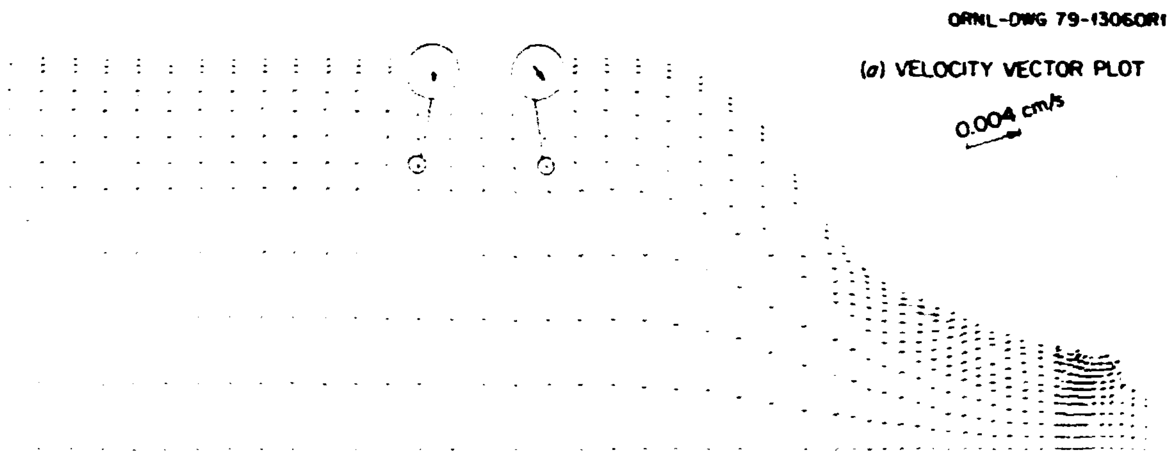

Fig. 7.3. Flow pattern in the ground-water system simulated by the present approach.

by the conventional approach and by our proposed approaches, respectively. It shows that the velocity by the conventional method is discontinuous at every nodal point as indicated by the multivectors at every point in Fig. 7.2. The discontinuity is completely eliminated with the proposed approach as can be seen from Fig. 7.3, which shows the unique velocity vector at all nodal points.

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8. ENVIRONMENTAL RESOURCES

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Introduction

The Environmental Resources Section (ERS) continues to provide support for many Environmental Sciences Division (ESD) research and management activities. In addition, section staff members contribute to scientific goals of the Division by collaborating with staff from other sections and programs in ESD and ORNL as well as by conducting research projects totally in the context of subjects specifically related to ERS.

The major support for ERS activities is from the Department of Energy (DOE) Office of Health and Environmental Research, with lesser support from the U.S. Army Corps of Engineers, U.S. Fish and Wildlife Service, U.S. Forest Service, and National Science Foundation, and other DOE offices.

Because scientific needs, staff, and support are so diverse, section capabilities and output are diverse. They range from expertise and major emphasis in both generic (i.e., broadly based studies involving mostly principles) and highly specific regional studies to use of software in routine statistical analyses. Specific groups within the section are Regional Studies, Modeling and Systems Analysis, and Data Management and Analysis.

Regional studies historically have focused on site-specific subjects which mainly characterize conditions involved in potential impacts. Such studies are closely tied to extant data bases or the collection of new data to meet new objectives in regional analysis. The value of such studies will continue, but additional approaches are being developed to help managers plan and predict alternatives relating to overall land use in a given region. This new emphasis, which is being tied more closely to system analysis procedures, is briefly outlined in later text. Systems analysis activities continue to be closely allied with research project planning and analysis. Three examples which have widespread implications are given in this report. Lastly, section staff provided considerable development and aid to ESD in numeric data activities through statistical and computer services in the past year. Further, continued acquisition, organization, updating, and use of both extant and newly collected data added significantly to ESD resources and capabilities. In addition to long-term data set development summarized in previous years, new activities were established this past year.

New projects which potentially could benefit from slight changes in Section emphasis point the way for the continuous dynamic process of updating overall Section activities. The most active areas of such evolutionary change are in Regional Studies and Data Management, mainly aided and driven by rapid changes in these fields of study and research and development needs in the ESD and elsewhere.

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Regional Ecology and Analysis

RARE-II

The past fiscal year marked the end of the DOE-funded project to analyze and evaluate the U.S. Forest Service's RARE-II (Roadless Area Review and Evaluation) tracts being considered for possible inclusion in the National Wilderness Preservation System. The goals of this project were twofold: (1) to estimate the energy resource potential of the tracts and (2) to evaluate the ecological resources within them. The results of the energy resource investigations are in Voelker et al. (1979 *a,b*).

We developed a hierarchical rating system for regional ecological assessment (Klopatek et al. 1980 *a,b*) that can be used to provide an objective and comparative ecological evaluation of land areas in the United States. The methodology can also be used to evaluate potential biotic and nonbiotic resource (e.g., mineral and energy) use conflicts and to structure and study alternatives to resolve such conflicts. Four general parameters were chosen to quantify land areas located anywhere in the conterminous United States. These are (1) vegetation—the principal vegetation communities within each area, (2) avian communities—the kinds and abundance of birds inhabiting an area and the quality of habitat provided by an area, (3) mammal communities—the species of mammals inhabiting an area, and (4) endangered or threatened species—the occurrence of species and whether or not the area provides critical habitat. Ratings of all four parameters were then combined to produce an Overall Ecological Index. Figure 8.1 shows the results for the Ponderosa pine—Douglas-fir ecoregion of the United States. As discussed in Auerbach et al. (1979), these rankings of individual tracts can then be used in a matrix to segregate the tracts according to their ecological ratings against their energy, critical mineral, timber, or other ratings to identify range and type of potential future conflicts.

As with any technique for regional analysis, this methodology has limitations, primarily centering on the level of resolution of the data. An ecological rating system requiring uniform resolution for the approximate 800×10^6 ha in the conterminous United States would require an enormous amount of data, probably more than can be justified or even acquired. Nonetheless, the data base has been designed so that when additional ecological data (applicable to the whole United States) become available, they can be added without much difficulty. Data that are both necessary and acceptable to improve current files include stage of vegetational succession; water quality (in terms of supporting biological life); distribution of reptiles, amphibians, and fish; and exact locations of federally and state-designated endangered and threatened species. In addition, definitions of vegetation type, successional sequence, and animals that inhabit that type are needed. This goal is being addressed by new research projects developed by staff of the ESD and the U.S. Forest Service.

Landscape Pattern Analysis

Since European settlement, the U.S. eastern deciduous forest formation has been continually fragmented to a point where most regions in the eastern United States are characterized by isolated patches of forest in a matrix of agricultural, urban, or other land uses. As part of a project on "Forest Island Dynamics in Man-Dominated Landscapes," soon to be published in book form, the distribution of forest islands in diverse areas in Ohio was analyzed. A major objective was to determine if regional environmental characteristics were sufficient to influence and control historical land use in selected regions that were initially covered by contiguous forest. Maps of Ohio counties, prepared by the Ohio Department of Forestry with Works Projects Administration (WPA) assistance in the late 1930s, portray sizes, shapes, locations, and (in some cases) forest type and condition class of all woodlots over 1 ha. Study areas of 10,000 ha were selected in Miami, Knox, Belmont, Summit, Holmes, and Coshocton counties. These regions, chosen solely for perceived differences in the pattern of forest islands that remain in the modern landscape, span environmental gradients of glacial history, topography, and soils.

ORNL-DWG 81-3882 ESD

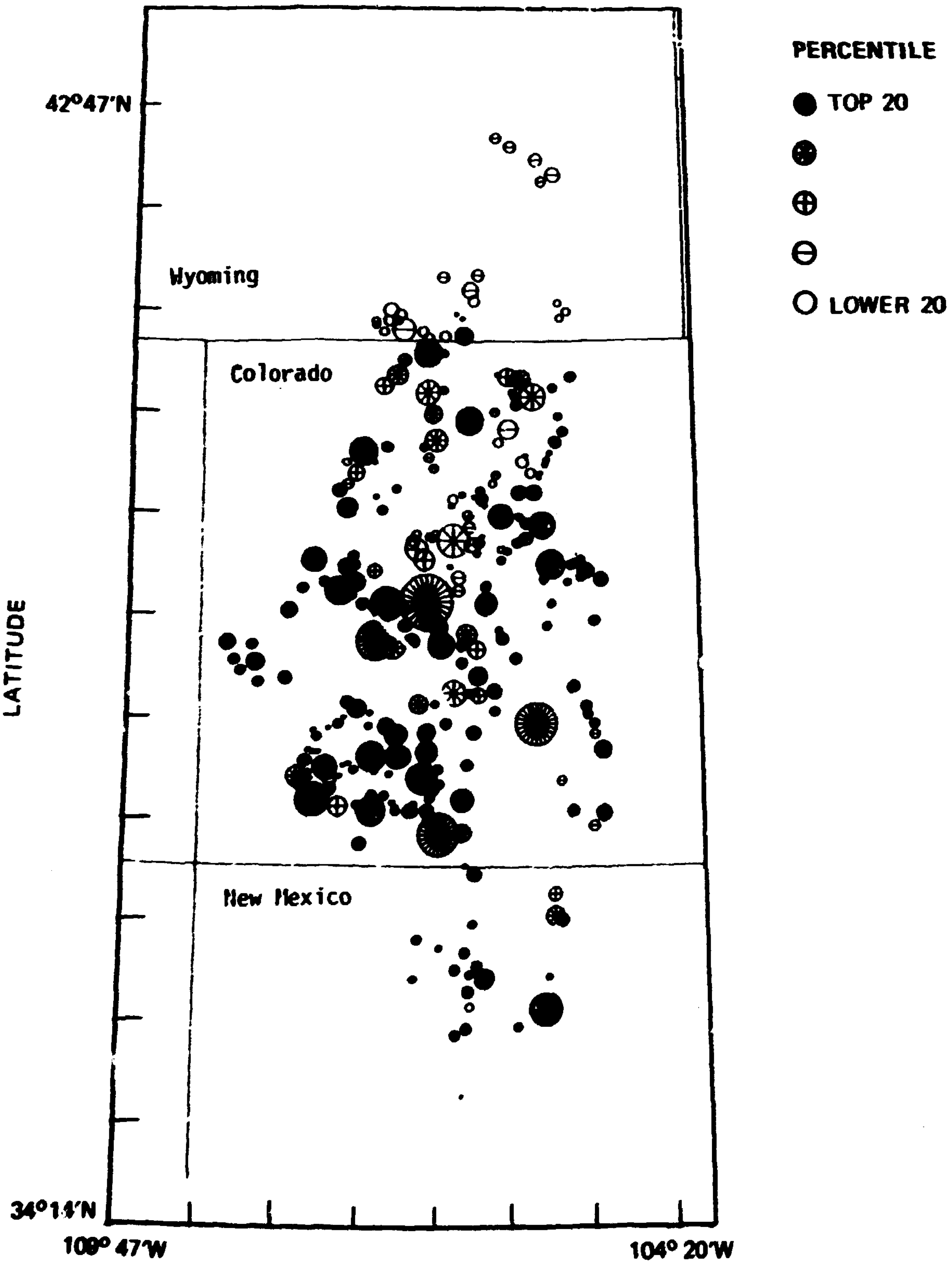

Fig. 8.1. Overall ecological indices for the Ponderosa pine–Douglas-fir ecoregion (M3113).

In Miami County, which is highly modified by agriculture, woodlots are generally small, few in number, widely scattered, and approach rectangularity, with the majority of the island edges formed by straight lines. In Belmont County, in the unglaciated eastern part of the state adjacent to the Ohio River, the islands are large, numerous, and very dissected, with virtually no straight boundaries anywhere. Areas in Coshocton, Holmes, Summit, and Knox counties, astride the glacial boundary in east-central Ohio, are intermediate.

Measurements of selected variables associated with forest islands in 15 study areas yielded landscape parameters of forest cover (percent), density (number per unit area), median island area, mean island Dissection Index (DI), landscape DI, and mean distance of separation (edge to edge). The DI gives the ratio of the perimeter of an island to the area of a circle of equal size and thus measures the degree of irregularity in island shape. A landscape DI, using the sums of perimeters and areas,

$$\mathrm{DI} = \sum_{k=1}^{k} P \; 2\sqrt{\pi \sum_{i=1}^{\eta} A}\;,$$

gives an independent measure of the amount of dissection for the landscape within a given region, which, when coupled with cover and density measurements, characterizes a given forest island pattern.

These variables were derived from a comparison of differences based on a hypothetical landscape composed of circular islands of uniform size. Because cultural landscapes harbor islands that are neither circular nor uniform in size, deviations from expected values based on hypothetical landscapes permitted placement of sampled areas in an orthogonal array.

Multivariate analyses then positioned the different forest island regions according to principal components axes related to cover (primarily) and density. Use of discriminant analysis determined that the variable landscapes could be separated based on environmental factors such as soils, topography, glacial history, and presettlement vegetation (Fig. 8.2).

ORNL-DWG 81-3897 ESD

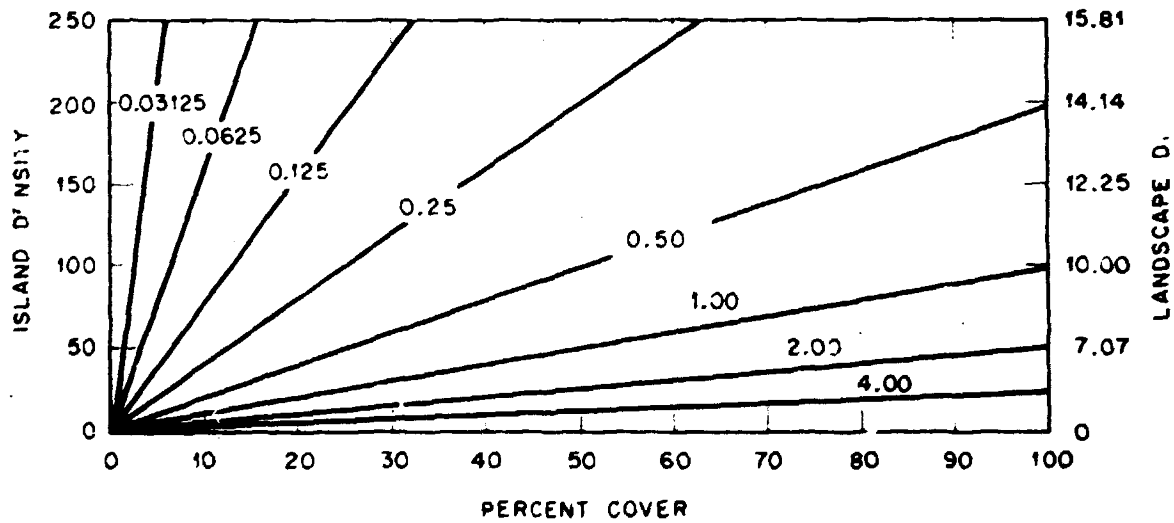

Fig. 8.2. Ecological hyperspace within which individual forest island landscapes can be plotted. Lines radiating from the origin denote lines of equal mean island area.

Woody Biomass Regional Studies

Short-rotation silviculture is the most intensive management scheme now proposed for producing wood for energy. Most plans for short-rotation production have certain common assumptions that allow analysis of possible patterns and impact of such program development. The most important of these assumptions is that the land used will be only marginal for conventional agricultural crops, though suitable for mechanical site preparation, cultivation, and harvesting. When we examined the distribution of such land in the Southeast not being used for crops, pasture, or forest products, portions of the Coastal Plain, peninsular Florida, and the Mississippi River Valley showed the greatest potential for producing enough short-rotation wood quantities to support large-scale conversion facilities (Ranney and Cushman, in press).

To understand implications of changes in the structure and composition of regional forest systems, we examined the distribution of forest types and existing harvesting patterns on lands suitable for short-rotation culture. Results show that effects on forest types will not be homogeneous across the coastal plains. Existing forests contain various mixtures of hardwood and softwood types. However, forest industries already use significant amounts of softwood forests in much of the region, and remaining hardwood types become th available. Though the largest conversion programs are expected to use loblolly shortleaf pine stand ne Atlantic Coastal Plain, bottomland hardwoods on river floodplains may be disproportionally affected across the Southeast.

A simulation study of the hydrologic consequences of converting coniferous forest to a sycamore (*Platanus occidentalis* L.) biomass farm in the coastal plain of South Carolina (Crandall and Luxmoore, submitted) identified a potential problem of rising water tables with the change in land use. Reduced annual evapotranspiration and increased drainage to water tables, predicted with the change from coniferous to deciduous species, could lead to an increase in swampland in the coastal plain region of southeastern United States.

Extension of Regional Models

The objective of this project is to formulate a comprehensive conceptual framework for regional analysis (ARIES) adaptable to a broad spectrum of environmental conflicts. The concepts are not based on any specific disciplinary paradigm, such as ordinarily used by demographers, resource economists, or environmentalists. This strategem is likely to be maintained, for the choice of any single paradigm might limit the scope of the effort because of a temptation to reframe problems into "familiar" terms.

At the heart of our conceptual framework is the hypothesis that three classes of state variables are necessary and sufficient for addressing a broad spectrum of potential regional environmental conflicts. These classes are (1) marketable assets, (2) environmental patterns, and (3) cultural responses within a region.

Regional marketable assets represent one facet of these potential conflicts. Ordinarily, they represent potential sources of revenue such as units of oil, mineral resources, or harvestable timber. In developing these resources commercially, other state variables are impinged, often resulting in conflicts among social units.

Of particular interest are changes in natural or managed systems of the region. To emphasize spatial characteristics of many of these changes, we designate certain relevant state variables as environmental patterns. Typical variables are indices of air or water quality and areas of unique habitat or productivity of these ecosystems in the region.

The involvement of society in the conflict is reflected in a set of cultural variables. We use the term "culture" to emphasize that not only population densities but also equally important variables reflecting values of the society such as energy demand per capita, recreation, and aesthetics are included.

Further, our hypothesis is that these three classes of state variables, about which we make our arguments characterizing social conflicts related to resources, adequately consider internal aspects of economics of resource extraction, potential environmental changes, and cultural reactions to the changes.

This approach implies that all major relevant aspects of the regional system are included and that we can study these implications. An implicit subhypothesis is that it is necessary to include externalities, which may often be the driving forces of the system, before the entire problem can be formulated and understood.

Results of this model have been demonstrated (Krummel et al. 1980, Auerbach et al. 1980) for a regional system in which the problem examined was dominated by assets. Figure 8.3 displays some results obtained from applying the ARIES conceptual framework to a regional-level problem strongly influenced by pattern. In this situation we analyzed the food supply, grazing, and cattle herding of an East African seminomadic herding

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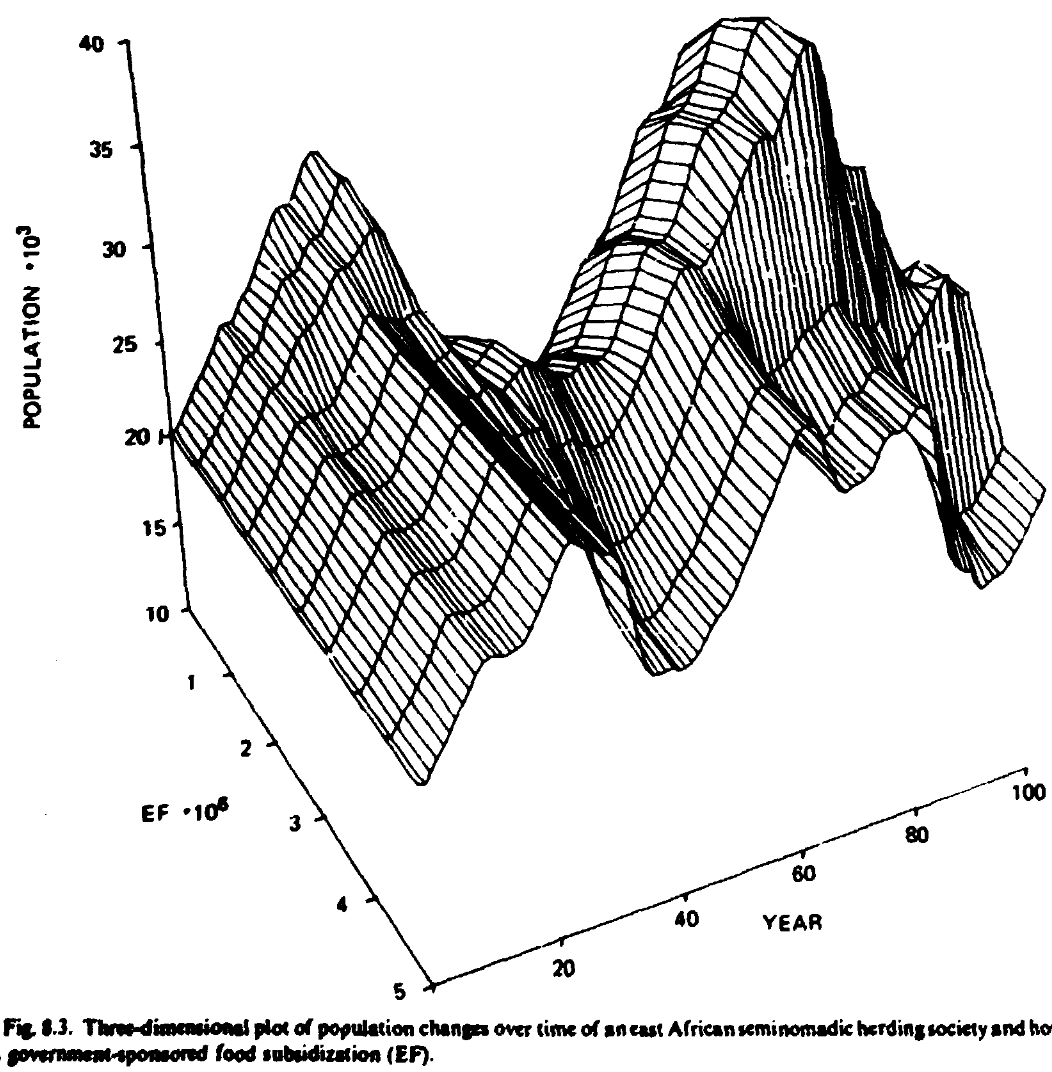

Fig. 8.3. Three-dimensional plot of population changes over time of an east African seminomadic herding society and how it is affected by a government-sponsored food subsidization (EF).

society. Environmental patterns associated with grazing, crop production, and rainfall are the critical factors in this problem. The influence of a food subsidy, when needed because of a crop failure or a decline in cattle population, is demonstrated. The results indicated that the population peaks at a lower initial value (than with no subsidy) with a high subsidy and a higher peak in later years. This behavioral aspect of the ARIES model is not fully understood at the present time, and we are attempting to explore the causes.

It is our premise that a wide variety of regional problems can be approached through use of this basic framework. We feel all such problems involve the dynamic interactions of regional assets, environmental patterns, and societal responses. Thus, these interactions, combined with any relevant external influences, should receive the greatest amount of attention in future studies on energy environment conflicts within given regions of the United States.

Ecological Toxicology Protocols

This project was initiated to aid the Office of Toxic Substances, Environmental Protection Agency (EPA), in the implementation of the Toxic Substances Control Act (TSCA). The TSCA authorizes the EPA Administrator to protect the public and the environment from potentially harmful chemical substances and mixtures by requiring testing and necessary use restrictions on chemicals that have been demonstrated to present an unreasonable risk.

The major objective of the project is to identify the potential for standardizing the testing of the effects of toxic substances on selected ecological parameters indicative of interspecific interactions, community dynamics, and ecosystem functions. This has been accomplished by reviewing and evaluating multispecies test methods, data evaluation procedures, and ecological parameters amenable to laboratory test development for their potential utility to the hazard identification and risk assessment processes of TSCA.

To enhance data collection and analysis activities, a series of six workshops was held on issues related to multispecies laboratory testing methodologies and environmental hazard assessment techniques. The workshops specifically addressed methods for measuring effects of chemicals on terrestrial population interactions, on aquatic population interactions, on terrestrial ecosystems, and on aquatic ecosystems. Mathematical models useful in chemical hazard assessment and assessment and policy requirements of multi-species test procedures were also addressed.

Efforts this year concentrated on the workshop series, including documentation of the results, and on the review and analysis of selected literature on laboratory methods for ecological toxicology. Two reports resulted from this project: (1) Ecological Test Systems (workshop results) and (2) Methods for Ecological Toxicology: A Critical Review of Laboratory Multi-species Tests. A companion report, Testing Effects of Chemicals on Ecosystems, was produced by the National Academy of Sciences Committee to Review Methods for Ecotoxicology.

Office of Environmental Assessment Activities

Researchers in the Environmental Resources Section participated in the Regional Issues and Identification Assessment (RIIA) for the Office of Environmental Assessment. This project sought to identify environmental issues associated with the implementation of the National Energy Plan (NEP II). Significant regional environmental problems identified as possible constraints to energy development were analyzed, and the magnitude of the environmental problem over regions was quantified. Our involvement consisted of an analysis of the ecological, water-quality, and land-use regional problems associated with increased projected energy development in Federal Regions IV and VI.

The regional ecological analysis focused on potential problem areas of natural vegetation and cropland associated with SO_x deposition. For example, possible impacts on commercial pine forests and soybean production were analyzed under the assumptions of NEP II scenario for coal-fired power plant sitings. Impacts on threatened and endangered (T and E) species from future energy developments (i.e., surface coal mining) were also examined by overlaying potential energy perturbations on county-level information on habitat requirements and present distribution of T and E species.

Regional land-use and water-quality analyses dealt primarily with projected increases in surface coal mining. The land-use analysis presented information on revegetation potential and the land-use categories most likely to be disturbed by mining activities. For example, lignite extraction in Texas will affect pasture land, commercial forest sites, and some wheat and sorghum cropland. The water-quality analysis addressed those drainage basins already experiencing water-related problems. Potential problems of acid mine drainage and increased sediment loads in certain streams and rivers associated with increased coal removal were analyzed.

Systems Ecology

Ecosystem Model Resilience Analysis

Models of food-web or trophic-level energetics and models of nutrient cycles have been treated separately in the literature in these areas, and different conclusions have been drawn about the factors that affect the resilience of these models. Resilience means the rapidity with which a stable ecosystem model returns to equilibrium following a perturbation. The study of energetics models led to the conclusion that the magnitude of flux, in this case energy or biomass, per unit standing crop through the system, or power capacity, is positively correlated with the system's resilience. The analysis of nutrient cycles, on the other hand, indicates that the recycling index (proportional to the average number of times a given nutrient atom would cycle through the system) is a determinant of resilience and that the resilience of a model decreases as the degree of recycling increases. Analytic work has shown that these conclusions are not mutually exclusive, and both factors can operate in a given model. Both the power capacity and the recycling index are measures of the speed with which units of energy of matter are carried through the system from input to output. In fact, it is possible to define a single index, the mean transit time (TT) from input to output, that incorporates the two factors of power capacity and recycling. This TT should, in principle, be strongly positively correlated with the mean recovery time (TR) of an ecosystem model in which a perturbation has been set and, therefore, inversely correlated with the resilience. Extensive Monte Carlo simulation appears to confirm this relationship. These results should bring us a little closer to understanding the influence of structure on stability in ecosystems.

Model of Technetium Isotope (^{95m}Tc) in a Pond

Nuclear power generators are enhancing the levels of radionuclides in the aquatic environment. Since many aquatic organisms in the human food chain are known to concentrate certain radionuclides, even very low levels of radionuclides entering lakes and streams are a matter of concern. Methods for estimating average body burdens in biota caused by chronic releases of nuclear wastes to the environment are needed.

A combination of empirical study and mathematical modeling is being used to study the fate of radionuclides in bodies of water. The bodies of water are simulated by small, carefully controlled ponds stocked with food chains that are simplified but representative of temperate climates (e.g., a few macrophyte species, periphyton, snails, crayfish, and a few species of fish). Short-term experiments have been performed involving initial pulses of technetium (^{95m}Tc). Following the pulse input, the radiation levels in the various biota were monitored at regular time intervals to determine ^{95m}Tc levels. These data were then used to determine the parameters of compartmental models of the system. From the models, extrapolations were made from the short-term experiments to predict the organism body burdens that would be caused by chronic radiation dosage to the ponds. The models are currently being validated by comparing their predictions with data from long-term dosage experiments.

The modeling techniques are applicable not only to radionuclides but also to chemical toxicants. In combination with the empirical pond studies, the modeling research should enable us to determine concentration factors for a variety of radionuclides and chemical toxicants under approximately natural conditions.

Models for Stream Ecosystem Nutrient Dynamics

A procedure for calibrating models of the cycling of phosphorus in a stream ecosystem has been developed. This work is in support of the ESD's stream spiralling project. Radioactive phosphorus, ^{32}P, has been released as a tracer for phosphorus cycling in the biotic and abiotic components of the Walker Branch Watershed stream ecosystem. A separate tracer, tritium, has been used for hydrodynamic transport because the flux of phosphorus due to the downstream flow of water was several orders of magnitude larger than the flux through the aquatic biota.

The model consists of a set of linear state equations which describe mass balance for 13 compartments repeated on 11 segments of the stream. The model was calibrated by adjusting 32 parameters to achieve a "best" fit between model response and measurements of radioisotope concentrations in each compartment. Nonlinear search by Marquardt's method, coupled with a numerical differential equation solver, was used to refine estimates of model parameters. This estimate and search process was iterative with parameter estimates from the search algorithm modified based on investigator intuitive understanding of the system.

Studies on Error Propagation in Models

As part of our continuing efforts to apply systems techniques to Division programs, density-independent and density-dependent Leslie models were investigated by Monte Carlo methods. Random values for parameters of striped bass (*Morone saxatilis*), white perch (*Morone americanus*), and tomcod (*Microgadus tomcod*) populations were selected from truncated normal distributions with standard deviations equal to 10% of the mean. Only total population size after 40 years was considered. The error propagation properties of the density-independent models are strongly influenced by model assumptions (e.g., calculating egg to one-year-old survival to ensure an eigenvalue of 1.0) and by the way model parameters are estimated (i.e., reestimated from data each year). Prediction errors on total population size depend on the number of age classes in a species but become insensitive when the number of classes exceeds seven. Under the very restrictive assumptions used here, there is little difference in the error-propagating properties of alternative density-dependent models.

Numeric Data Activities

Ecosystem Analysis Data Center (EADC)

Activities concentrated on carbon dioxide and environment studies. On a global basis, 0.5 × 0.5 cells were constructed to build a data base containing 42 classifications by vegetative and climatic factors. Initial data were obtained from the General Motors Research Laboratory surface albedo data base (Hummel and Reck 1979) and updated with information obtained from various map and atlas sources. These data were mapped using the DISSPLA (ISSCO 1978) mapping capabilities. The North American portion of the data base was the focal point for a more detailed analysis, especially for eastern North America. An ancillary file developed for areal extent calculations contains areal data on the 0.5 × 0.5 quadrilaterals. The areal extent file was used to summarize the global ecosystems data base by latitude bands and vegetation type.

Temperature and precipitation data extracted from the World Weather Records serve as a valuable data base for the climatology and inventory subtasks of the carbon projects. Station locations were mapped, and a bio-temperature data base was developed to complement the temperature files.

Other files developed this year include an FAO land-use data base and a preliminary population data base. The FAO land-use file contains eight land uses and has areal extent of each use category by country for 1970 to 1977. The population data base is also by country and contains data for 1970 to 1977. We plan to update this data base and compile as comprehensive a file as possible on historical as well as modern population levels. Also, an elevational data base on a 1° × 1° cellular grid will be interpolated to the 0.5° × 0.5° grid we have chosen, to provide for compatible frames of reference for all our inventory efforts.

In a joint effort with Oak Ridge Associated Universities (ORAU), the DOE Office of Carbon Research has funded a project on CO_2 Information Systems. The EADC and the Carbon Information Center are cooperating on a subtask with the EADC focusing on the numeric data management aspects. Our initial effort was to conduct a survey of scientists involved in carbon dioxide research to identify (1) persons and/or groups conducting carbon research, (2) the types of numeric data being collected or extant data being utilized, and (3) the scope of the numeric data and its availability. Of the 275 surveys mailed in July 1980, 102 have been returned. These responses are being computerized and will be made available to the scientific community in a directory format. We are also developing a data base on carbon in U.S. rivers. We used the EPA STORET data base to extract selected parameters for 83 stations. We also scanned the Water Availability System (WAS) developed in the Energy Division to obtain drainage area information for the selected stations to be merged with the STORET retrieval.

The US/IBP ABSTRACTS series was completed [Volumes V(2) and V(3-4)]. To document the IBP studies as completely as possible, theses and presentations were included as published by each biome with a total of 1300 new entries presented in these two volumes. Data on the 1979 vegetation survey for the east portion of Walker Branch Watershed and the Oak Ridge area meteorological data were added to the numeric data files.

Carbon Cycling

The question of carbon pool size in the terrestrial biosphere has been controversial, both for plants and soils. One reason for confusion about the answer is that no single strategy has combined the needed estimates of area (a) and carbon density per unit area (d) to obtain the sum of products of $(a)(d) = v$ for both natural and more or less disturbed ecosystems. A basic ecosystem critique on the NSF-supported carbon project, noted elsewhere in this annual report, combined with data base activities for computerized mapping supported by DOE, provides a range of credible estimates that are all below those most commonly quoted in some of the literature on global carbon cycling.

We found that an earlier published estimate of near 560 Pg (or Gton, i.e., 10^{15} g or 10^{9} tons) is well within a low to medium range of values derived from revised mapping of ecosystem areas and amounts of live plant carbon (phytomass C) in typical natural, completely deforested, and regrowth areas. The estimates of 680 Pg [Baes et al. 1976 (Table 1) and 1977] are plausible as initial conditions for simulations of land-use changes over recent centuries. Higher ones (e.g., 830 Pg of Whittaker and Likens 1973) are difficult to reconcile with the widespread disturbance history and broad extent of suboptimal sites in the more extensive parts of tropical vegetation. Estimates like those of Basilevich et al. (1971) are possible for times prior to agriculture and expanded savanna burning by humans, perhaps, but probably not for modern or even ancient historic times.

Implications of these lowered estimates lead directly to lower estimates of some of the more dramatic and inexplicable nonfossil CO_2 inputs to the atmosphere (5 to 18 Pg/year), which the geophysical community at large finds impossible to reconcile with known constraints of geochemistry and physical circulation of the ocean. Our prior estimates of 1.2 to 3.2 Pg/year for the tropical forest cutting and partial clearing may be partly offset by regrowth within parts of the tropics and partly by net carbon storage in some parts of the temperate and boreal zones. The role of soils both as recent sources and potential sinks for CO_2, mainly involving resistant humus compounds, is still a priority area for continuing research on global cycling. Because equations for both vegetation and humus balance are influenced by climate-controlled rates, it continues to be important to strengthen the linkage of biogeochemical studies with bioclimatology.

Remote Batch Station

The ESD has operated a Remote Batch Station (RBS) since 1972. Over the years this facility has grown, and both hardware and software have been added to meet current and projected needs of the Division.

The RBS has a Modcomp II and a Modcomp Classic which communicate with the ORNL main computer complex through a Remote Job Entry (RJE) link. The Modcomp II also has a telephone link with the COMNET's Washington Computer Center (WCC) to allow access to EPA's STORET data base. A flow diagram showing the linkages of the RBS with other computing facilities is shown in Fig. 8.4.

The RJE link is used for submission and retrieval of batch jobs that are processed on the IBM computers. Jobs submitted through the CSD PDP-10 system are also printed locally through the link. Figure 8.5 shows recent use patterns in the number of jobs processed, lines printed, and cards read through the RBS. An added advantage of the RBS to ESD is the ability to maintain reasonably large data bases on magnetic tapes (held in the RBS tape library) for in- . tion into the job stream to the main computer complex. This saves storage space on the main computers and also decreases job turnaround time, an aid to staff productivity. A Ver- .ec printer/plotter was recently added to the system to enable staff to obtain computer-generated plots quickly and efficiently.

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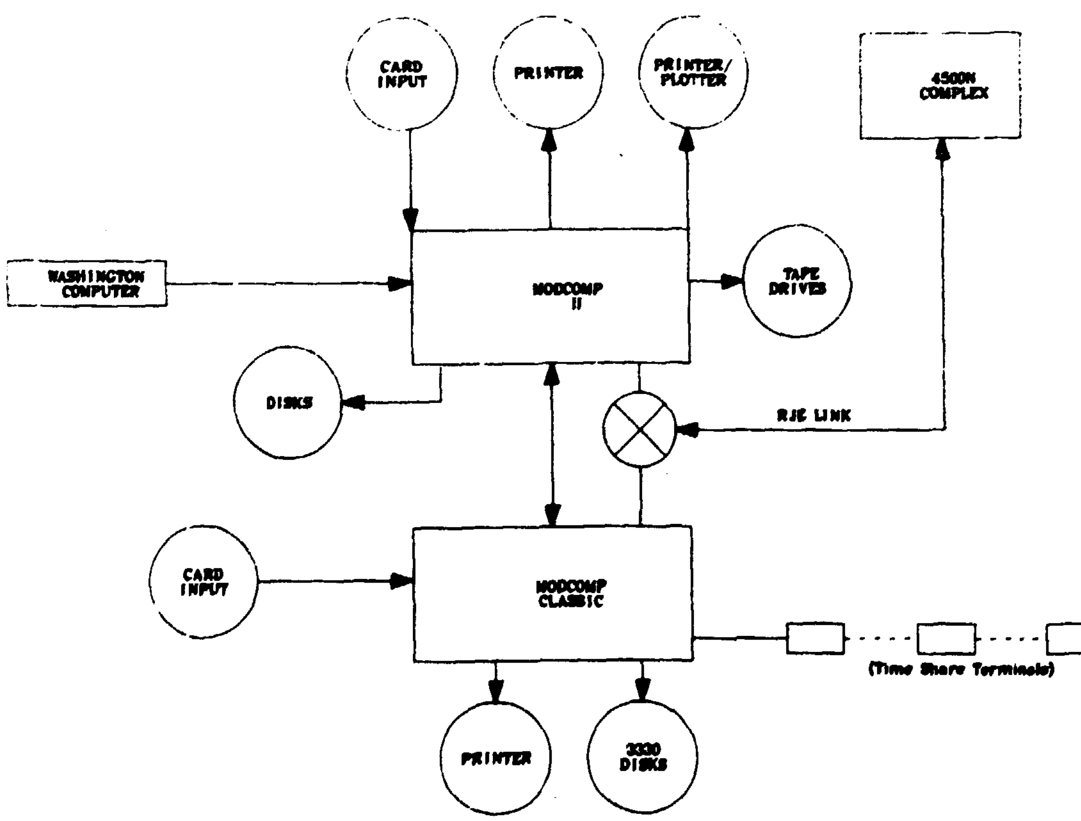

Fig. 8.4. The Environmental Sciences Division remote batch station.

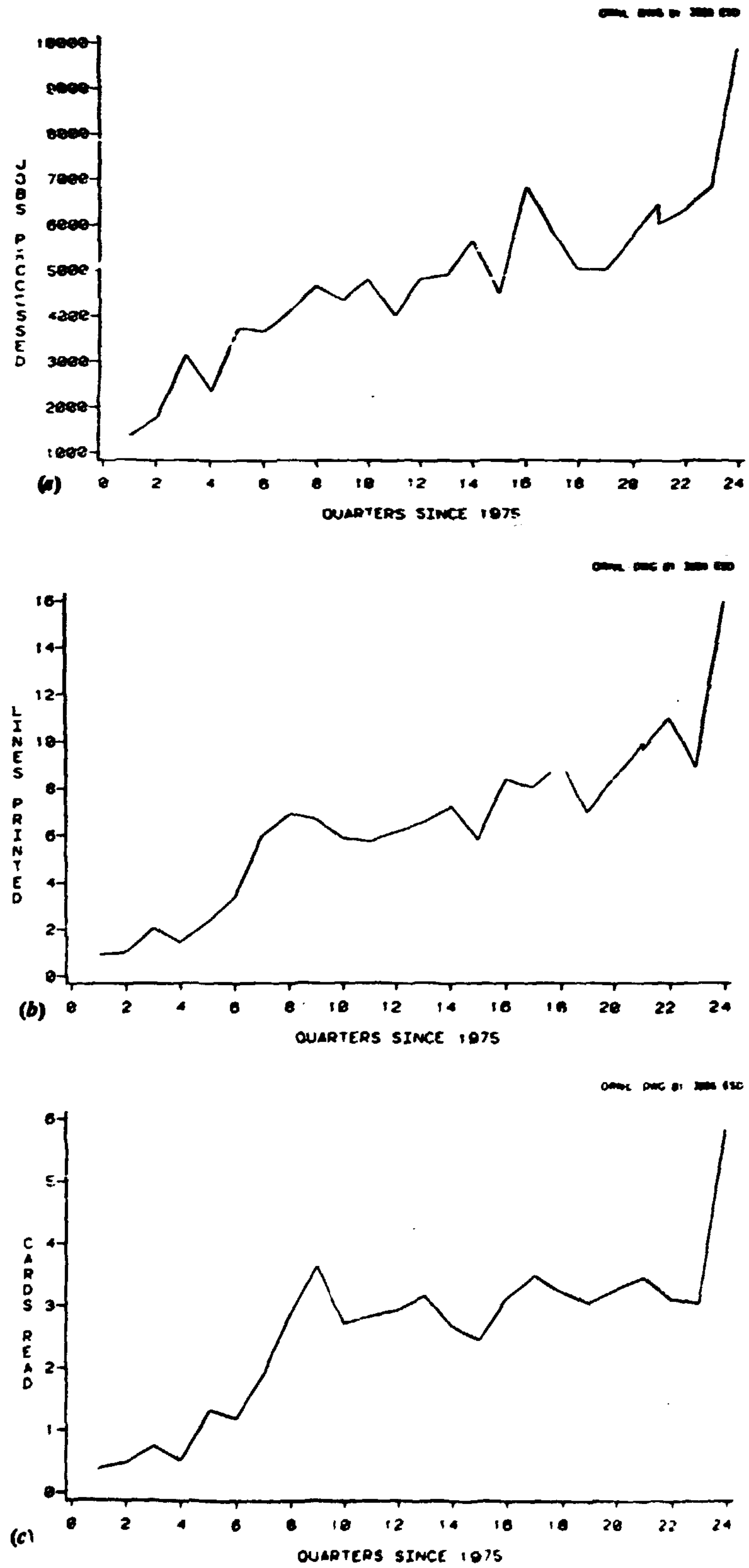

Fig. 8.5. (*a*) Total number of jobs processed, (*b*) total number of lines printed (in millions), and (*c*) total number of cards read (in millions) per quarter since 1975.

The Modcomp Classic has 768K of memory with capability to communicate with the Modcomp II. Recently, several hardwire lines were installed to various points within the ESD laboratory. Terminals can be attached to these ports for time-share processing of jobs on the Modcomp Classic. Two 3330-type disks (with a total capacity of 600 megabytes) and a time-share software (TSX) and a data management system (INFINITY) were installed. In its final configuration, the Modcomp Classic can be used to preprocess data for submission to the main computer and for local processing.

The Modcomp Classic is also used to develop data bases for projects such as those in Small Scale Hydroelectric Generation, Coal Gasification, and the Geoecology Data Base and for the development of analysis and simulation programs by the ESD staff.

The Geoecology Project

The Geoecology Data Base contains integrated natural resource data for use in regional environmental analysis and assessment studies. Selected data on 13 major environmental parameters are available for county units in the conterminous United States. The parameters are soils, terrain, water resources, forestry, vegetation, agriculture, land use, wildlife, air quality, climate, natural areas, population, and endangered species. All data are stored in metric SI units. The data base has been operational since 1975, and ESD staff continue to provide expansion as new data or research needs are identified.

This past year the Geoecology Data Base entered a new mode of operation with the publication of a user's guide and data documentation report (Olson et al. 1980). The report gives examples of applications and provides users information on how to access the data base. Each of the 105 data sets is described, including source of the data, spatial and temporal characteristics, variables and labels, and other comments related to using and interpreting the data. The data base and report will be expanded as new data sets are added. Thus the Geoecology Data Base has become a readily available resource to ORNL staff. In addition, copies of data sets have been distributed to DOE and other national laboratories.

Research Data Management

Data management historically has consisted of implementing computer programs for analyzing, summarizing, tabulating, and graphically displaying research data. By combining the tools of computer science and statistics with disciplines within environmental sciences, new capabilities for organizing, analyzing, and synthesizing research findings dealing with complex environmental issues have been developed. Several ongoing activities with the ORNL Environmental Sciences Division have resulted in the development of computerized systems for the management of data and information relative to environmental monitoring parameters and biological effects data.

When more than one researcher or more than one project task in an interdisciplinary laboratory requires computer programming, data management modes should be employed. Experience gained in over eight years of involvement in multidisciplinary research programs in the ESD and with other research organizations has shown many benefits when a data management approach includes working with researchers and management throughout the development of a project. Organizational requirements, data formats and codes, analyses, and reporting requirements are all planned well in advance of program deadlines. The definition of requirements for each task or project feeds into the development and implementation of computer programs for accomplishing the total data management needs of the research program.

Such data management activities have necessitated development of support systems that can be categorized into four subject areas: (1) Decision Support Systems (DSS), (2) Project Results Tracking System (PRTS), (3) Research Data Management Systems (RDMS), and (4) Analysis and Reporting Systems (ARS).

The DDS involves the development of a computer-based system for management of environmental research projects. This includes a plan of study for determining status of project research at different sites and criteria documenting the numeric standards or limits (e.g., EPA/RCRA guidelines) within a research project.

The PRTS activities help determine fate of samples taken during a project. For instance, analytical characterization and expected dose-effects relationships of any noxious materials can be provided instantly and easily. Any step being made towards completing analyses to be taken on each sample, tabulation of all experimental data provided on each sample, and the interfacing between DSS and PRTS to maintain project progress and completion can be provided easily to the manager. This potential is an important attribute of research data management.

The RDMS tasks require acquisition, development, and implementation of computer software and hardware capabilities. These provide for appropriate computer files, quality assurance control, data management and retrieval systems, and specific data analysis and graphic output. An ancillary function which has been implemented in this task is the development of forms for reporting results and the adoption of coding schemes for identifying research results.

The ARS involves procedures which are developed for project evaluation and assessment. Specific activities have included computer-generated report summaries, statistical analyses, summaries, data synthesis for mathematical and statistical modeling, and site/generic summaries for assessments.

The ERS research and support staff dealing with large assemblages of raw data and other types of information on environmental subjects have dedicated much of their effort to ensuring that the capabilities discussed above are available and useful. Many large-scale projects discussed in this part of our annual report, as well as in other section and program reports, utilize some form of the ESD data handling and analysis procedures routinely. Without them, many ESD research and reporting activities would function much less efficiently.

Environmental Water Quality Operational Studies

An Interagency Agreement was established between ESD and the U.S. Army Corps of Engineers, Waterways Experiment Station, Vicksburg, Mississippi, to provide an Environmetrics Program approach to management of specific research data. General management, as well as detailed analyses for the Long-Term Field Studies of the Environmental Water Quality Operational Studies, will be provided. This six-year research program was established to evaluate new or improved technologies needed to solve selected environmental quality problems associated with civil works activities by the Corps in the nation's waterways.

Data collected from the Mississippi River, Tennessee-Tombigbee, and other riverine systems are subjected to rigorous quality assurance checks before and after entry into the developing data bases. All data entries have been coded using "nonsense codes" (i.e., sequentially assigned numeric values) which our research has shown to be subject to fewer errors in transcription. The annotated computer output from the ten quality assurance programs documents a wide variety of potential errors in the data bases for appropriate action by the field researchers. Once the data are free of errors, they are consolidated and a series of phase I tabular and graphical summary reports are generated for each of the major components of the studies (e.g., fish, benthos, water quality, etc.). Subsequent detailed analyses are developed based on these preliminary refinements.

Although these studies emphasize applied problems associated with riverine systems, basic research is also being conducted on new approaches for evaluating community structures in widely fluctuating environments. A series of over 50 algorithms was developed to ascertain the sensitivity of community indices in detecting natural variations in community composition. These research efforts into the analysis of relationships in environmental systems will aid in understanding the dynamics of riverine systems.

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9. EARTH SCIENCES

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Introduction

Most of the contributions of the Earth Sciences staff are directed to accomplishing the missions of programs within the Environmental Sciences Division: these include the Synthetic Fuels, Nuclear, Low-Level Waste, and the Multimedia Modeling programs. This section contains reports of projects that are unique or in early developmental stages and projects that represent new initiatives. Thus, the progress reports in this section are diverse and lack a unifying theme; nonetheless they are vital to the Division and represent potential growth areas.

A continuing growth area is represented by the Nonnuclear Solid Waste Technology efforts. The contribution to this progress report was separated into two major segments: the research related to the

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biological aspects is reported in the Advanced Fossils Energy Program; the area strongly related to the Resource Conservation and Recovery Act (RCRA) is reported here.

Two reports represent work where the major effort or interest is in other divisions. The report on monazite is part of a study of synthetic compounds which may be useful in incorporating and immobilizing long-lived radionuclides. The second report provides data on the quality of some leachates collected from natural rainfall events on different coal types.

Finally, a short report is included to indicate several areas of new initiatives being developed and pursued by members of this section.

Nonnuclear Solid Waste Technology

Last year's annual report (Auerbach et al. 1980) presented data indicating that the gasifier ash slags tested would not be classified as hazardous under the regulations of the RCRA proposed at that time. On May 19, 1980, the Environmental Protection Agency (EPA) published revised hazardous waste regulations, which appear to make it more certain that gasifier ash slags will not be considered toxic and, as a result, will not require disposal using hazardous waste guidelines.

RCRA requires that all nonhazardous wastes be disposed in sanitary landfills. In the past, the term sanitary landfill was poorly defined; in fact, some open dumps were called sanitary landfills. The EPA has now published a new set of regulations concerning land disposal of nonhazardous wastes titled "Criteria for Classification of Solid Waste Disposal Facilities and Practices" (44FR 53438-53464); the most critical criterion for gasifier ash slag disposal appears to be the protection of ground water from solid waste leachates. The regulations state that the disposal facility (landfill) shall not contaminate an underground drinking water source beyond the solid waste boundary or beyond an alternative boundary specified by the state in which the facility is located. Ground water is considered contaminated according to the RCRA criteria if the maximum contaminant levels (MCL) listed in the NIPDWR are exceeded due to landfill leachates. Thus, although the leachate produced by the EPA leaching technique (EP) [illegible] contain up to 100 times the MCL without the waste being considered hazardous, these same elements in the ground water in the vicinity of the landfill cannot exceed the MCL. As a result, some nonhazardous waste landfills may require liners and leachate collection systems if the geology or hydrology of the site will not provide adequate attenuation or dilution of leachates.

On September 13, 1979, an amendment (44FR 53465-53468) was proposed to the criteria which would add the MCL values included in the National Secondary Drinking Water Regulations (NSDWR) to the ground water MCL values already listed in the criteria. If the amendment is approved, MCL values will exist for sulfate, Fe, Mn, Cu, Zn, chloride, and total dissolved solids (TDS). Thus, gasifier ash slag and other coal ashes may not be declared hazardous by RCRA testing, but their disposal in nonhazardous waste landfills may be almost as expensive as disposal of hazardous waste. Liners, special soil treatments, leachate collection and treatment systems, etc., may be required to meet the nonhazardous landfill criteria in certain cases. Thus characterization of solid waste is becoming even more important as environmental protection criteria become more stringent.

Stored Solids Study

Earlier studies on the leachates from laboratory waste columns indicated that certain contaminants in addition to those listed in the NIPDWR will be leached from the gasifier ashes. To determine if these constituents in the leachates will present a problem in landfill design, the leachates from initial water applications to columns containing ash slags were analyzed for most of the MCLs listed in the NSDWR. The results of these analyses are shown in Table 9.1.

Table 9.1. Chemical analysis of leachate from column leaching of five gasification/liquefaction solid wastes (mg/L)

Waste type	Leachate pH	Ca	Mg	Fe	Mn	SO_4	Cl	K	Na	Cu	Zn	TDS
C	8.2	6.1	2.1	<0.5	<0.1	1	0.3	0.6	1.4	<0.1	<0.5	460
C	8.2	5.8	2.2	<0.5	<0.1	1	0.2	0.5	1.4	<0.1	<0.5	212
E	6.3	25.0	3.2	<0.5	<0.1	56	11.4	2.7	6.1	<0.1	<0.5	312
E	3.6	103.1	25.5	1.2	2.9	530	3.0	10.8	36.2	0.3	3.3	1090
G	8.0	56.2	2.0	<0.5	0.1	182	0.5	29.0	16.2	<0.1	<0.5	4800
G	7.4	50.1	2.0	<0.5	0.2	171	0.6	27.3	15.6	<0.1	<0.5	4840
H	3.7	69	150	5.0	12.0	4020	2.3	272	78.8	2.0	11	7000
H	3.6	66	150	5.6	12.3	4070	2.8	279	79.5	2.0	11	7250
I	5.7	425	236	928	6.5	3190	56	56.0	176	<0.1	0.6	6170
I	5.7	438	139	918	6.4	3000	50	55.2	181	<0.1	0.7	6280
Standards	6.5–8.5			0.3	0.05	250	250			1.0	15	500

Second column volume.

First column volume.

EPA secondary drinking water standards.

It can be seen (Table 9.1) that the initial elemental concentrations in the leachates from some of the gasifier ashes tested may represent a potential problem by exceeding the MCLs listed in the secondary standards (Cu, Zn, Fe, Mn, SO_4, and TDS). Landfills for these wastes must be located in soils having satisfactory properties to attenuate transport of these pollutants or there will need to be some hydrological dilution if these leachates are not to violate ground-water criteria for use as a public water supply. If sufficient attenuation or dilution is not available at the site, mitigating measures such as liners or leachate collection systems will be required.

In addition to small-scale batch and column leaching experiments, leachate production and soil attenuation in large-scale ash soil columns are being investigated. Six leaching columns were loaded with 30.5 cm of site soil from the Waste E plant and overlain with a 30.5-cm depth of Waste E. Each of the six waste-soil lysimeters was subjected to a series of simulated rainfalls of 2.44 cm week. Leachate samples resulting from each simulated rainfall were periodically checked for changes in pH and electrical conductivity. The data indicate that thus far the leachate pH from all six lysimeters remained in the neutral range (6.2–8.2) and did not appear to be increasing or decreasing with time. It should be mentioned that this site soil showed a slightly basic pH, whereas other site soils showed pH in the range of 4.5 to 5.0. Laboratory-scale experiments with this same waste showed that the leachate pH was in the range of 3.7 to 4.1 as a result of the acidic nature of the waste. The observed neutral pH range of the leachate pH is evidence of the strong buffering capacity of the soil.

After 30 water applications (73 cm rainfall), one of the lysimeters was disassembled to examine the release of metals from the waste and their movement through the soil layer. The soil layer was removed in 1.5-cm increments for the first 7.5-cm depth, followed by 7.5-cm increments until all of the soil was removed from the lysimeter.

Representative samples were taken and extractions performed on each soil increment using distilled water, 0.1 *M* hydrochloric acid, and a 1.0 *M* ammonium acetate (pH 7). To date, only the results for Ni, Ca, and sulfate in the extracts have been obtained. In addition, pH and electrical conductivity measurements were made on the distilled water extract. These latter results including nickel are given in Table 9.2. The pH of each increment of soil remained relatively constant, but the electrical conductivity increased with depth and is approaching the value obtained from soil only. A possible explanation for the increasing conductivity is that soluble materials were being leached from the upper layers of the soil and distributed downward in the soil.

Table 9.2. Soil-extracted nickel concentrations using selected solvents (1:1 soil-solution ratio); soil pH and conductivity measured in distilled water extract

Soil depth (cm)	Nickel in extract (μg/g soil)				Conductivity (μS/cm)
	H_2O	NH_4OAc	HCl	pH	
0-1.5	0.21	1.06	2.04	7.6	2244
1.5-3.0	0.04	0.20	0.41	7.6	2240
3.0-4.5	0.03	0.19	0.24	7.7	2260
4.5-6.0	0.02	0.11	0.15	7.7	2290
6.0-7.5	0.02	0.07	0.11	7.7	2320
7.5-15.0	0.02	0.04	0.07	7.7	2610
15.0-22.5	0.01	0.04	0.04	7.6	2630
22.5-31.0	0.03	0.06	0.11	7.7	2770
Control soil[a]	0.02	0.07	0.08	7.7	3250

[a]Not subjected to the 30 water applications.

The distribution of Ni shows that it is distributed about 6 cm into the soil. The first 1.5-cm increment contains the highest Ni content based on all the extracts. The ammonium acetate extraction was applied to evaluate the exchangeable Ni concentration; the water extract should reflect the water-soluble fraction. The difference between the acid and ammonium acetate extract values may be considered the "fixed" Ni concentration.

The soil adsorption was calculated by using the acid-soluble values as the amount on the solid phase and the concentration in the water as the liquid phase. A common expression for this adsorption is the distribution coefficient (K_d), in mL/g, which can be simply expressed as the ratio of the amount adsorbed per unit weight to that remaining in solution per unit volume. The simplified mathematical model used to depict the distribution is based on incremental additions to the column for 30 "simulated rains" and is defined as

$$C_w^n = \frac{C_w^{n-1} + \rho_s^{n-1}/\eta_e}{R_d}$$

and

$$R_d = 1 + \frac{\rho K_d}{\eta_e} .$$

where C_w and C_s denote the concentration of Ni in the water and solid phase, respectively of soil layer L, n is the number of applications of rain, ρ is the bulk density, η_e is the effective porosity, R_d is the retardation factor, and K_d is the distribution coefficient as defined earlier. Because the mathematical model had been prepared to depict the downward transport of trace metals, the observed distribution in the first four layers of segmented soil was compared using K_d values of either 10, 20, or 100; the latter was the expected equilibrium K_d value measured in the laboratory using Waste E site soil. The results in Table 9.3 suggest that the K_d of 20 more nearly depicts the observed distribution. Furthermore, since dispersion was not considered in the present model, the results suggest the possibility of closer agreement if this parameter is included. The possible disagreement of the expected and the observed K_d may lie in the time-dependent function of achieving equilibrium. The considerations of dispersion and time dependency of K_d are now being examined.

Table 9.3. Calculated and observed distribution (%) of nickel in soil after 30 water applications

Depth (cm)	Calculated based on K_d of			Observed
	100	20	10	
0 1.5	96	80	66	78
1.5 3.0	4	17	26	13
3.0 4.5	0	3	7	6
4.5 6.0	0	0	2	3

Watering of the remaining five lysimeters was continued with a second lysimeter removed from service after 55 waterings; the third lysimeter will be watered until 90 events have occurred. The soil from these lysimeters will be sampled as described for the first lysimeter and the results used to further validate the predictive model. The remaining three lysimeters were disassembled after 55 waterings and are being analyzed to determine the variability of results from this type of ash soil attenuation experiment.

Comparison of EPA-Leachate and Ground Water

The EPA extraction procedure (EP) is a 24-h batch extraction using 0.5 *N* acetic acid to adjust the solid waste suspension to pH 5. This extraction, however, has been criticized as being irrelevant and not representative of authentic solid waste leachates or ground water found in "real world" conditions. The objectives of this study were to sample solid wastes and the available ground water from landfills with known biohazards, to extract the solid wastes using the EP, and to compare NIPDWR contaminant concentrations in the EP extracts with that in the solution obtained directly from the landfill.

Table 9.4 summarizes the results comparing the NIPDWR contaminant concentrations. In five of the six landfills sampled, the NIPDWR concentrations were exceeded in the EP or ground-water samples collected. The only elements found in concentrations exceeding NIPDWR were As, Ba, and Cr. At only one site (No. 1) did both the EP extract and the ground water both exceed NIPDWR concentrations for a specific element. Three of the sites (Nos. 2, 4, and 5) showed higher concentrations in the EP extract than those in the collected ground water. On the other hand, one site (No. 3) showed higher concentrations of both Ba and Cr in the ground water. Part of the reason for the observation at site No. 3 may be due to the

Table 9.4. Toxic elements exceeding NIPDWR concentrations in EP extracts and landfill leachates ground water from six landfill sites

Landfill site	Toxic elements exceeding NIPDWR concentrations	
	EP extract	Landfill leachate ground water
1	As	As
2	Cr	*a*
3	*a*	Ba, Cr
4	Cr	*a*
5	Ba	*a*
6	*a*	*a*

a Concentrations were less than those listed in NIPDWR.

fact that the ground water had not moved through the surrounding geologic media when samples were collected. However, more information is necessary before further conjecture is justified. Factors that influenced the concentrations include differences in hydrologic conditions, pH of the media, age of the waste, chemical character of the toxic elements, type of landfill, and the attenuating quality of the geologic materials.

Supporting Research Activities

The category of supporting research activities includes two contributions related to waste products or effluent products. The report on monazite is a summary of the critical review of the existing literature on the stability and alteration of the monazite group of minerals. Experimental research is actively being pursued in the Solid State Division of ORNL; we are also providing support in this area. The report on coal pile leachate is part of a general coal pile leachate study; the summary included here is mainly to provide information on the quality of leachate from five coal types that were exposed to the ORNL environment in contrast to earlier studies conducted in the laboratory.

Review of Monazite Stability

A commonly used approach to aid the evaluation of crystalline waste forms for high-level waste disposal is to examine the stability of their natural analogs in geological geochemical environments through time. One of the most promising ceramic host phases for actinide-bearing wastes is synthetic analogs of the monazite group of minerals [(Ce, La, Ca, Th, U)(P, Si)O_4]. The most important properties of monazite-type phases for disposal are (1) the similar geochemical behavior of lanthanides and actinides which allows energetically favorable ionic substitutions of radioactive species within the crystal structure and (2) the reportedly high resistance of natural monazites to alteration and nuclear radiation damage. We examined the geologic evidence for monazite stability at ambient T and P (i.e., during weathering), at elevated T and P (hydrothermal conditions), and with regard to metamictization.

Monazite is a widely distributed accessory mineral that occurs in a variety of igneous, metamorphic, and sedimentary terrains. Along with other relatively insoluble heavy minerals it tends to be concentrated in detrital placer deposits because of its physical and chemical inertness. A recent review of minerals considered as candidate hosts for radionuclides (DOE 1979) concluded that, while monazite is extremely stable, it can alter to members of the rhabdophanite group of minerals: rhabdophane (Ce, Y, La) (PO_4, CO_3)·H_2O, brockite (Ca,Th,Ce) (PO_4, CO_3)·H_2O, and grayite (Th, Pb, Ca) PO_4·H_2O. Despite this claim, there are few, if any, well-documented descriptions of monazite altering to these hydrated phosphates. The rhabdophanite group and the related phosphate ningyoite [CaU(PO_4)$_2$·1.5 H_2O] typically occur as fine-grained secondary phases in supergene deposits and as weathering products in oxidizing environments; only occasionally are they associated with monazite. In most occurrences the rhabdophanite minerals appear to have formed at the expense of other rare-earth-bearing minerals (e.g., apatite) or are associated with fine-grained earthy monazite of secondary origin; primary monazite is usually absent. In at least one instance, earthy monazite may have formed by the dehydration of rhabdophane (Mitchell et al. 1976). This observation is consistent with laboratory experiments demonstrating that the crystal structures of the rhabdophanite group readily transform to the monoclinic monazite structure upon heating.

Where observed, the alteration of monazite is typically described as a surface incrustation of fine-grained opaque material of unknown nature, often tentatively identified as rhabdophane. In decomposed granitic rocks that have undergone intense in situ chemical weathering (saprolitization), this surficial alteration tends to be lost by abrasion and is usually absent from detrital monazite. However, some monazites from saprolite were observed to alter internally along cleavage traces and in patches to an Fe-rich nonhydrous amorphous material: the degree of alteration is directly correlated with the increased development of multiple cleavages and opacity (up to 75%).

Alteration of monazite affects its U-Th-Pb isotopic systematics used in geochronology. The U-Pb and Th-Pb ages tend to be discordant due to loss of Pb or U and Th, indicating that open system conditions prevailed at some time in the past. However, monazite has less tendency than zircon to lose its radiogenic Pb. The discordance in some (perhaps most) dated monazite samples appears to be due to surficial weathering.

With regard to a radiation damage, there is considerable controversy as to whether monazite undergoes metamictization. Partly metamict monazites identified by x-ray diffraction studies were described only from Indian beach sands (Karkhanavala and Shankar 1954, Ghouse 1968). These studies are difficult to interpret because of a lack of detailed sample descriptions, especially petrographic and compositional data which would indicate whether the samples were altered. Such data are important because the rate at which metamictization occurs is believed to be a function primarily of structural stability, α-particle flux, and alteration due to hydrothermal (primary) or weathering (secondary) effects. The inherent stability of the monazite-type structure is well demonstrated by the extreme rarity of reported metamict occurrences, not only of monazite but also of the isostructural mineral huttonite ($ThSiO_4$); total metamict or fully amorphous examples of these minerals have never been reported. Very large α-particle doses have not noticeably affected the crystallinity of monazites containing high concentrations of U + Th [e.g., 36% ThO_2 + 6% U_3O_8 (Finney and Rao 1967); 16% U_3O_8 + 11% ThO_2 (Gramaccioli and Segalstad 1978)]. These observations suggest that primary or secondary alteration may be the cause of the diffuse diffraction patterns attributed to metamictization.

Based on the available geologic data, it appears that additional critical information needs to be gathered and evaluated before synthetic monazite-type minerals can be selected as host phases for actinide wastes. Research needs include a better understanding of:

- The leaching mechanism(s) involved in a monazite decomposition and how these affect the mobility of rare-earth elements as well as U-Th-Pb systematics.
- The relative stabilities of the monazite and rhabdophan groups of minerals as a function of kinetic and thermodynamic parameters (e.g., pH and Eh); the genetic relationship between these mineral groups (which also include the synthetic rhabdophane-like minerals, $AcPO_4 \cdot 0.5\ H_2O$ and $PuPO_4 \cdot 0.5\ H_2O$) needs to be established in the presence of weathering solutions and hydrothermal fluids.
- The physical and chemical conditions under which monazite can become metamict and the potential role that alteration, including the possible formation of hydrated phosphates, may play in the metamictization process. This last point is particularly relevant in view of the conflicting evidence. Detailed investigations of a large suite of monazites are needed, as well as a careful re-examination of the partially metamict monazites reported in the literature.

Leachates from Coal Storage

Various environmental problems will arise in the handling and storage of large volumes of coal. Rain or snow will either penetrate or run down the outer surfaces of the pile; in either case, particulates and various inorganic and organic elements will be leached from the stockpile. Chemical analysis of the leachate from high-sulfur eastern coals indicates that it is similar in quality to the acid drainage from mines, having low pH values and high concentrations of dissolved Fe, sulfate, and trace metals (see Table 9.5).

Table 9.5. Summary of coal pile leachate quality collected from five coal types subjected to 12 natural rainfall events with all parameters reported as means

Parameter	Illinois 6	Montana Rosebud	Kentucky 9	Pittsburgh 8	Ohio 9
Runoff (% of rainfall)	73	72	71	78	73
pH	2.2	6.3	2.1	2.9	7.9
Acidity (mg/L as $CaCO_3$)	21,200	*a*	33,100	990	*a*
Electrical conductivity (μS/cm)	15,200	2,670	10,500	2,730	7,570
Sulfate (mg/L)	21,500	1,800	27,300	1,240	8,810
Iron (mg/L)	7,710	0.43	9,850	296	0.10
Arsenic (μg/L)	147	*b*	5,050	16.2	*b*
Barium (mg/L)	<0.2	*b*	<0.2	<0.2	*b*
Cadmium (μg/L)	268	*b*	166	9.5	*b*
Chromium (μg/L)	438	*b*	<24	11	*b*
Lead (μg/L)	14	*b*	12	7.6	*b*
Selenium (μg/L)	438	*b*	829	<20	*b*
Silver (μg/L)	0.35	*b*	<0.05	<0.05	*b*
Mercury (μg/L)	0.12	*b*	0.20	0.08	*b*

[a]No measurable acidity.
[b]Measurement not made.

The purpose of this research is to investigate the potential environmental problems associated with coal pile runoff and to suggest methods of circumventing the acidic leachate. Specific controlled laboratory and field-scale experiments which identify and investigate various factors believed to be influential in determining leachate quality have been carried out. These factors include coal type (high or low sulfur content), exposed coal surface area, storage moisture conditions, and rainfall intensity, frequency, and duration.

Runoff samples resulting from the leaching of Illinois 6 and Montana Rosebud coals indicate that leachate from laboratory-scale column leaching experiments does not adequately predict the quality of leachate which occurs from larger volumes of the same type of coal stored under natural field conditions. Comparisons of leachate quality between laboratory and field-scale experiments could only be made after the data had been normalized based on the weight of coal in storage and the ratio of rainfall volume to unit coal surface area. It is recommended, therefore, that in laboratory experiments designed to simulate the leachate from actual coal storage piles, the rainfall volume per unit time be identical to expected field conditions and the exposed coal surface area be adjusted so that the ratio of rainfall volume to unit area of coal surface be similar to that occurring in the actual coal pile.

As a result of leaching experiments, recommendations have been made for a coal storage strategy which will yield a leachate containing the lowest possible concentration of pollutants.

New Initiatives

Three new areas of involvement have been identified and are being actively pursued. These include assuring responsibility for management and coordination of the Waste Isolation Program, developing a broader-based geoscience program, and becoming involved in the Uranium Mill Tailings Remedial Action Program (UMTRAP). At the request of DOE/EV a program plan for solid waste research was developed. A summary of the plan is included in this section because new areas of opportunities have been identified in the plan.

Waste Isolation Program

During the last year, the Division assumed responsibility for management and coordination of the Waste Isolation Program, supported by the Office of Nuclear Waste Isolation (ONWI). This program is heavily research-oriented with the major emphasis on geologic-geochemical aspects associated with disposal of high-level nuclear wastes in deep repositories. Research projects have included (1) evaluation of the physical parameters (temperature, etc.) of importance in determining performance criteria for repositories in different rock types; (2) the prediction of how the presence of water in a salt repository might compromise the integrity of the disposal system; (3) a study of the ability of different rock types to conduct the heat associated with wastes; (4) the investigation of changes in the geochemistry of brines during irradiation at elevated temperatures; (5) the feasibility of considering thick shales, which are present in the eastern United States as repository hosts; and (6) the expected chemical reactions which would occur between ground water, backfills, and waste canisters in the repositories. We have also continued research on the ground water geochemical parameters which affect the mobilization of long-lived radioactive elements, especially Tc, Np, and Pu.

During the last year, increased emphasis was placed on providing an up-to-date data base on waste isolation for ONWI and the public. This effort included preparation of bibliographies and active participation workshops. In addition, a new project was initiated, which is oriented toward an assessment of the impact of nuclear waste facility siting on local and state host areas and the identification of arrangements which are acceptable to local interests.

Most of these program areas will continue during FY 81 and some are planned for following years. Emphasis is being placed on expansion of the geological geochemical aspects of the program; this emphasis is in close accord with the interest of the Division and ORNL in expansion of the geosciences.

Geoscience Program Development

For several years ORNL management has expressed a strong desire to expand the geoscience staff and research emphasis. This plan is especially timely now in light of the heavy involvement of geoscience activities in environmental, waste disposal, and resource-related questions. The Division is actively involved in this expansion through the hiring of new geoscientists and through the integration of geology into a wide variety of divisional research projects, as well as the initiation of new geologic research endeavors.

One of the more active areas for geoscience development was in the waste disposal programs. We are investigating the geology of ORNL's shallow low-level waste facilities to ensure environmentally safe disposal of radioactive waste and to understand natural mechanisms by which radionuclides migrate or are retained. Within the last year the Division assumed management responsibility for the Waste Isolation Program, which has the responsibility of examining geologic aspects of deep repository disposal of high-level nuclear waste.

In conjunction with the Chemistry Division, geologists in Environmental Sciences are developing an expanded geoscience program, supported by the Basic Energy Sciences Section of DOE.

We have identified two major areas of involvement, one dealing with "surficial processes" and the other with "organic geochemistry." The surficial process program will involve geochemical and stratigraphic studies of oil shales and metamorphosed equivalents in the eastern United States and a second project dealing with ground-water flow through fracture media. The first project will involve an examination of the mechanisms by which trace metals are incorporated in hydrocarbon rich shales, relating the concentration to paleoenvironmental criteria and eventually to look at the behavior of these metals during progressive changes in temperature and pressure, from diagenetic to high-grade metamorphic conditions. The second project will deal with modeling of flow patterns through fracturing rock and the chemical reactions which occur between rock and water. This Division's involvement in organic geochemistry is closely tied to the research on oil shales and is expected to include work on trace metal uptake by organisms.

A further new area into which geology from the Division is growing involves mineral resources. Divisional geologists are examining the geochemistry and origin of sedimentary iron ores, massive sulfide deposits containing Cu and Zn, and granitic Sn ores. Also, ORNL is planning future involvement in resource-related research projects, and the Division was instrumental in helping to plan this activity. We anticipate the development of a program dealing with basic research on low-grade deposits, the type which will represent reserves for the nation in future years after the turn of the century.

Geoscientists in Environmental Sciences have also initiated a Laboratory-wide seminar, entitled "Topics in Geology," and are becoming actively involved in a wide variety of other projects, including remote sensing, environmental resource analysis, and impact statement preparation.

UMTRAP Involvement

The Uranium Mill Tailings Radiation Control Act of 1978 (PL 95-604) identifies 22 inactive uranium tailings sites which are candidates for remedial action. It has been estimated that 140 million tons of tailings are stored at these sites. Due to the amount of material involved, remedial action such as earthen or man-made covers is preferred over removal of the existing piles and emplacement in specially prepared locations.

Existing tailings piles represent a potential source of surface and/or ground water and air contamination. Attempts were initiated mainly to retard Rn gas flow from the storage piles by applying asphaltic cover materials, but in certain cases this resulted in an accelerated movement of contaminants to the surface of the piles. Attenuation of contaminant movement through soil liners and covers may represent a more feasible solution to this problem. Special soils, or soil-clay admixtures, may reduce infiltration of water into and out of the tailings, reduce contaminant transport, and retard Rn gas flow.

Studies were initiated in the latter part of the reporting period to evaluate potential variations which might occur in the parameters controlling gas and leachate movement, to provide remedial solutions for existing tailings piles, and to suggest new disposal practices for future tailings production. This effort is supported by DOE through the Albuquerque Operations Office.

Program Plan for Solid Waste Research

At the request of DOE/EV a program plan for solid waste research was developed. A program planning workshop was organized and held in July 1980 to define the scope of the program and to identify specific research needs. Over 40 scientists and engineers from various federal agencies and private industry participated in the workshop, with ORNL playing a leading role. The program plan addresses the management alternatives for solid wastes generated in the energy technologies with the major emphasis on the emerging nonnuclear energy technologies. Significant increases in the quantities of nonnuclear solid wastes are anticipated because the need to convert coal, oil shale, and biomass to liquid and gaseous fuels and the increasingly stringent air and water pollution control regulations will result in larger accumulations of the contaminants in the form of solid wastes.

The program plan was developed in a manner that will permit a DOE solid waste management policy to be adopted based on sound relevant experimental data in concert with a risk-benefit strategy. The major objective of the plan is to provide a coordinated research and development program for safe and economic management of solid wastes produced by the various energy technologies to ensure that solid waste management cannot be considered a deterrent to the orderly development of the technologies.

The initial strategy is to develop environmentally acceptable disposal methods for solid wastes that are currently being generated. This strategy also holds for those wastes that will result from the emerging technologies that require an acceptable solid waste management plan before approval can be made implementing their construction. However, the major theme in the plan is the development of alternatives to disposal; that is, utilization of solid wastes. Research and development initiatives were outlined evaluating the possible use of energy-related solid wastes in construction materials and as source materials in land and civil engineering reclamation projects. Research needs in characterization of solid wastes and methods of disposal were also addressed. The plan considers environmental impacts from the utilization as well as disposal of solid wastes. The most significant contribution resulting from the implementation of the plan will be the development of a data base from which decisions can be made regarding the management of energy-related solid wastes. This data base will allow the employment of a "degree of hazard/degree of control" disposal strategy as well as enhance the beneficial utilization of energy-related solid wastes.

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10. TERRESTRIAL ECOLOGY

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Introduction

The Terrestrial Ecology Section provides expertise in terrestrial environmental sciences to both basic and applied research areas. The section is currently involved in ecosystem studies, environmental impacts, advanced fossil energy, and nuclear programs. Staff members are also assigned to other research divisions at ORNL. Within the section, a basic research program is maintained to ensure continued development of our technical abilities in selected areas of terrestrial ecology. Current section research encompasses three major areas: ecological effects of air pollutants, element cycling studies on Walker Branch Watershed, and ecosystem studies. Section research projects also require input from other units of the Division. In particular, geological and hydrological expertise is provided from the Earth Sciences Section to assist with research activities on Walker Branch Watershed. Progress during the current year by terrestrial ecologists participating in Division programs is highlighted in technical summaries of programs in this report. The following paragraphs highlight the research activities contained within the Terrestrial Ecology Section.

Research activities on ecological effects of air pollutants are aimed at evaluating both present and future ecological risks associated with pollutants from coal combustion and other energy technologies. The controlled fumigation facility described in last year's annual report (Auerbach et al. 1980) was completed during this year, and experiments were initiated quantifying the effects of relative humidity on the uptake of ozone and SO_2. Initial results indicate that increasing humidity causes a substantial increase in foliar uptake of both ozone and SO_2. Currently, the exposure system is being utilized to examine the influence of combinations of levels of SO_2 and O_3 for individual pollutant uptake. In addition to laboratory studies on air pollutant effects, we are continuing our efforts on documenting plant responses under ambient pollutant burdens.

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In our continuing work on cooling tower drift and emissions from uranium enrichment facilities, we assisted the Paducah and Oak Ridge gaseous diffusion plants in evaluating cooling tower windage. Windage occurs when cooling water is lost from the sides of the tower rather than from the top and is subsequently transported to streams as runoff. This influences the water quality of regulated streams and can constitute a National Pollutant Discharge Elimination Systems (NPDES) permit violation as an unregulated discharge. Results from measurements of chromium deposition within 5 m of cooling towers provided quantitative evidence of windage at the Oak Ridge Gaseous Diffusion Plant. The problem is primarily restricted to cold season months when the towers are operated without man-induced draft and the soils have high moisture content. Our results will assist the Department of Energy (DOE) in developing engineering design studies to ensure compliance with discharge regulations.

Acid-rain studies concerning impact on vegetation are continuing. Studies with bush beans, radishes, and wheat are being conducted to look at direct effects of rain pH on senescence growth and yields, interactive effects of varying levels of rain pH and ozone, and genetic differences in plant response to simulated acid precipitation. Results from these studies indicate (1) that rain pH effects are direct on foliage rather than indirect through interactions within soil, (2) that the combined effects of ozone and increasing rain acidity are greater than additive, and (3) that plant response to acidic precipitation is further confounded by genetic differences among plant species and cultivars.

Research on atmospheric deposition on Walker Branch Watershed focused on identification of organic constituents in rain above and below a forest canopy. Extracted material observed in throughfall samples proved to be largely aliphatic and was identified by comparison of experimental mass spectra. Organic acids and plasticizers were found in all samples. Chlorinated organic compounds were also observed, as were turpinoids derived from coniferous vegetation. Rainfall samples included all compounds found in throughfall, but at considerably lower concentrations.

Acid precipitation and soil mobility studies continued to concentrate on the development of a working hypothesis for why certain soils leach sulfate anion and others do not. Results to date indicate that the presence of free iron and aluminum account for considerable sulfate absorption in watersheds in East Tennessee, North Carolina, and Costa Rica. In contrast, watersheds in New Hampshire and Washington accumulate none of their incoming sulfate and are being leached. Our studies will continue to examine the role of acid rain versus naturally produced acid, determine the role of organic matter in types of free iron and aluminum in sulfate absorption, and ultimately develop simple soil criteria for susceptibility to leaching by sulfuric acid.

Hydrologic research on Walker Branch Watershed continued to further develop the variable source-area concept and to understand the role of soil macropores in the subsurface flow of water. Significant increases in streamflow were found to be associated with both side slope valleys and outcrops of resistant layers of bedrock on Walker Branch. These findings may help to explain the subsurface flow between the east and west forks of Walker Branch. Hydrologic consequences of soil macropores were investigated with a modified version of our hydrology model by including algorithms for macropore flow. Initial runs indicate that macropores can cause a major change in simulated drainage patterns under high rainfall conditions.

Bioclimatology studies continued to focus on establishing a sound basis for both tree-ring and pollen chronology work in the southeastern United States. We recently showed that climate can be reliably reconstructed from tree-ring data in East Tennessee and Iowa. When the simplest form of statistical analyses was used, our correlation coefficients between actual and reconstructed values were significant at the 99% confidence level in 12 of the 13 sites analyzed. These coefficients are based on 40 years of independent data at each site.

Recent results from our global carbon work indicate that terrestrial vegetation accounts for 560 Pg (Gton). This estimate is well within the ranges which come from revised mapping of ecosystem areas and amount of live carbon plant material averaged over typical, natural, cutover, and regrowing woods. The implications of this lower estimate lead directly to lowering some of the more dramatic and unexplainable estimates of high nonfossil CO_2 inputs to the atmosphere which we have not been able to reconcile with known constraints. Currently, we are addressing the role of soils both as recent sources and as potential sinks for CO_2, and this continues to be a priority area in our global carbon cycling research.

Forest resource management activities on the DOE–Oak Ridge Reservation took on new directions during the past year. A move from multiple-use, sustained yield to a research support role results primarily from the termination of the long-term timber contract. We are continuing pulpwood sales, emergency timber removals, and sales of timber for research purposes. Current research activities include timber removal on the whole-tree harvested research areas (described in the Ecosystem Studies Program section of this report) and preparation of sites for research on the ecological effects of intensive silviculture.

Ecological Effects of Air Pollutants

Coal-Derived Air Pollutant Effects on Vegetation

The Environmental Sciences Division's Air Pollution Effects Project is aimed at evaluating both present and future ecological risks associated with pollutants from coal combustion and other energy technologies. In laboratory, greenhouse, and field studies, we are conducting research along four specific lines: definition of concentration thresholds for plant response to individual and combined exposures to SO_2, O_3, and acid rain; evaluation of physiological indicators of stress; assessment of critical characteristics of exposure dose; and field monitoring of physiological and growth responses of native vegetation exposed to ambient pollutant levels. Collectively, these studies are aimed at evaluating the efficacy of present ambient air quality standards and evaluating potential damages to terrestrial ecosystems which may accompany large-scale implementation of coal combustion technologies.

Our capabilities in conducting laboratory studies on plant-pollutant-environment interactions were substantially improved this year with the completion of a 12-chamber exposure system for pollutant dispensing, control, and monitoring (Fig. 10.1). The system permits simultaneous, controlled exposure of plants with up to three pollutants per chamber. The facility is shared by researchers addressing effects of atmospheric pollutants from coal combustion, coal conversion, and uranium enrichment technologies.

Initial experiments in the exposure system were directed toward quantifying the effects of relative humidity on uptake of O_3 and SO_2 by plants (McLaughlin and Taylor 1980). Comparisons of uptake of these gases into plant leaves at low (35%) and high (75%) relative humidity showed two- to threefold increases in uptake of SO_2 and three- to fourfold increases in uptake of O_3 at high humidities. This provides a physiological basis for the documented enhancement effect of humidity on plant sensitivity to air pollutants. In addition, it may eventually provide a basis for evaluating regional differences in adverse effects from atmospheric pollutants. The arid Southwest, for example, would be expected to sustain considerably less damage from an equivalent level of air pollutants than the humid East. Thus, relaxed standards may be justified in this region. Additional work on the influence of SO_2 and O_3 alone and in combination is being conducted to determine how individual pollutant uptake is influenced by multiple pollutant exposure.

While laboratory experiments are aimed at determining concentration thresholds for plant response and providing a basis for understanding important concepts of pollutant dose, field work continues to document plant responses under ambient pollutant burdens. In previous work (Mann et al. 1980), we documented the chronology of foliar disorders and accompanying chronic decline in white pines under chronic air pollution stress. During the past year, we documented ring-width chronologies, compared photosynthetic rates, and studied the dynamics of ^{14}C-photosynthate allocation in trees with varying degrees of symptom development (McLaughlin et al. 1980). Results indicated that chronic decline was caused primarily by premature senescence o.

Fig. 10.1. Control center for dispensing and monitoring air pollutants to 12 advance-design exposure chambers provides a versatile system for exposing plants to air pollutants from both coal combustion and coal conversion processes. Both rates of pollutant uptake and effects of exposure on photosynthesis can be measured simultaneously with this system.

older needles with resultant reduced availability of storage capacity in the fall and reduced supply of carbohydrates to newly developing needles in the spring. Shorter needles in affected trees function well photosynthetically but apparently do not meet the total carbohydrate needs of the tree. Chronic decline in sensitive trees results in reduced growth and an apparent modulation of growth responses to favorable environmental conditions. Under these conditions trees can be expected to be more susceptible to other forms of environmental stress, particularly root diseases.

Cooling Tower Windage

Cooling towers at DOE contractor-operated gaseous diffusion plants in Kentucky, Ohio, and Tennessee require the addition of a chromate, zinc-phosphate corrosion inhibitor to the recirculating cooling waters for protection of copper in cooling condensors. During the past decade, the impact of cooling tower drift on terrestrial environments has been a major consideration. Recent studies at the Paducah Gaseous Diffusion Plant suggest that there is also a significant potential for aquatic impacts. Blowdown at the Paducah facility and the Oak Ridge Gaseous Diffusion Plant (ORGDP) is engineered for zero chromate discharges to receiving streams. Past experiences at the Paducah facility without chromated discharges mysteriously resulted in violations of National Pollutant Discharge Elimination Systems (NPDES) permit standards for hexavalent chromium. These episodes of noncompliance were associated with high winds perpendicular to the tower axis and tower operation without fan-induced draft. Operation of the cooling towers without fans is an operational procedure effected during winter to maintain a minimum required temperature for the enrichment cascade. Under these conditions, cooling water is lost from the sides of the tower instead of from the top as with drift and is subsequently transported to streams as runoff. This loss of water, termed "windage," has a potential to impact the water quality of regulated streams or simply constitute a permit violation as an unregulated discharge.

The DOE requested the ORGDP Environmental Management Group to determine if windage was also a problem at Oak Ridge and to quantify the losses. In a collaborative effort between the Environmental Sciences Division (ORNL) and ORGDP, a series of studies was conducted on several mechanical-draft cooling towers. Effective windage volume was collected as precipitation along a distance gradient from the tower base. Depth (height of the water column) was calculated from the relationship of the measured volume to the diameter of the collector and termed effective wetfall (cm/h). Pilot studies indicated that evaporation might be an important consideration. Because evaporative processes would not affect the total chemical residue in the collected samples, volume inferred by chemical methods would be more representative of true windage volume. Consequently, true windage volume was calculated from the total chromium residue present in each sample and the measured chromium concentration of the recirculating water system. Similarly, true wetfall (cm/h) was calculated from the corrected volume.

A comparison of results from the two methods indicates that estimates of effective windage contain a significant negative bias (~30%) in assessing the magnitude of the wetfall. Maximum effective windage measured adjacent to (0.5 m) a newly constructed 295-m^3/min (78,000-gpm) tower was 10 cm/h in contrast to a true wetfall maximum of 14 cm/h.

The data were further summarized as windage flux to the ground ($L\,m^{-2}\,h^{-1}$) and best-fit curves plotted using spline functions. Results during tower operation with fans on and fans off are depicted in Fig. 10.2. Wind was from the southwest, gusting from 4 to 7 m/s. Most (>95%) of the windage water was deposited (fans off) within 5 m from the base. Losses from cells operating with fans on depict water entrained in exit air flow and deposited as drift. The point of intersection of the two curves (8 m) represents the maximum distance windage was transported from the tower. The windage water drains to an open ditch and is transported to Poplar Creek. To estimate the total chromium deposited as windage (fans off), the area under the curve was integrated over the distance from the tower (10 m) and along the length (100 m) of the tower, assuming no end effects. This represents a worst-case example because all cells would be in operation without utilizing the fans. Total hexavalent chromium discharged through windage was calculated assuming a 9-ppm water concentration. Under the meteorological conditions of this specific example, it was estimated that 1.7×10^4 L of chromium-laden water (153 g of hexavalent chromium) were lost per hour of operation. Similar studies were conducted on several other cooling towers during varying meteorological conditions (wind speed). Since drift does not contribute significantly to runoff, the point where windage flux is equal to drift flux becomes important in predicting the greatest distance of windage transport. The relationship of windage transport (distance) to wind speed is described by the linear model, $Y = 1.6 + 1.36X$, $r = 0.986$.

Results of the combined investigations provided quantitative evidence of windage from the ORGDP cooling towers. The problem is primarily restricted to cold months (November through March), when the towers are sometimes operated without fan-induced draft and soils have a high moisture content such that the deposition is quickly transported as runoff. The research was an important contribution to engineering design studies submitted to DOE for construction approval of long-term abatement structures to attain NPDES compliance. Results of the research also have significance for other technologies using evaporative cooling towers, because a common practice to prevent icing in the winter is to operate without fan-induced draft.

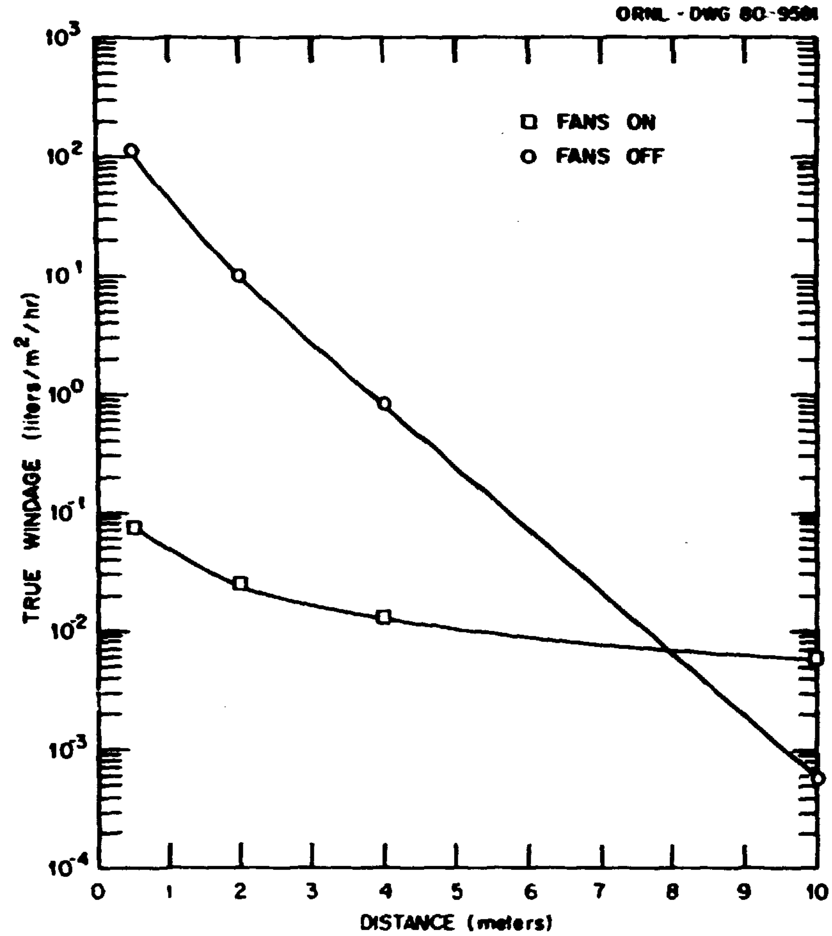

Fig. 10.2. Windage from the K-892J cooling tower on December 7, 1979. Wind was from the SSW at 4 to 7 m/s ($\bar{X}$ = 5 m/s).

Effects of Acid Rain on Vegetation

Precipitation acidity is an issue of primary concern resulting from the long-range transport of sulfur and nitrogen oxide air pollutants generated by fossil-fuel combustion. Although current levels of precipitation acidity are generally regarded as not being a direct threat to the growth and yield of terrestrial plant species, the long-range impact of chronic exposure of crop and forest species to acid rain alone and in combination with gaseous pollutants of regional concern remains to be resolved. This report highlights several recent studies aimed at clarifying the potential role of precipitation chemistry in the response of vegetation to the overall level of pollutant stress potentially occurring from expanded national reliance on fossil-fuel utilization.

Bush bean plants (*Phaseolus vulgaris* L. 'Blue Lake 274') were exposed to simulated rain at pH 5.6, 4.0, or 3.2 twice weekly during the third through the seventh week of growth. Solutions of identical chemistry and volume were added to the soil of another set of plants. The threshold for visible injury and significant growth reduction due to rain exposures was between pH 4.0 and 3.2. Exposure to pH 4.0 or 3.2 rain caused premature senescence of the unifoliate leaves, but trifoliate leaves of the same plants often had greater leaf chlorophyll concentrations, thus apparently compensating for the observed premature senescence. Comparison of the growth between plants exposed to rain at a constant pH 3.2 level and those exposed to rain that increased in pH from 2.8 to 4.0, with a pH 3.2 average, indicated that rain events with a high peak level of acidity may cause greater deleterious effects on bean plants than those characterized by a constant pH level. The pH of the solutions that were added to the soil had no significant effect on any of the parameters that were measured. Therefore, the significant effects of rain pH were direct foliar effects, rather than indirect effects mediated by effects on the soil media.

In an experiment comparing constant and varying acidity levels, radish plants were grown in a growth chamber and exposed to pH 5.6 or 3.3 simulated rain. Comparison was made between plants exposed to pH 3.3 rain applied at a constant pH 3.3 level and those exposed to rain in which the pH increased during exposure from pH 2.9 to 4.0 with a pH 3.3 mean. Although analysis yielded nonsignificant F-tests, the plants exposed to the constant pH 3.3 treatment tended to weigh less (34%) than those exposed to either the pH 5.6 or the changing pH 3.3 treatments.

It is important to note that the response pattern observed with this species was not in agreement with the pattern observed for bush bean, indicating the importance of species-specific variation in response pattern. The fact that such variation exists in response pattern will be critical to understand in efforts to develop predictive capabilities for assessment of large-scale impacts of precipitation chemistry on plant response.

To determine interactive responses to pollutants, radish plants were grown in a growth chamber and exposed to simulated rain, twice weekly for two weeks, at pH 5.6, 4.0, 3.3, or 3.0 and to ozone (O_3) at 0.0, 0.1, 0.2, or 0.4 ppm for 4 h on each of 3 d in a 4-factorial design. Parameters measured were percent leaf area necrotic (% LAN) of the first through fifth leaves, chlorophyll concentration (mg/g) of the second and fourth leaves, and the dry weight of the leaves and roots. Ozone at 0.4 ppm caused significant (>20%) injury on the first to fifth leaves, reduction of root weight (57%), and chlorophyll concentration (60%). The threshold O_3 concentration to cause significant effects was between 0.2 and 0.4 ppm. Ozone did not affect the dry weight of leaves, even though significant amounts of injury were present. Rain at pH 3.0 significantly affected injury to the first and second leaves. Rain pH did not significantly affect any of the other parameters that were measur[illegible] Interactive effects of O_3 and rain pH resulted in injury to the second leaves. The combined effect of increasing O_3 concentration and increasing rain acidity was greater than additive. Over the range of concentrations used during this study, O_3 caused significant damage to radish plants. The effect of rain pH was restricted to the older leaves of the radish plant, and there was no significant interaction of O_3 and rain pH on radish growth processes.

Three wheat cultivars (*Triticum aestivum* L. 'Arthur I,' 'Abe,' and 'Oasis') were grown in a greenhouse and exposed to simulated rain acidified to pH 4.3, 4.0, 3.3, 3.0, or 2.3 with equal volumes of 6 *N* sulfuric and nitric acid. Rain (1.1 cm) was applied twice weekly for three weeks. Tiller number and number of leaves greater than 10% necrotic were counted and dry weight measured 32 d after planting. Dry weight and tiller number were reduced an average of 12% by exposure to pH 4.3, 4.0, and 3.3 rain for cultivars Arthur I and Abe and were stimulated an average of 21% by pH 2.3 rain for all three varieties. This study demonstrates the complex nature of plant response to acidic precipitation. Different cultivars of a species may respond to rain chemistry differently. The bimodal response pattern shown by two cultivars suggests that more than one mechanism is responsible for plant responses to acidic precipitation.

Element Cycling Studies on Walker Branch Watershed

Organic Constituents in Rain Above and Below a Forest Canopy

Forest canopies can be important sites of deposition of atmospheric gases and particles. During dry weather, the forest canopy may exude components that accumulate on leaf surfaces along with dry-deposited atmospheric constituents. These accumulations are subsequently washed off, perhaps only partially, by precipitation events which follow. Rain collected under a forest canopy (throughfall) may therefore contain constituents from several sources, including the leaf interior, the external environment, and the incident rain itself. Forest canopies are thus sites of physical and chemical interactions that affect the composition of rainfall which ultimately reaches a forest floor. The current study (Hoffman et al. 1980) was designed to identify the organic components of throughfall and to define the relationship to deposition and leaching phenomena. This research is a portion of ongoing deposition studies at the Walker Branch Watershed.

Rain samples were collected on an event basis from August 1977 to June 1978. Lindberg et al. (1979) described the sampling sites, the sampling procedures, and the precipitation collectors (HASL-type, wetfall-only) used. Samples from above (incident rain) and below (throughfall) the forest canopy (*Quercus prinus* L., chestnut oak) were collected for 43 rain events representing ~90% of the precipitation volume that occurred during the sampling period.

The interception of incoming rain by a fully foliated forest canopy produced a large increase in the organic content of resultant throughfall compared to the organic content of incident rain. In the absence of leaves the organic content of throughfall decreased substantially, although it remained above that of incident rain. Material recovered from dichloromethane extracts of incident and throughfall samples followed this pattern as well. The organic content of incident rain samples generally appeared to be unaffected by seasonal factors.

Constituents found in extracts of incident rain samples were invariably present in lower concentrations than those found in comparable throughfall. Virtually all throughfall constituents were observed at some time in incident rain-sample-extract chromatograms. Excepting dioctylphthalate and dioctyladipate, however, they were generally at or below detection limits. If an absolute detection limit of 1 ng is assumed, based on instrument specifications, no component below ~0.5μg L in the rain could be identified.

The extracted material in throughfall samples proved to be largely aliphatic and was identified by comparison of experimental mass spectra with reference spectra and, where available, with spectra of reference compounds. Octanoic and decanoic acids were the only organic acids found, and of these, only octanoic (or isomeric C_8 acids) appeared consistently. Only dioctylphthalate was present in all samples, incident and throughfall. Dioctylphthalate and dioctyladipate (or their 2-ethylhexyl isomers) are widely used plasticizers and have been distributed in the environment for over 20 years. Dioctyladipate was frequently present but was not usually predominant. Regularly spaced peaks were noted at the high-temperature end of the chromatogram, particularly in autumn throughfall samples. In the spring, throughfall chromatograms were much simpler, traces of the high-temperature series were rarely seen, and fewer different low-concentration components were observed.

Some terpenoid-like materials and highly chlorinated compounds were observed in extraction isolates also. Mass spectra of the chlorocompounds did not coincide with those of halogenated pesticides known to be used in small quantities in the area (i.e., endosulfan, dieldrin, aldrin, and heptachlor). However, compounds very similar in spectra to isodrin and an apparent homolog were observed. Terpenoids are common atmospheric components derived from coniferous vegetation in the southeastern United States and consequently might be expected in low concentrations. Both chlorocompounds and terpenoids seem likely to come from external sources rather than from the deciduous trees themselves.

Specific organic compound types present in single rain event samples are probably related to processes of deposition, leaching, and weathering in a forest system. Information as to where the observed compounds originate, therefore, can provide a rational glimpse of chemical pathways in these biological systems. Plasticizers and chlorohydrocarbons identified in this study appear to be related to sources external to the deciduous trees examined (*Quercus prinus* L.). Organic acids and high-molecular-weight "waxy" materials were also detected and are likely derived from the metabolism, or the attrition, of the leaves themselves.

Acid Precipitation and Soil Ion Mobility

Because of the requirement for electrochemical neutrality in soil solutions, acid rain will have no effect upon nutrient cation leaching unless the associated anion (sulfate or nitrate) is mobile in the ecosystem (Johnson 1979).

Because sulfate is the major anionic component of acid precipitation and sulfate mobility is an important component of ongoing research on sulfur cycling in Walker Branch Watershed, considerable effort was expended in determining the factors affecting sulfate mobility in soils, including the testing hypotheses developed from Walker Branch studies on soils from a wide range of forest ecosystems whose sulfur budgets are known.

Walker Branch Watershed as a unit appears to be accumulating approximately 40% of incoming sulfate by adsorption in free iron- and aluminum-enriched B horizons (Shriner and Henderson 1978, Johnson and Henderson 1979). Consequently, the potential for acid-rain-induced nutrient cation leaching from the ecosystem is reduced by 40%. Similarly, watersheds at Camp Branch, Tennessee, and Coweeta, North Carolina, and a tropical ecosystem at La Selva, Costa Rica, are accumulating 40 to 90% of incoming sulfate as a whole, most likely by adsorption in subsurface horizons (Johnson et al. 1980). In contrast, Hubbard Brook Watershed, New Hampshire, and the Thompson Site, Washington, accumulate none of their incoming sulfate and are therefore being leached by incoming sulfuric acid to its fullest potential.

Several factors were shown to influence the abilities of soils to retain sulfate and therefore to retain their resistance to leaching by sulfuric acid, the most important of which are free iron and organic matter content (Johnson et al. 1980). Soils with high free iron and organic matter content, such as subsurface horizons from Hubbard Brook and surface horizons from La Selva and Coweeta, are poor sulfate adsorbers and highly susceptible to sulfuric acid leaching. Surface soils from Walker Branch and Camp Branch are low in free iron and high in organic matter, making them particularly vulnerable to leaching by sulfuric acid, also. Ongoing lysimeter studies on Walker Branch confirm that surface soils are being heavily leached by sulfuric acid, a potentially deleterious situation in view of the low base saturation and high rooting density in those horizons.

Current research is aimed at assessing the exact roles of acid rain vs naturally produced acids (largely carbonic) in cation leaching from soils of Walker Branch and at making realistic assessments of total capacity of these soils to retain sulfate (i.e., how long it will be before the ecosystem is fully susceptible to acid rain leaching such as Hubbard Brook apparently is now). A second major goal is to determine the role of organic matter and types of free iron and aluminum in soil sulfate adsorption and to specifically determine whether organic ligands block potential sulfate adsorption sites or whether the less crystalline nature of free iron and aluminum in organic horizons precludes effective sulfate adsorption in organic matter-rich soils. The ultimate aim of these studies is to develop simple soil criteria, such as color, for the assessment of susceptibility to leaching by sulfuric acid.

Hydrologic Transport

Recent advances in the understanding of subsurface flows and the spatial heterogeneity of runoff processes have highlighted the importance of variable hydrologic source areas and the role of macropores during major runoff events. Because water is the primary transport carrier for contaminants and nutrients, our work on hydrologic transport focused on these two areas during the past year.

One aspect of hydrologic transport that is very important is the location and characterization of variable hydrologic source areas. In conjunction with an ecological study of the west fork of Walker Branch Watershed, tritiated water was released as a tracer to allow determination of streamflow increases along a 120-m reach of the stream channel. Because streamflow increases are expected to be associated with the presence of hydrologic source areas, the results can be used to infer source area location and factors responsible for their occurrence. Significant increases in streamflow were found to be associated with both side-slope valleys and outcrops of resistant layers of bedrock. The side-slope valley apparently concentrates subsurface drainage at the valley outlet. The resistant bedrock layers occur at right angles to the orientation of the stream channel and dip sharply in the downstream direction. They appear to trap subsurface flow moving parallel to the main channel and force it out into the channel just above resistant outcrops. This latter finding suggests both a mechanism and pathway for subsurface flow transfer between the east and west forks of Walker Branch Watershed. Such information should be useful in understanding mineral cycling studies at Walker Branch

The proportion of soil pores larger than 1 mm diam (macropores) was estimated to be 0.05 and 0.09 m^3 m^3 for the A and B horizons of Fullerton cherty silt loam according to an analysis of results from a field soil drainage study on Walker Branch Watershed (Luxmoore et al., submitted). The hydrologic consequences of soil macropores were investigated with a modified version of the Terrestrial Ecosystem Hydrology Model (TEHM) that included algorithms for macropore flow. Three new subroutines were written and coupled to TEHM in cooperation with two students from the MIT Practice School in Chemical Engineering at ORNL (Fong et al., in press). Sensitivity tests of the modified model showed that macropores could cause a major change in simulated drainage patterns under high rainfall conditions for soils of low hydraulic conductivity. Macropores in a profile allowed increased drainage and less lateral flow than from a similar profile without macropores. The computer analysis highlights the need for experimental procedures for quantifying macroporosity; however, the work suggests that geometrical aspects (pore size and shape) may not need characterization. Macropore effects on pollutant movement in Walker Branch Watershed (SO_4^{--}) and in the low-level radioactive waste management areas are likely to be among the most important controls on chemical transport.

Ecosystem Studies

Bioclimatology

Studies of past variations of climate and vegetation improve our understanding of the nature of climatic change and of subsequent biotic response. Biological indicators of past climate can be used to provide long records of the natural component of climatic variability, which must be superimposed on any projected anthropogenic effects on future climate. Long records of past climate provide many examples of climatic change for hypothesis testing and also provide information on the extremes of climatic variability which have not occurred in the period of written record, but have occurred in the more distant past and are likely to occur again in the future.

Tree rings have been used to reconstruct past climatic variability in the arid western United States (Fritts et al. 1979), and Cook and Jacoby (1977) showed that this can also be done in the Northeast. We recently showed that past climate can also be reliably reconstructed from tree-ring data in the southeastern and northcentral portions of the United States.

We reconstructed past climate and verified the reconstructions in two selected areas. Eastern Tennessee was selected because (*a*) its location was near the center of the southeastern United States and near our laboratory, (*b*) available ring-width chronologies there extended back before A.D. 1700, and (*c*) the responses to moisture stress of the species involved (white oak, *Quercus alba*, and shortleaf pine, *Pinus echinata*) had been investigated (Boggess 1957). White oak chronologies from Iowa were also investigated because those chronologies had been extended to over 300 years in length and because climatic reconstructions from the central United States are necessary if climatic reconstructions from the East are ever to be geographically merged with those from the West.

Statistical analyses indicated that precipitation during the growing season (May–June in particular) could be reconstructed from the chronologies in eastern Tennessee. We used straight-line regression to estimate May–June precipitation from the average ring-width index of the two available chronologies. The reconstructions were tested on 60 years of independent data and were significantly corrected (99% confidence level) with the actual values.

The white oak chronologies in Iowa were accurate indicators of annual precipitation. Straight-line regression was again used to estimate the precipitation values from the ring-width indices. The regression coefficients were calculated using the most recent 60 years of data, and the resulting precipitation estimates were verified on the previous 46 years of independent data. The correlation coefficient between actual and estimated values was +0.74 for the recent 60 years and +0.72 for the preceding 46 years of independent data.

We noted that ring-width chronologies of white oak were almost invariably sensitive to moisture stress. To examine the general applicability of tree-ring data to climatic reconstructions in the southeastern United States, we used straight-line regression to estimate past values of the Palmer Drought Severity Index from ring-width data at all stations where white oak chronologies are currently available. Correlation coefficients between actual and reconstructed values were significant beyond the 99% confidence level at 12 of the 13 sites analyzed. These correlation coefficients are based on over 40 years of independent data at each site.

The above results were all based on the simplest possible form of statistical analysis. The use of multivariate techniques, incorporating additional ring-width chronologies and prior growth variables, is expected to provide improved results, as it has in previous studies for the western United States.

Global Carbon Cycling

How large and changeable are the main pools of organic carbon in the biosphere? This question has been controversial, both for plants and soils. One reason for confusion about the answer is that no single strategy has combined the needed estimates of area (*a*) and carbon density per unit area (*d*) to obtain the sum of products of $(a)(d) = v$ for both natural and disturbed ecosystems. A basic ecosystem critique from our NSF-supported carbon project, with data-base support for computerized mapping for DOE, led to a range of credible estimates that are all below those commonly quoted in some of the literature on global carbon cycling.

Our findings are that our earlier published estimate of near 560 Pg (or Gton, i.e. 10^{15} g or 10^{9} ton) is well within the low-to-medium range which seem to follow from revised mapping of ecosystem areas and amounts of live plant carbon averaged over typical, natural, cutover, and regrowing woods. The estimates of 680 Pg (Baes et al. 1976, 1977) are plausible as initial conditions for simulations of land-use changes over recent centuries. Higher ones (e.g., 330 Pg of Whittaker and Likens 1973) are difficult to reconcile with the widespread disturbance history and broad extent of suboptimal sites in the more extensive parts of tropical vegetation. Estimates like those of Bazilevich et al. (1971) are conceivable—for times prior to agriculture and expanded savanna burning by humans, perhaps—but were not set forth by their authors as applicable for modern or even ancient historic times.

Implications of these lowered estimates lead directly to lower some of the more dramatic and inexplicable estimates of high nonfossil CO_2 inputs to the atmosphere (5 to 18 Pg/year), which the geophysical community at large finds impossible to reconcile with known constraints of geochemistry and physical circulation of the ocean. Our prior estimates of 1.2 to 3.2 Pg/year for the tropical forest cutting and partial clearing apparently are offset partly by regrowth within parts of the tropics and partly by net carbon storage in some parts of the temperate and Boreal zones. Soils, both as recent sources and potential sinks for CO_2, include ephemeral litter, logs, and more resistant humus compounds. Estimating their carbon fluxes is still a priority area for continuing research on global cycling. Because equations for both vegetation and humus balance are influenced by climate-controlled rates, it continues to be important to strengthen the linkage of biogeochemical studies with bioclimatology.

Forest Resources Management

The Forest Resources Management program on the DOE–Oak Ridge Reservation took a new direction in 1980 from a multiple-use sustained-yield program to a more research supportive roll. This is due primarily to the termination of the long-term timber contract and elimination of timber sales. Pulpwood sales through plantation thinnings, emergency timber removals, and sales for research purposes continue in our activities. Plantation thinnings to eliminate suppression and enhance growth totaled 145.4 ha (360 acres) with 7462 m^3 (2082.2 cords) of pulpwood and 1296 m^3 (139 million board feed) of sawtimber. Emergency sales volume totaled 2848.5 m^3 (794.8 cords) on 32.3 ha (80 acres). The only sawtimber sale of 261 m^3 (28 million board feed) was sold by spot bid on our Whole-Tree Harvesting Project research area.

Management activities over the past year were primarily cultural operations including site preparation and reforestation of old beetle kill areas and understocked areas on 78 ha (193 acres). Species planted were loblolly pine (*Pinus taeda*), white pine (*Pinus strobus*), yellow poplar (*Liriodendron tulipifera*), eastern cottonwood (*Populus deltoides*), and sycamore (*Platanus occidentalis*). Average seedling survival rates for 1980 were 75% for hardwoods and 74% for the pines. These combined rates are the lowest ever recorded on the reservation and can be attributed to below-average rainfall from June through October which was 40% of the normal rainfall.

Site preparation for the 1981 planting season was completed ahead of schedule with 54.5 ha (135 acres) cleared, piled and burned and harrowed ready for planting. This figure includes 4 ha to be replanted from the 1980 season due to a 35% survival rate. All areas were double harrowed this season to facilitate planting and improve the survival rate. Species to be planted on these areas will be similar to those of past years but will include more pine because the majority of sites are located on ridge tops.

Work is progressing well on the fertilizer study and the sewage effluent study areas. Final results will not be known for another year or two; meanwhile, preliminary results indicate positive responses on poor sites with little or no responses on fertile sites. Measurements on both studies are taken annually at the end of the growing season. A site preparation study was initiated in 1978 to ascertain the benefits of varied site-preparation techniques. Treatments included clearing-planting, clearing-window piling-harrowing, and clearing-window piling-burning-harrowing-planting. Initial results indicate very poor seedling survival (30%) in the first treatment as opposed to 90% survival in the second two treatments. Assessments of growth responses will be ascertained over the next five-year period.

Long-term forest resource planning is important in formulating goals and coordinating activities of diverse research-management organizations to meet these goals. Extensive forest inventory data are required in all aspects of forest resource planning. Therefore, to complete the timber type-mapping and inventory data collection on the DOE Reservation in 1980, the department hired three summer forest students for eight months to complete the Permanent Plot Survey and Continuous Forest Inventory and to assist in coding these data into the IMGRID format. The IMGRID programming will develop various vegetation, soils, slope, ground water, elevation, and depth to bedrock maps of the entire reservation. During this eight-month work period, 13 compartments with 4993 ha (12,361 acres) were mapped and cruised. Only two compartments, Alternates 1 and 4, with 1226 ha (3035 acres) remain to be inventoried. Five of the compartments will require recruising due to off-scale maps and the need for updating. To date, 33 compartments, 13,703 ha (33,918 acres), have been mapped and cruised.

Hardwood plantation seedling release for 1980 totaled 61 ha (150 acres) comprised of eight different species of both pine and hardwoods. The three methods utilized were bushhog mowing 56.6 ha (140 acres), spraying 2.8 ha (7 acres), and discing 1.2 ha (3 acres). Results from all three treatments were satisfactory, with mowing being the most inexpensive.

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PART III. EXTRAMURAL ACTIVITIES

11. EDUCATIONAL ACTIVITIES

ESD Seminar Program

During the past year the seminar committee offered a diverse program of guest lectures aimed at informing Division staff and other interested members of the local scientific community on topics of general interest in environmental sciences (Table 11.1). The seminar series relies largely on suggestions from Division staff members for the selection of outstanding speakers, an arrangement that was very successful in the past year.

Undergraduate Education Program

Several programs for undergraduate student participation in Division research and assessment projects provide a continuing opportunity for interaction between students and staff. A summary of these programs is provided in Table 11.2.

Students involved in these programs are assigned to individual Division advisors who guide them through an experiment or project associated with one of the Division's programs. The student is required to document results in a report and present a seminar to the Division staff. This research participation experience is designed to expose the student to the research process in a large laboratory. The greatest benefit to students is frequently an expanded outlook on career opportunities in research and an understanding of practical approaches to research problems.

In addition to the programs listed in Table 11.2, six students who completed the B.S. degree were associated with ESD as part of the Laboratory's summer research intern program. This program provides students just entering graduate schools the opportunity to participate in research at an advanced level.

Graduate Education Program

The Division provides opportunities for graduate and postdoctoral research consistent with the mission of the Oak Ridge National Laboratory. During this reporting period, 17 graduate students were supported through a contract with the University of Tennessee *Graduate Program in Ecology*, one by Vanderbilt University, and one through Miami University, Oxford, Ohio. Supported students receive stipends administered by the universities and are guided in their research by selected staff members, one of whom serves on the student's academic guidance committee at the university. In addition, research done by students not requiring Division support was accommodated on a more limited basis, and graduate students were also supported through research subcontracts to various universities.

During this past year, periodic meetings were held involving all the graduate students and the Division's graduate education coordinator. The purpose of the meetings was to explain Division programs to new students and to provide a forum for comments and suggestions relating to the graduate program.

Table 11.1. Environmental Sciences Division invited speakers October 1, 1979, to September 30, 1980

Date	Speaker	Title
10 30 79	Dr. G. Richard Marzolf Kansas State University Manhattan, Kansas	Biological processes in reservoirs: Lakes or wide places in rivers?
1 8 80	Dr. Andrzej Prejs University of Warsaw Warsaw, Poland	Herbivorous fishes for biological control of aquatic plants—a panacea or just new problem?
1 9 80	Dr. Krystyna Prejs University of Warsaw Warsaw, Poland	Meiobenthos in lakes of different trophy—Nematodes as indicators of lake degradation.
1 10 80	Dr. Patrick Brezonik University of Florida Gainesville, Florida	Aspects of metal-organic interactions in natural waters.
2 14 80	Dr. Peter Vitousek University of North Carolina Chapel Hill, North Carolina	Nitrogen cycling and loss in disturbed ecosystems: An experimental analysis.
3 13 80	Dr. Michael J. Duever National Audubon Society Immokolee, Florida	Ecology, controls, and maintenance requirements in cypress swamp ecosystems
4 17 80	Dr. George W. Salt University of California Davis, California	Density effects on the process of predation
4 23 80	Dr. Donald R. Whitehead Indiana University Bloomington, Indiana	Paleoecological investigations of watershed-lake relationships in the Adirondack region of New York State
5 13 80	Dr. John W. Farrington Woods Hole Oceanographic Institution Woods Hole, Massachusetts	Biochemistry of polynuclear aromatic hydrocarbons in marine ecosystems
5 20 80	Dr. Robin Vannote Stroud Water Research Center Academy of Natural Sciences of Philadelphia Avondale, Pennsylvania	Temperature affects size and fecundity of aquatic insects. Some geographic and community implications
7 12 80	Dr. P. Kihlo Park National Oceanic and Atmospheric Administration Rockville, Maryland	Radioactive waste dumping in the ocean
9 11 80	Dr. Gerard Fisher Battelle Columbus Laboratories Columbus, Ohio	Physical properties and toxicology of coal fly ash
9 17 80	Dr. Vaclav Smil The University of Manitoba Winnipeg, Manitoba	Energetics of the developing nations

Table 11.2. Numbers of students in ESD undergraduate programs, October 1, 1979–September 30, 1980

Program	Number
Oak Ridge Associated Universities	9
Southern College and University Union	2
Emory University	6
Great Lakes Colleges Association	2
University of Wisconsin–Stevens Point	3
Jackson State University	1

12. ENVIRONMENTAL SCIENCES DIVISION RESEARCH AND DEVELOPMENT SUBCONTRACTS AND INTERAGENCY AGREEMENTS

Title of subcontract interagency agreement	Subcontractor	Division technical contact
SUBCONTRACTS		
Development and testing of organic anions for use as ground-water tracers	Arizona, University of	N. H. Cutshall
Provide engineering process descriptions for conventional full alcohol plants in size range of 15 to 150 million gal year for use in assessing the environmental, health, and safety issues of such plants	Battelle Columbus Laboratories	J. F. McBrayer
Research to determine the nature, character, and extent of understory vegetation within uneven-aged pine and pine-hardwood southern forest and the effects of periodic harvests of such understory vegetation on site quality	Arkansas, University of	J. W. Ranney
Evaluation and technical review of the Alternate Fuels Programmatic Environmental Impact Statement	Battelle Memorial Institute	R. M. Reed
Assistance in developing the preliminary relationships between remote-sensing-derived surface classes and stored organic carbon in the soil	California, University of	R. I. Van Hook
Ecosystem effects of whole tree harvesting	Clemson University	D. C. West
Toxicological and chemical characterization of the water-soluble fraction of three oils will be studied. Tests will be short-term lethality studies with chemical characterization and fractionation determined by initial biological responses	Colorado State University	C. W. Gehrs
Involvement with the National Atmospheric Deposition Program requires sample analysis by a central analytical laboratory for comparability of data on atmospheric deposition on a national scale	Colorado State University	S. E. Lindberg
Literature abstracting for shallow land burial of radioactive waste	Dames & Moore	T. Tamura
Provide an evaluation of the techical issues relating to land burial of low-level radioactive waste	Evaluation Research Corporation	R. B. Fitts
Ecosystem effects of whole-tree harvesting: Florida Coastal Plain Flatwoods	Florida, University of	D. C. West
Studies to increase the biomass production of short-rotation coppice forest	Georgia Research Institute, University of	J. H. Cushman
Assistance in conducting an environmental compliance workshop on fuel alcohol in Federal Region IV	Georgia Tech Research Institute	J. F. McBrayer

12. ENVIRONMENTAL SCIENCES DIVISION RESEARCH AND DEVELOPMENT SUBCONTRACTS AND INTERAGENCY AGREEMENTS

Title of subcontract interagency agreement	Subcontractor	Division technical contact
Material spiralling in stream ecosystems: Feasibility of manipulating natural streams using pesticides	Georgia, University of	W. Van Winkle
Assistance to the Environmental Impacts Program in preparing two guidance documents being submitted to DOE	Gilbert Associates	R. M. Reed
Studies on the mobility of organic molecules in ground water	Indiana University	N. H. Cutshall
Cooperation between Indiana University School of Public and Environmental Affairs and ORNL on environmental sciences research and education programs.	Indiana University	S. G. Hildebrand
Program integration for the DOE Ecological Program in coal synthetic fuels	International Research and Technology Corp.	C. W. Gehrs
Determination of the best species and management techniques for short rotation production of fuel wood in the Great Plains	Kansas State University	J. W. Ranney
Aquatic toxicity tests on organic contaminants originating from coal conversion	Kentucky, University of	R. F. Millemann
Determine the optimum sites and identify equipment needs for the first air quality and meteorological stations at the Pike County, Kentucky, Gasifier-in-Industry facility	Kenvirons, Inc.	C. W. Gehrs
Assistance in the expansion of the Geoecology Data Base, with the primary responsibility being development of files for the system	Lockheed Missile & Space Co., Inc.	R. J. Olson
Description of the status and well-being of the Ohio River fish community to provide a background against the impacts of site-specific projects which can be assessed by regulatory agencies	Louisville, University of	S. M. Adams
Internship program	Miami University	S. I. Auerbach
Air quality monitoring and studies relative to coal gasification plant and biomedical effects	Minnesota, University of	G. W. Suter
Provide for collection, preparation, and shipment of process samples and plant area samples and the operation and maintenance of on-line monitors, plant area monitors, and a data acquisition system as part of the comprehensive environmental and health monitoring and testing program for the UMD Gasifier Project	Minnesota-Duluth, University of	K. F. Cowser

12. ENVIRONMENTAL SCIENCES DIVISION RESEARCH AND DEVELOPMENT SUBCONTRACTS AND INTERAGENCY AGREEMENTS

Title of subcontract interagency agreement	Subcontractor	Division technical contact
The influence of NO_2, SO_2, and O_3 combined at three concentrations on the growth of several plant species	North Carolina State University	D. S. Shriner
Development of a method of ensuring long-term contractual wood chip supplies to expedite the use of waste wood for fueling local wood-fired power plants and to overcome wood fuel procurement barriers	Page, Edward L.	R. M. Reed
Evaluation on paper of the economic efficiency of wood-energy plantations and delineation of needed further research to properly and accurately evaluate wood-energy plantations	Penn State University	J. W. Ranney
Sampling, monitoring, and analysis of meteorology, air quality, and water quality for Pike County coal gasification plant	Pikeville College	R. M. Cushman
Legionnaires disease bacterium in power plant cooling waters	Savannah River Laboratory	S. B. Gough
Site-specific environmental data acquisition and review for small hydroelectric demonstration sites	Science Applications, Inc	S. G. Hildebrand
Perform a survey and preliminary assessment of modeling and monitoring techniques associated with radionuclide containment release from the burial of low-level waste	Science Applications, Inc.	R. S. Lowrie
Provide conference facilities and personnel to handle six two-day workshops re: information needed to review and evaluate ecological toxicology tests at the multispecies level	Science Applications, Inc.	A. S. Hammons
Terrestrial and aquatic ecology support for Fossil Energy Environmental Project	Science Applications, Inc.	S. G. Hildebrand
The role of terrestrial ecosystems in the global carbon cycle and the effects of climate change on carbon amounts and distribution	Southern Illinois University	R. I. Van Hook
Survey of cooling towers within Oak Ridge Operations for presence of the Legionnaires disease bacterium	Tennessee, University of	R. L. Tyndall
Impact of coal conversion and shale contaminants on the microbial activity of aquatic sediments	Tennessee, University of	C. W. Gehrs
A cooperative venture between the Environmental Sciences Division (ORNL) and the University of Tennessee Graduate Program in Ecology	Tennessee, University of	R. E. Millemann

12. ENVIRONMENTAL SCIENCES DIVISION RESEARCH AND DEVELOPMENT SUBCONTRACTS AND INTERAGENCY AGREEMENTS

Title of subcontract interagency agreement	Subcontractor	Division technical contact
A cooperative venture between the Environmental Sciences Division (ORNL) and the University of Tennessee Graduate Program in Geological Sciences	Tennessee, University of	T. Tamura
Model morphological characteristics of impoundments using surface area and slopes of reservoir bottom configurations as variables	Tennessee, University of	S. G. Hildebrand
Field collection of data and sediments from lakes and ponds in Tennessee adjacent to Kentucky	Tennessee, University of	A. M. Solomon
Automated biomonitoring applications to remote water quality stations and satellite data retrieval	Tennessee, University of	W. Van Winkle
Environmental consequences of the disposal of coal conversion solid waste	Vanderbilt University	W. J. Boegly
Evaluation of wastewater treatment models for their suitability for use by EPA in assessing the fate of organic chemicals in the environment and their risks to human and nonhuman populations	Vanderbilt University	C. C. Coutant
Spatial heterogeneity of forest ecosystems	Virginia, University of	R. I. Van Hook
Materials spiralling in stream ecosystems: Effects of physical, chemical, and biological factors on organic matter spiralling	Virginia Polytechnic Institute and State University	R. I. Van Hook
Analysis of the impact of air pollutants emitted from a coal degasifier on native and planted forest vegetation	Virginia Polytechnic Institute and State University	D. S. Shriner
Modeling area biomass dynamics of terrestrial forest ecosystems at the subcontinental scale	Virginia Polytechnic Institute and State University	R. I. Van Hook
A construct for analysis of ecosystem perturbations based on input output analysis. II. Uncertainty analysis	Washington, University of	S. G. Hildebrand
Impact of whole-tree harvesting and residue removal on productivity and nutrient loss from selective soils of the Pacific Northwest	Washington, University of	D. C. West
Environmental research for small hydroelectric technology	Washington, University of	S. G. Hildebrand
Evaluation of the effect of atmospheric sulfur deposition on the nutrient status of soil and plants from two forested ecosystems in western Washington	Washington, University of	D. W. Johnson

12. ENVIRONMENTAL SCIENCES DIVISION RESEARCH AND DEVELOPMENT SUBCONTRACTS AND INTERAGENCY AGREEMENTS

Title of subcontract interagency agreement	Subcontractor	Division technical contact
Review of existing data on three heavy metals (zinc, cadmium, and mercury) in New York Bight and development of a comprehensive picture of their transport and cycling among waters and sediments of the Bight	Wesleyan University	N. H. Cutshall

PART IV. APPENDICES

PUBLICATIONS,* PRESENTATIONS, THESES, AND PROFESSIONAL ACTIVITIES

Publications

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*A complete listing of Environmental Sciences Division publications is available from S. I. Auerbach, Director, Environmental Sciences Division, Oak Ridge National Laboratory, Oak Ridge, Tennessee 37830.

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"Quantitative approaches for analyzing and evaluating ecological effects of power plant thermal discharges." Annual Meeting, American Institute of Biological Sciences, Tucson, Arizona, August 1980.

"Factors affecting growth efficiency and body composition of *Tilapia* in sewage oxidation ponds." Annual Meeting, American Fisheries Society, Louisville, Kentucky, September 1980.

"NEPA and the impact statement process," ORAU Training Seminar Series, Oak Ridge Associated Universities, Oak Ridge, Tennessee, Fall 1979.

Auerbach, S. I.

"The implications of nuclear energy in our total energy picture," presented to the B'nai B'rith, Chattanooga, Tennessee, for the Laboratory Speakers' Bureau, May 1980.

Barnthouse, L. W.

"Differential responses of *Daphnia laevis* and *D. pulex* to predation by *Ambystoma*," 43rd Annual Meeting of the American Society of Limnology and Oceanography, Knoxville, Tennessee, June 1980.

Barnthouse, L. W., and B. L. Kirk

"Modeling power plant impacts on multipopulation systems," Annual Meeting, American Institute of Biological Sciences, Tucson, Arizona, August 1980.

Barnthouse, L. W., and W. Van Winkle

"The direct impact of impingement on the Hudson River white perch population," Fifth National Workshop on Entrainment and Impingement, San Francisco, California, May 1980.

Barnthouse, L. W. (F. S. Sanders and L. W. Barnthouse)

"An integrated approach to ecological impact assessment," Annual Meeting, American Institute of Biological Sciences, Tucson, Arizona, August 1980.

Blasing, T. J.

"Map pattern classification at a prescribed level of generality," Sixth Conference on Probability and Statistics in Atmospheric Sciences, American Meteorological Society, Banff, Alberta, Canada, October 1979.

"Multivariate analysis of environmental data," Department of Mathematics, University of Tennessee, Knoxville, November 1979.

"The development of dendroclimatology and its extension to the southeastern United States — The tree-ring circus comes to town," Department of Geological Sciences, University of Tennessee, Knoxville, January 1980.

"Exploring climatic change — risks and discoveries," Department of Geography, University of Tennessee, Knoxville, January 1980.

"Weather, climate, and climatic change," 1980 Annual Conference of the National Association of Independent Schools, New Orleans, Louisiana, March 1980.

Blasing, T. J., D. N. Duvick, and D. C. West

"The use of tree rings to estimate annual precipitation in central Iowa since A.D. 1700," Annual Meeting, American Institute of Biological Sciences, Tucson, Arizona, August 1980.

Blaylock, B. G.

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Boegly, W. J., Jr.

"Disposal characteristics of solid residues from coal gasification," Air Pollution Control Association, Montreal, Canada, June 1980.

Burgess, R. L.

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Cada, G. F., J. M. Loar, and K. D. Kumar

"Diel patterns of ichthyoplankton length-density relationships in upper Watts Bar Reservoir, Tennessee," Fourth Annual Larval Fish Workshop, Oxford, Mississippi, February 1980.

Cada, G. F., J. S. Suffern, K. D. Kumar, and J. A. Solomon

"Investigations of entrainment mortality among larval and juvenile fishes using a power plant simulator," Fifth National Workshop on Entrainment and Impingement, San Francisco, California, May 1980.

Christensen, S. W.

"An example of FORTRAN support of MAPPER: Easy Perry-type visuals," MAPPER Users Group Meeting, Oak Ridge National Laboratory, October 1979.

"Use of monitoring program results in modeling aquatic environmental impacts," University of Tennessee class, at Oak Ridge National Laboratory, February 1980.

"Position paper: The best approach to impact assessment is to use empirically based or simulation models to forecast impacts," Fifth National Workshop on Entrainment and Impingement, San Francisco, California, May 1980.

Coutant, C. C.

"Underwater telemetry," Wildlife Society Student Chapter, The University of Tennessee, Knoxville, January 1980.

"Introduction to fishery research," Seminar Class, The University of Tennessee, Knoxville, January 1980.

"Environmental quality for striped bass," Fifth Marine Recreational Fisheries Symposium, Boston, Massachusetts, March 1980.

"Trends in environmental legislation," EPRI Task Force on Environment, Atlanta, Georgia, May 1980.

"Resource partitioning by striped bass," Fishery Ecology Class, Tennessee Technological University, Cookeville, May 1980.

"Thermal niche and resource partitioning in striped bass," Tennessee Technological University, Tech-Aqua Field Station, July 1980.

"Striped bass studies," Oak Ridge Kiwanis Club, July 1980.

"Striped bass behavior as evidence of water quality problems," Cherokee Reservoir Interagency Task Force, Knoxville, Tennessee, August 1980.

"Striped bass telemetry in Tennessee reservoirs," Tennessee Outdoor Writers Association, Annual Meeting, Newport Resort, Spring City, Tennessee, September 1980.

"Thermal niche analysis for predicting predator-prey interactions," American Fisheries Society Annual Meeting, Louisville, Kentucky, September 1980.

Craig, R. B.

"Environmental constraints on geothermal energy," Second International Conference on Energy Use Management, Los Angeles, California, October 1979.

Craig, R. B., P. Kanciruk, and G. F. Sabbadini

"Components of the feeding behavior of the American kestrel," Annual Meeting, American Institute of Biological Sciences, Tucson, Arizona, August 1980.

Cushman, J. H.

"Short-rotation silviculture for energy," 1980 Solar Update—Tennessee, Tennessee Solar Energy Association, Knoxville, May 1980.

Cushman, J. H., and J. W. Ranney

"Silvicultural energy farms in the southeast: Implications for change in the structure and composition of regional forest systems," Annual Meeting, American Institute of Biological Sciences, Tucson, Arizona, August 1980.

Cushman, R. M. (R. J. Haynes, R. M. Cushman, J. F. McBrayer, and R. D. Roop)

"Determining environmental impacts of future lignite mining in the South," Second International Conference on Energy Use Management, Los Angeles, California, October 1979.

Cushman, R. M., J. F. McBrayer, R. J. Haynes, and R. D. Roop

"Lignite mining in the South: Scoping environmental impacts," poster session, Annual Meeting, American Institute of Biological Sciences, Tucson, Arizona, August 1980.

Cutshall, N. H.

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"Assay of low-level solid wastes at ORNL," LASL DOE Waste Assay Instrumentation Workshop, Los Alamos, New Mexico, October 1979.

"Low-level radioactive waste management — The U. S. national program," Drexel University, Philadelphia, Pennsylvania, November 1979.

"Low-level waste R&D at ORNL," National Low-Level Waste Information Meeting, Las Vegas, Nevada, December 1979.

"Remedial measures at old shallow land burial sites," NRC Headquarters, Silver Spring, Maryland, March 1980.

"Effectiveness of hydrologic control measures at shallow land burial sites," IAEA Coordinated Research Program Meeting on Migration and Dispersion of Radionuclides from Storage of Radioactive Wastes in the Terrestrial Environment, Gothenburg, Sweden, August 1980.

Davis, E. C.

"Modeling waste assimilation after channelization," ASCE Environmental Engineering Specialty Conference, New York, July 1980.

"Water quality problems associated with coal storage," U.S. Geological Survey Gulf Coast Hydroscience Center, Bay St. Lewis, Mississippi, February 1980; ORNL Environmental Sciences Division, Oak Ridge, Tennessee, February 1980.

"A laboratory and field analysis of factors affecting quality of leachate from coal storage piles," Vanderbilt University, Nashville, Tennessee, April 1980.

DeAngelis, D. L.

"Some theoretical results concerning energy flow, nutrient cycling, and ecosystem resilience," Department of Biology, Princeton University, February 1980.

DeAngelis, D. L., B. A. Schaich, and C. C. Coutant

"A model for the movement and distribution of fish in a body of water," Annual Meeting, American Institute of Biological Sciences, Tucson, Arizona, August 1980.

DeAngelis, D. L., C. C. Coutant, and M. E. Cochran

"Mathematical modeling of size-dependent phenomena in fish population model." 110th Annual Meeting, American Fisheries Society, Louisville, Kentucky, September 1980.

Delcourt, H. R., and W. F. Harris

"The southeastern United States as regional carbon source and sink," Annual Meeting, American Institute of Biological Sciences, Tucson, Arizona, August 1980.

Delcourt, H. R., A. M. Solomon, D. C. West, and P. A. Delcourt

"Application of paleoecologic records and forest simulation models to reconstruct Quaternary vegetation response to climate change in the eastern United States." Sixth Biennial Meeting, American Quaternary Association, Orono, Maine, August 1980.

Dye, L. L., and J. S. Mattice

"Egg hatching and growth rates of *H. bilineata*," North American Benthological Society, Savannah, Georgia, March 1980.

Edwards, N. T.

"Effects of whole tree harvest and residue removal on ecosystem processes — the Oak Ridge experimental design," University of Tennessee Plant Ecology Class, Oak Ridge, Tennessee, November 1979.

Elwood, J. W.

"Phosphorus spiralling in a woodland stream ecosystem," Ecology Seminar Program, Kansas State University, Manhattan, April 1980.

"Nutrient spiralling in stream ecosystems: The concept and field studies," Ecology Seminar Program, University of Tennessee, Knoxville, April 1980.

"Acid rain: Effects on aquatic ecosystems," ORAU Training Program, Oak Ridge Associated Universities, Oak Ridge, Tennessee, August 1980.

Elwood, J. W., and J. D. Newbold

"Material spiralling in stream ecosystems," Oregon State University, Corvallis, November 1979.

Elwood, J. W., J. D. Newbold, and R. V. O'Neill

"Phosphorus spiralling in a woodland stream: The role of the microbial community." Annual Meeting, American Society of Limnology and Oceanography, Knoxville, Tennessee, June 1980.

"The role of the microbial community in phosphorus spiralling in a woodland stream." 21st Congress of the International Association of Theoretical and Applied Limnology, Kyoto, Japan, August 1980.

Emanuel, W. R., W. M. Post, and H. H. Shugart

"Modeling the role of terrestrial ecosystems in the global carbon cycle." Pittsburgh Conference on Modeling and Simulation, Pittsburgh, Pennsylvania, May 1980.

Farrell, M. P.

"Aquatic ecology of the Mississippi River," ORAU Traveling Lecture Program, Miami University, Oxford, Ohio, March 1980.

"Behavioral systems in small mammal populations," ORAU Traveling Lecture Program, Miami University, Oxford, Ohio, March 1980.

"Statistical problems associated with NOEC testing," Oak Ridge National Laboratory, July 1980.

Farrell, M. P., R. H. Strand, A. D. Magoun, C. H. Pennington, H. Schramm, S. P. Cobb, and K. Daniels

"Quality assurance controls in research data management: Nonsense codes in hierarchical file structures," Fifth Annual SAS Users Group International Conference, San Antonio, Texas, February 1980.

Farrell, M. P., R. H. Strand, and C. W. Gehrs

"New coal technologies: A case study for resource data management in environmental research," Annual Meeting, American Institute of Biological Sciences, Tucson, Arizona, August 1980.

Farrell, M. P., R. H. Strand, and H. N. Polovino

"Redundancy estimates among relational data structures," Annual Meeting, American Statistical Association, Houston, Texas, August 1980.

Farrell, M. P., and R. H. Strand

"Environmetrics of the UMD gasifier," University of Minnesota-Duluth, Duluth, Minnesota, February 1980.

"Tracking quality assurance controls in environmental research," Meetings of the American Society of Quality Control, Tulsa, Oklahoma, October 1980.

"N-dimensional pattern recognition in environmental systems," DOE Statistical Symposium, Berkeley, California, October 1980.

Fitts, R. B., and R. S. Lowrie

"The DOE program for development of low-level waste disposal technology," invited paper, American Nuclear Society Annual Meeting, Las Vegas, Nevada, June 1980.

Floran, R. J., M. Rappaz, M. M. Abraham, and L. A. Boatner
"Hot and cold pressing of $LaPO_4$-based nuclear waste forms," Workshop on Alternative Nuclear Waste Forms, Gatlinburg, Tennessee, May 1980.

Francis, C. W., and E. A. Bondietti
"Sorption-desorption of long-lived radionuclide species on geologic media," Task 4. Third Contractor Information Meeting, Waste Isolation Safety Assessment Program, Seattle, Washington, October 1979.

Francis, C. W., and C. W. Hancher
"Biological denitrification of high-nitrate wastes generated in the nuclear industry," Conference on the Biological Fluidized Bed Treatment of Water and Wastewater, University of Manchester Institute of Science and Technology, Manchester, England, April 1980.

Francis, C. W., M. P. Maskarinec, J. L. Epler, and D. K. Brown
"The utility of extraction procedures and toxicity testing with solid wastes," Sixth Annual Research Symposium, Chicago, Illinois, March 1980.

Gardner, R. H.
"Estimating the uncertainties of some ecological models," Visiting Scientist Lecture Series, Taylor University, Upland, Indiana, September 1980.

Garten, C. T., Jr.
"Field experiments on the behavior of technetium in soils and vegetation," Annual Meeting, American Institute of Biological Sciences, Tucson, Arizona, July 1980.

Gehrs, C. W.
"History of synthetic fuels environmental research at Oak Ridge National Laboratory," Battelle Pacific Northwest Laboratory: DOE Review of PNL's Environmental Program in Synthetic Fuels, October 1979.

"Potential environmental costs of coal conversion and coal liquids transportation," invited paper at the Water Pollution Control Federation Pre-Conference Symposium on Water and New Energy Resources — A Burning Issue?, September 1980.

Giddings, J. M.
"Pollution studies in aquatic microcosms," Third International Symposium on Aquatic Pollutants, Jekyll Island, Georgia, October 1979.

"Four-hour algal bioassays for assessing the toxicity of coal-derived materials," Symposium on Process Measurements for Environmental Assessment, Atlanta, Georgia, February 1980.

"Toxicity of shale oil to freshwater algae: Comparisons with petroleum and coal-derived oils," Symposium on Health Effects Investigation of Oil Shale Development, Gatlinburg, Tennessee, June 1980.

Haase, C. S.

"Multisystems analysis of phase relations in the system CaO—(Fe,Mg)O—Al_2O_3—Fe_2O_3—SiO_2—CO_2—H_2O): A petrogenetic grid for metamorphosed iron-formation." Annual Meeting, Geological Society of America, San Diego, California, November 1979.

"Metamorphic petrology of the Negaunee iron-formation, Northern Michigan." University of Tennessee Geology Department Seminar, Knoxville, May 1980.

Haase, C. S., and D. M. Rye

"Stable isotope geochemistry of the Negaunee iron-formation, Marquette District, Michigan: I. Preliminary $\delta^{13}C$ and $\delta^{18}O$ data from carbonates at the Empire Mine." Annual Spring Meeting, American Geophysical Union, Toronto, Ontario, Canada, May 1980.

Herbes, S. E.

"Transformations of polycyclic aromatic hydrocarbons in water and sediments." Gordon Research Conference (Environmental Sciences: Water), New Hampton, New Hampshire, June 1980.

Herbes, S. E., and G. R. Southworth

"Polycyclic aromatic hydrocarbons in sediments." Third International Symposium on Aquatic Pollutants (EPA American Chemical Society), Jekyll Island, Georgia, October 1979.

Hildebrand, S. G.

"The small scale hydroelectric resource: Environmental issues and research priorities." Vanderbilt University, Department of Environmental and Water Resource Engineering, April 1980.

Hildebrand, S. G., and G. B. Grimes

"The Department of Energy environmental subprogram plan for small hydroelectric development." Waterpower 79: An International Conference on the Potential for Small Scale Hydropower, Washington, DC, October 1979.

Hildebrand, S. G., W. Van Winkle, C. C. Coutant, J. W. Elwood, J. S. Mattice, and R. B. McLean

"Comparative reservoir research at Oak Ridge National Laboratory." Symposium on Surface Water Impoundments, Minneapolis, Minnesota, June 1980.

Huber, E. E. (R. L. Burgess and E. E. Huber)

"Monitoring on rights-of-way and the National Biomonitoring Inventory." 2nd National Symposium on Environmental Concerns in Rights-of-way Management, University of Michigan, Ann Arbor, October 1979.

Huff, D. D.

"Hydrologic studies by computer," invited seminar, Florida State University, Tallahassee, Florida, November 1979.

"Workshop Summary: Parameters constraints in hydropower simulation optimization models." Hydroelectric development: Ecological issues at the river basin level, Oak Ridge, Tennessee, September 1980.

"The water cycle and groundwater." Topics in Geology, ORNL, September 1980.

Johnson, D. W.

"Effects of acid rain on forest nutrient status," ORAU Traveling Lecture Series, Clemson University, South Carolina, December 1979; West Virginia University, Morgantown, West Virginia, March 1980; and Duke University, Durham, North Carolina, April 1980.

Johnson, D. W., J. W. Hornbeck, J. M. Kelly, W. T. Swank, and D. E. Todd

"Regional patterns of soil sulfate accumulation: Relevance to ecosystem sulfur budgets," Second ORNL Life Sciences Symposium, Atmospheric Sulfur Deposition: Environmental Impact and Health Effects, Gatlinburg, Tennessee, October 1979.

Johnston, J. W., D. S. Shriner, and C. I. Klarer

"The chlorophyll, growth, and yield responses of beans exposed to simulated acid rain," 12th Annual Air Pollution Workshop, Fort Collins, Colorado, May 1980.

Kirk, B. L. (B. W. Rust and B. L. Kirk)

"The global CO_2 problem — A time series perspective I," Fall 1979 Meeting, Society for Industrial and Applied Mathematics, Denver, Colorado, November 1979.

Kirk, B. L., and B. W. Rust

"The global CO_2 problem — A time series perspective II," Society for Industrial and Applied Mathematics, Fall 1979 Meeting, Denver, Colorado, November 1979.

Kitchings, J. T., and D. Levy

"Habitat patterns in a small mammal community," 41st Annual Meeting, Association of Southeastern Biologists, Tampa, Florida, March 1980.

Kitchings, J. T., and J. D. Story

"Home range and diet of bobcats in eastern Tennessee," Bobcat Research Conference, Front Royal, Virginia, October 1979.

Klopatek, J. M.

"Regional ecological assessment of acid precipitation on soil," Second ORNL Life Sciences Symposium, Atmospheric Sulfur Deposition: Environmental Impact and Health Effects, Gatlinburg, Tennessee, October 1979.

"Environmental impacts of energy technology in the U.S. in the year 2000," International Conference on Energy Use Management, Los Angeles, California, October 1979.

"An overview of regional environmental analysis," U.S. Forest Service, Fort Collins, Colorado, November 1979.

"A theoretical approach to regional ecological analysis," Annual Meeting, American Institute of Biological Science, Tucson, Arizona, August 1980.

Krummel, J.

"Sexual reproduction in isolated clones of *Daphnia pulex*," Annual Meeting, American Institute of Biological Sciences, Tucson, Arizona, August 1980.

Krummel, J., J. Klopatek, J. B. Mankin, and R. V. O'Neill

"A simulation approach to a regional resource-environment conflict," Summer Computer Simulation Conference, Seattle, Washington, August 1980.

Kumar, K. D., and R. J. Olson

"Regional analysis — Concepts and applications," American Statistical Association Annual Meeting, Houston, Texas, August 1980.

Larsen, Ingvar L., and Norman H. Cutshall

"Beryllium-7 in coastal and estuarine sediments," American Society of Limnology and Oceanography, University of Southern California, Los Angeles, January–February 1980.

"Peak-by-peak background correction and error analysis package for low-level Ge(Li) spectroscopy," ND6600 User's Meeting at Fourth International Conference on Nuclear Methods in Environmental and Energy Research, University of Missouri, Columbia, April 1980.

"Radionuclides in the coastal zone," Seminar presented at the Comparable Animal Research Laboratory, Oak Ridge, Tennessee, March 1980.

Lindberg, S. E.

"Use of surrogate surfaces to measure dry deposited aerosol flux to forest systems," invited presentation at the EPA Workshop on Dry Deposition Methodology, Argonne, Illinois, December 1979.

"Research needs in atmospheric deposition and its effects," invited presentation at the International Conference on Current Status and Future Needs of Research on Effects and Technology of Air Pollution, Banff, Alberta, Canada, May 1980.

"The forest canopy: A source or sink for trace elements in the atmosphere?," invited presentation at the Gordon Research Conference on Aerobiology, Meridan, New Hampshire, July 1980.

Luxmoore, R. J.

"Modeling pollutant uptake and effects on the soil-plant-litter system," Effects of Air Pollutants on Mediterranean and Temperate Forest Ecosystems: An International Symposium, University of California, Riverside, June 1980.

Mann, L. K., and W. M. Post

"Modeling the effect of drought on forest growth and composition," Poster Session, Annual Meeting, American Institute of Biological Sciences, Tucson, Arizona, August 1980.

J. S. Mattice

"Optimum chlorination at power plants," Third Conference on Water Chlorination, Colorado Springs, Colorado, October–November 1979.

"Chlorine research," presented to Alan Moghissi, U.S. Environmental Protection Agency, at Oak Ridge, March 1980.

"Chlorine effluent limits," presented to Dr. Johannes von Rensberg, National Institute for Water Research, Pretoria, South Africa, at Oak Ridge, July 1980.

"Trophic dynamics of reservoir benthos," presented to Heyward Hamilton, Department of Energy, Oak Ridge, January 1980.

McBrayer, J. F.

"Environmental consequences of collecting crop residues for energy production," Annual Meeting, American Institute of Biological Sciences, Tucson, Arizona, August 1980.

"NEPA-compliance in licensing nuclear power plants," ORAU Workshop on Nuclear Power and the Energy Crisis, October 1979.

"Fertility and tilth effects of fuel crop residue removal," DOE/SOLAR contractors review, Washington, DC, October 1979.

McLaughlin, S. B.

"Air pollution impacts on vegetation," Junior Science and Humanities Symposium, Oak Ridge, Tennessee, March 1980.

"Carbon allocation by forest trees," Seminar at DOE Headquarters, Washington, DC, April 1980.

"Effects of relative humidity on uptake of SO_2 and O_3 by plants," Air Pollution Workshop, Fort Collins, Colorado, May 1980.

"Current problems and future research needs in the acquisition, interpretation, and application of data in terrestrial vegetation — Air pollution interaction studies," International Conference on Current Status and Future Needs of Research on Effects and Technology of Air Pollution, Banff, Alberta, Canada, May 1980.

"Seasonal changes in energy allocation by white oak," Annual Meeting, American Institute of Biological Sciences, Tucson, Arizona, August 1980.

"SO_2, vegetation effects, and the air quality standard: Limits of interpretation and application," Air Pollution and Control Association Specialty Conference, Atlanta, Georgia, September 1980.

McLean, R. B.

"Hermit crab competition for new shells: Ramifications for the structuring of a marine benthic community," Annual Meeting, American Institute of Biological Sciences, Tucson, Arizona, August 1980.

Moran, Mary S.

"The impacts of deep geothermal fluid production on shallow ground-water systems," National Water Well Association Convention and Exposition, Oklahoma City, Oklahoma, October 1979.

Presentation on the National Low-Level Waste Management Program's alternatives to shallow land burial element, to Nuclear Regulatory Commission staff, March 1980.

Mulholland, P. J.

"Formation of particulate organic carbon in water from a southeastern swamp-stream," American Society of Limnology and Oceanography Annual Meeting, Knoxville, Tennessee, June 1980.

"Deposition of organic carbon in floodplains, wetlands, and deltas," National Research Council's Workshop on the Flux and Fate of Organic Carbon in the World's Rivers, Woods Hole, Massachusetts, September 1980.

Newbold, J. D., J. W. Elwood, and R. V O'Neill

"Nutrient limitations in streams: A mechanism and prediction based on concepts of nutrient spiralling." American Society of Limnology and Oceanography Annual Meeting, Knoxville, Tennessee, June 1980.

Nungesser, M. K., and R. J. Olson

"Regional ecological analysis and data base applications." Fifth Annual SAS Users Group International Conference, San Antonio, Texas, February 1980.

Nungesser, M. K., G. E. Taylor, Jr., and R. J. Olson

"Regional impacts of air pollution on vegetation," Annual Meeting, American Institute of Biological Sciences, Tucson, Arizona, August 1980.

Oakes, K. M.

"Land use siting considerations for hydrothermal energy facilites," Twentieth Annual Meeting of the Institute of Environmental Sciences, Philadelphia, Pennsylvania, May 1980.

Olsen, Curtis R.

"Reactor nuclides and fine-particle transport and accumulation patterns in the coastal waters of Barnegat Bay and adjacent N. J. shelf." Annual Meeting of American Society of Limnology and Oceanography, Stony Brook, New York, June 1979.

"Anthropogenic radionuclides in the sediments of the Susquehanna River and Upper Chesapeake Bay." Middle Atlantic Regional Meeting of the American Chemical Society, Valley Forge, Pennsylvania, April 1980.

Olson, J. S.

"Carbon budgets, climate and burning." USDA Forest Service and Oregon State University, Corvallis, January 1980.

"Global carbon estimates and maps." Woods Hole Marine Biology Laboratory, NSF Coordination Meeting, July 1980.

"Probable biospheric responses to changes in CO_2 and climate." NSF DOE Workshop, Duke University, Durham, North Carolina, March 1980.

O'Neill, R. V.

"Uncertainty in ecological models." University of Tennessee, Knoxville, May 1980.

Parr, Patricia D.

"Rare plants on the DOE Reservation." University of Tennessee Plant Ecology Class, at Oak Ridge National Laboratory, November 1979.

Parr, Patricia D., and Fred G. Taylor, Jr.

"Chromium incorporation in soybeans (*Glycine max*) through root uptake and foliar absorption pathways." Association of Southeastern Biologists, Tampa, Florida, March 1980.

Post, W. M.

"Models of the evolution of mutualism: Some problems and hypotheses." Society for the Study of Evolution, Tucson, Arizona, June 1980.

Ranney, J. W.

"Biomass measurement needs in wood energy research." Southern Biomass Working Group, Raleigh, North Carolina, June 1980.

"Research needs in woody biomass as an energy source." Conference on Research at Predominantly Black Institutions, Williamsburg, Virginia, June 1980.

Ranney, J. W., and J. H. Cushman

"Recent research developments in producing wood for energy." Southern Forest Energy Tour, Bioenergy '80, Atlanta, Georgia, April 1980.

Reichle, D. E.

"Renewable natural resources management." University of Tennessee U.S. Department of State training course on Environment Management in Developing Nations, Tremont Campground, Gatlinburg, Tennessee, July 1980.

"Use of systems analysis to predict responses of ecosystems under altered conditions." Annual Meeting, American Institute of Biological Sciences, Tucson, Arizona, August 1980.

"Oak Ridge National Environmental Research Park Program." U.S. Department of Energy, Ecological Research Division working meeting, Germantown, Maryland, September 1980.

Rust, B. W., and B. L. Kirk

"Applications of empirical time series modeling to the carbon dioxide problem." American Statistical Association, Houston, Texas, August 1980.

Solomon, A. M., D. C. West, and H. R. Delcourt

"Simulating the effects of climate change and of species immigration upon forest succession." NSF DOE, Workshop on Forest Succession, Mountain Lake, Virginia (workshop presentations), June 1980.

"Simulating the effects of climate change and of species immigration upon forest composition." 5th International Palynological Conference, Cambridge, England (presented papers), June–July 1980.

Solomon, A. M., and H. R. Delcourt

"Forest-stand simulation models in paleoecology: Application of scanning electron microscopy to identify species of *Quercus* pollen." Sixth Biennial Meeting, American Quaternary Association, Orono, Maine, August 1980.

"Chemical treatments of soil to decrease radiostrontium leachability." UCCND and Goodyear Atomic Waste Management Seminar, Friendship, Ohio, April 1980.

"Influence of soil organic matter on radiostrontium mobility in soil." USDA Technical Committee No. 59 Meeting, Ottawa, Ontario, Canada, August 1980.

Shriner, D. S.

"Terrestrial vegetation — air pollutant interactions: Non-gaseous pollutants, wet deposition." International Symposium on the Effects of Air Pollutants on Terrestrial Ecosystems, Banff, Alberta, Canada, May 1980.

"Effects of acidic precipitation on plants." Department of Botany Seminar, North Carolina State University, Raleigh, November 1979.

"Acid rain," Smoky Mountain Chapter, Trout Unlimited, Knoxville, Tennessee, September 1980.

"Ecological effects of acid rain," Briefing for the Assistant Secretary for Environment, U.S. Department of Energy, Washington, DC, April 1980.

Shugart, H. H.

"Overview of existing ecosystem models," Effects of Air Pollutants on Mediterranean and Temperate Forest Ecosystems: An International Symposium, University of California, Riverside, June 1980.

"Multivariate statistical methods for bird habitat studies," Workshop for Multivariate Methods in Wildlife Studies, University of Vermont, Burlington, April 1980.

"Succession models," Workshop on Applications of Mathematics to Environmental Problems, University of Tennessee, Knoxville, December 1979.

"Dynamic habitat simulation," University of Tennessee, Knoxville, October 1979.

"Succession modeling," Rutgers University, New Brunswick, New Jersey, November 1979.

"Models of forest dynamics," University of New Brunswick, Fredericton, New Brunswick, Canada, April 1980.

"Forest succession models," 2nd USSR-USA Biosphere Reserve Workshop, The Everglades, Florida, March 1980.

"Landscape modeling," US-French MAB SCOPE Symposium on Natural and Man-Altered Landscapes, Stanford University, Stanford, California, July 1980.

Sigal, L. L., and T. H. Nash, III.

"Lichens as ecological indicators of photochemical oxidant air pollution." International Symposium on Effects of Air Pollutants on Mediterranean and Temperate Forest Ecosystems, Riverside, California, June 1980.

Sigal, L. L.

"The effects of peroxyacetyl nitrate fumigations on lichens from southern California forest," Botany 80 Conference, Vancouver, British Columbia, July 1980.

Story, Jay D.

"Bobcat research at ORNL," Tennessee Chapter of The Wildlife Society and Tennessee Wildlife Resources Agency Research Review Meeting, Land Between the Lakes, Golden Pond, Kentucky, October 1980.

Stow, S. H., and J. F. Tull

"Geology and geochemistry of massive sulfides, Pyriton District, Clay County, Northern Alabama Piedmont," Geological Society of America Southeastern Section Annual Meeting, Birmingham, Alabama, March 1980.

Stow, S. H., with M. J. Neilson

"Mafic and ultramafic rocks from the Dadeville complex, Inner Piedmont of Alabama," Geological Society of America Southeastern Section Annual Meeting, Birmingham, Alabama, March 1980.

Strand, R. H.

"Research data management of the UMD gasifier facility - A status report," Gasifier-in-Industry Advisory Group, Washington, DC, October 1979 and June 1980.

"Historical aspects of the Environmental Sciences RJE computer facility," presented to C. R. Richmond, Oak Ridge National Laboratory, Oak Ridge, Tennessee, November 1979.

"Environmetrics of the UMD gasifier," UMD Gasifier Research Participants, Duluth, Minnesota, February 1980.

"Environmetrics of UMD gasifier," Advisory Group and Research Participants, Gasifier-in-Industry Advisory Group, Duluth, Minnesota, August 1980.

"Using graphics to recognize multidimensional patterns," American Statistical Association Meetings, Houston, Texas, August 1980

Suter, G. W. II.

"Protection of golden eagle, ferruginous hawk and prairie falcon nest sites," Annual Meeting, American Institute of Biological Sciences, Tucson, Arizona, August 1980.

"Field perturbation experiments, an alternate approach to the assessment of human effects on terrestrial ecosystems," Second U.S.-USSR Symposium on Biosphere Reserves, Everglades National Park, Florida, March 1980.

Tamura, T.

"Leaching studies of coal gasification solid waste to meet RCRA requirements for land disposal," Second DOE Environmental Control Symposium, March 1980.

"ORNL site-specific needs in low-level waste disposal," DOE ET Site Review Meeting, August 1980.

Taylor, Fred G., Jr.

"Cooling tower windage: A new aspect to environmental assessment," UCCND and Goodyear Atomic Waste Management Seminar, Shawnee State Park Lodge, Friendship, Ohio, April 1980.

"Use of pine foliage as an indicator of fluoride from UF_6 technologies, 13th National Air Pollution Workshop, Colorado State University, Fort Collins, May 1980.

Taylor, G. E., Jr.

"Physiology of plant differences in response to sulfur dioxide," Seminar, Corvallis Environmental Research Laboratory, Corvallis, Oregon, November 1980.

"Sulfur dioxide—leaf interactions: The bidirectional flux of sulfur gases," Botanical Society of America Annual Meeting, Vancouver, British Columbia, July 1980.

"Population differences in response to sulfur dioxide: A physiological analysis," Effects of Air Pollutants on Mediterranean and Temperate Forest Ecosystems: An International Symposium, Riverside, California, June 1980.

"Effective pollutant dose," 32nd Annual School of Agriculture "Effects of Gaseous Air Pollutants in Agriculture and Horticulture," Sutton, Bonington, United Kingdom, September 1980.

Tolbert, V. R., G. L. Vaughan, and D. M. Stair, Jr.

"Benthic insect communities as indicators of stream alterations resulting from coal strip-mining disturbance," Annual Meeting, American Institute of Biological Sciences, Tucson, Arizona, August 1980.

Trabalka, J. R.

"Russian experience," DOE Workshop on Environmental Decontamination, Oak Ridge, December 1979.

"Analysis of the 1957-58 Soviet nuclear accident," Electric Power Research Institute, Palo Alto, California, October, 1979; Department of Environmental and Industrial Health, The University of Michigan, Ann Arbor, Michigan, January 1980; Silver Anniversary Meeting, Health Physics Society, Seattle, Washington, July 1980; Annual Bluegrass Chapter Meeting, Health Physics Society, Slade, Kentucky, September 1980.

Trabalka, J. R., C. T. Garten, E. A. Bondietti, and R. G. Schreckhise

"Differential behavior of actinide elements in food chains," DOE Workshop on Measurements and Interpretation of Actinide Accumulation by Man, Snowbird, Utah, October 1979.

Trabalka, J. R., S. C. Tsai, J. S. Mattice, and M. B. Burch

"Effects of chlorinated organic compounds produced during control of fouling organisms," Third Conference on Water Chlorination: Environmental Impact and Health Effects, Colorado Springs, Colorado, October-November 1979.

Tsai, S. C.

"Partition coefficients of mercuric compounds and their toxicity and bioaccumulation in aquatic animals," Department of Agricultural Chemistry, National Taiwan University, Taipei, Taiwan, November 1979.

"Aquatic toxicology of mercuric compounds," Institute of Zoology, Academia Sinica, Taipei, Taiwan, November 1979.

Tsai, S. C., J. S. Mattice, and M. B. Burch

"Chlorine sensitivity of early life stages of common carp and threadfin shad," American Fisheries Society, 110th Annual Meeting, Louisville, Kentucky, September 1980.

Turner, R. R.

"Impact of urban land use on stream hydrology and water quality," ORAU Traveling Lecture Program, College of William and Mary, Williamsburg, Virginia, March 1980.

"Environmental effects of trace elements," University of Tennessee Biomedical School Seminar, Knoxville, May 1980.

Tyndall, R. L.

"Control of *Legionella pneumophila*, pathogenic amoeba and pathogenic fungi in cooling waters," Third Conference on Water Chlorination, Colorado Springs, Colorado, October–November 1979.

Tyndall, R. L., E. L. D. .ingue, C. B. Fliermans, and E. Willaert

"Isolation of encephalitis Acanthamoeba from thermally enriched water," Second International Conference on the Biology and Pathogenicity of Small Free-Living Amoebae, Gainesville, Florida, March 1980.

"Gasohol," ORNL Program Committee, Oak Ridge, March 1980.

"Effects of trace elements in the environment," Oak Ridge Biomedical Graduate School, Oak Ridge, May 1980.

"Woody biomass activities at ORNL," Southeastern Forest Experiment Station, Directors' Staff Meeting, Asheville, North Carolina, May 1980.

"Food and energy," ORNL Senior Planning Group, Oak Ridge, August 1980.

Van Hook, R. I., D. W. Johnson, and D. C. West

"Environmental impacts of harvesting forests for energy," Environmental Impacts Seminar, Bio-Energy '80, Atlanta, Georgia, April 1980.

W. Van Winkle

"Aquatic research at Oak Ridge National Laboratory," U.S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi, January 1980.

"Population-level assessments should be emphasized over community/ecosystem-level assessments," Fifth National Workshop on Entrainment and Impingement, San Francisco, California, May 1980.

"An analysis of the ability to detect reductions in year-class strength of the Hudson River white perch population," Annual Meeting, American Fisheries Society, Louisville, Kentucky, September 1980.

Vath, J. E.

"Feed conversion industry," Briefing for Uranium Enrichment Group of Australia, at Oak Ridge, June 1980.

Vaughan, D. S.

"Applications of the Leslie matrix to fish population dynamics," invited seminar, Workshop on Applications of Mathematics to Environmental Problems, University of Tennessee, Knoxville, December 1979.

"Introduction to module on age structure models in fishery science," 110th Annual Meeting, American Fisheries Society, Louisville, Kentucky, September 1980.

Vaughan, Nancy D.

"Data bases on environmental aspects of the nuclear fuel cycle," American Nuclear Society Winter Meeting, San Francisco, California, November 1979.

Voorhees, L. D.

"The environmental impact statement for nuclear power plants." Oak Ridge Associated University Training Institutes, Oak Ridge, Tennessee, April and June 1980.

"Ecological effects of the front end of the nuclear fuel cycle," Annual Meeting, American Institute of Biological Sciences, Tucson, Arizona, August 1980.

Walton, B. T., and M. V. Buchanan

"Teratogenic effects of fuel oils on insects developing in contaminated substrates," Second Chemical Congress of the North American Continent, Las Vegas, Nevada, August 1980.

Walton, B. T., E. F. Maggart, Jr., and E. G. O'Neill

"Penetration, metabolism and toxicity of acridine in *Acheta domesticus* (L.)," Entomological Society of America Annual Meeting, Denver, Colorado, November 1979.

Wright, L. L., and J. S. Mattice

"Models of *H. bilineata* growth in laboratory constant temperatures," Annual Meeting, American Institute of Biological Sciences Tucson, Arizona, August 1980.

Yeh, G. T.

"An integrated compartment method for the numerical solution of Navier—Stokes equations," Summer Computer Simulation Conference, Seattle, Washington, August 1980.

"A systematic approach assessment of alternative nuclear waste management strategies," International Symposium on Scientific Basis for Nuclear Waste Management, Boston, Massachusetts, November 1979.

"An interstitial water transport model in aquifer system by finite element method," International Conference on Water Resources Development, Taipei, Taiwan, May 1980.

Theses

Davis, E. C. 1980. A laboratory and field analysis of factors affecting quality of leachate from coal storage piles. Ph.D., Vanderbilt University, Nashville, Tennessee.

Schaich, B. A. 1979. A biotelemetry study of spring and summer habitat selection by striped bass in Cherokee Reservoir, Tennessee, 1978. M.S., University of Tennessee, Knoxville.

Sledz, J. 1980. Computer model for determining fracture porosity and permeability in the Conasauga Group, Oak Ridge National Laboratory, Tennessee. M.S., University of Tennessee, Knoxville.

Professional Activities

ADAMS, S. M.

Participant: Preparation of two proposals to Electric Power Research Institute, ORNL seed money proposal, and proposal to Department of Interior, Office of Water Research; Annual Meeting, American Institute of Biological Sciences, Tucson, Arizona, August 1980; Annual Meeting, American Fisheries Society, Louisville, Kentucky, September 1980; Union Carbide Management System course, ORNL, September 1980; Workshop on Microcosms, ORNL-EPA, Oak Ridge, Tennessee, February 1980.

Advisor: M. M. Huffman, Research Intern, University of the South, Sewanee, Tennessee.

Ad Hoc Reviewer: *Transactions of the American Fisheries Society, Journal of the Water Pollution Control Federation, Hydrobiologia, Estuaries*; proposals: NSF.

AUERBACH, S. I.

Member: Commission on Natural Resources for the National Research Council, National Academy of Sciences; State Advisory Council for the Water Resource Center, University of Tennessee, Knoxville, Tennessee.

Chairman: Admissions Committee, Oak Ridge Chapter, Sigma Xi.

BARNTHOUSE, L. W.

Chairman: Workshop on Mathematical Models Useful in Toxicity Assessment, Oak Ridge, Tennessee, January 8–9, 1980, sponsored by the Office of Toxic Substances, U.S. Environmental Protection Agency.

Participant: Workshop on Acid Rain and Fish Resources, Ann Arbor, Michigan, August 25–29, 1980.

Witness: Technical advisor and expert witness for the U.S. Environmental Protection Agency, Region II, in the Hudson River Power Case, represented EPA in technical meetings related to out-of-court settlement of the case, testified at hearings on September 16–18, 1980.

Ad hoc reviewer: Proposals: ORNL Seed Money Committee, EPRI.

BLASING, T. J.

Participant: Sixth Conference on Probability and Statistics in Atmospheric Sciences, American Meteorological Society, Banff, Alberta, Canada, October 1979; DOE Climate Workshop, Washington, D.C., April 1980; Massachusetts Institute of Technology Workshop on Climatic Risk, Washington, D.C., May 1980; Annual Meeting, American Institute of Biological Sciences, Tucson, Arizona, August 1980.

Ad hoc reviewer: Monthly Weather Review, Transactions of the American Society of Mechanical Engineers; proposals: NSF.

Other: Treasurer, East Tennessee Chapter of the American Meteorological Society, 1980.

BLAYLOCK, B. G.

Member: Research Committee, Water Pollution Control Federation; National Research Board of Canada, Panel on Radioactivity in the Aquatic Environment; Task Group 2 of Scientific Committee 64 of the National Council on Radiation Protection and Measurements.

Faculty: Adjunct Professor, University of Tennessee, Knoxville.

Consultant: Committee on Federal Research on Biological and Health Effects of Ionizing Radiation (FREIR), National Research Council.

Ad hoc reviewer: *Radiation Research*.

BOEGLY, W. J., Jr.

Member: Committee on Utilities (A1A03), Transportation Research Board, National Academy of Sciences, National Academy of Engineering; Committee on Dual Distribution Systems, American Water Works Association; Working Commission W-62 (NAS/NRC) on Water Supply and Drainage in Buildings; Program Committee, ORNL Conference on the Leachability of Radioactive Solids.

Faculty: Associate Professor of Civil Engineering (Environmental Engineering), University of Tennessee, Knoxville.

Advisor: Jeffrey E. Christian, M.S.C.E., University of Tennessee, Knoxville; Thomas Carson, M.S.C.E., University of Tennessee, Knoxville; Lawrence Roberts, Ph.D., University of Tennessee, Knoxville; Edward C. Davis, Ph.D., Vanderbilt University, Nashville, Tennessee.

Ad hoc reviewer: Proposals: EPRI, DOE.

Other: Energy Conservation Coordinator, Environmental Sciences Division.

BRADBURN, D. M.

Chairman: Tennessee Tree Farm Association, District II.

Member: Society of American Foresters; American Forestry Association; Tennessee Forestry Association.

Participant: IMGRID Workshop, Norris, Tennessee, December 5, 1979.

Ad hoc reviewer: Manual for Christmas Tree Growers in Tennessee, Prepublication Limited Edition; Savannah River Forest Management Program, November 1979.

BROWMAN, M. G.

Participant: Gordon Conference on Water: Predicting the Concentrations of Organic Compounds in Natural Waters, New Hampton, New Hampshire, June 15–20, 1980.

BROWN, D. K.

Chairman: Co-chairman, Environmental Sciences Division 1980 United Way Campaign.

Participant: Sixth Annual Research Symposium, Treatment and Disposal of Hazardous Waste, Chicago, Illinois, March 1980.

BURGESS, R. L.

Chairman:	Program Committee, Ecological Society of America.
Member:	Editorial Board, Arid Lands Abstracts; Board of Directors, Tennessee Chapter of The Nature Conservancy; Committee on Ethics and Professionalism, Ecological Society of America; Committee on Historical Records, Ecological Society of America; Subcommittee on Environmental Quality, Tennessee-Tombigbee Corridor Study, Corps of Engineers; Program Committee, American Institute of Biological Sciences.
Participant:	Meeting, AIBS Program Committee, University of Arizona, Tucson, December 1979; *Meetings, Board of Directors, Tennessee Chapter of the Nature Conservancy:* Chattanooga, November 1979, Nashville, April 1980, Knoxville, August 1980; AIBS Meeting, Tucson, Arizona, August 1980.
Faculty:	Adjunct Professor, University of Tennessee, Knoxville.
Other:	Education Program Coordinator, Environmental Sciences Division.

CADA, G. F.

Participant:	Workshop on Reservoir Ecology, Oak Ridge, Tennessee, October 1979; Fourth Annual Larval Fish Workshop, Oxford, Mississippi, February 1980; Fifth National Workshop on Entrainment and Impingement, San Francisco, California, May 1980; 43nd Annual Meeting of the American Society of Limnology and Oceanography, Knoxville, Tennessee, June 1980. Preparation of AID Project Paper for small hydro development in Peru.
Advisor:	Secondary advisor to Nancy Daley, M.S., Tennessee Technological University, Cookeville.
Consultant:	Agency for International Development and National Rural Electric Cooperative Association, Washington, D.C.
Witness:	Expert witness on behalf of U.S. Environmental Protection Agency (Region II) in the Hudson River Power Plant case.

CHRISTENSEN, S. W.

Participant:	Workshop on Comparative Reservoir Research, Oak Ridge Associated Universities, October 9–10, 1979; Workshop on the Feasibility of Basing Regulatory Actions on the Achievement of Mitigation Criteria, Oak Ridge National Laboratory, October 23–24, 1979; Hudson River Power Case.
Witness:	Hudson River Power Case: Expert Witness, Exhibit EPA-200, September 16–18, 1980.
Ad hoc reviewer:	*American Naturalist.* Ecological Analysts, Inc. U.S. Fish and Wildlife Service. U.S. Environmental Protection Agency (Region II).

COUTANT, C. C.

Chairman:	National Advisory Council of the Electric Power Research Institute.
Member:	Editorial Advisory Board for Environmental Science and Technology. Program committees of the American Fisheries Society and the Fifth National Entrainment and Impingement Conference. ORNL General Energy Conservation Committee. ORNL Wigner Fellowship Selection Committee.

Participant: Reservoir Workshop, ORNL Aquatic Ecology Section, October 9–10, 1979; Workshop on Effects of Chemicals on Aquatic Population Interactions, Oak Ridge, Tennessee, March 18–19, 1980; Marine Recreational Fisheries Symposium V: Striped Bass, Boston, Massachusetts, March 27–28, 1980; Fifth Entrainment and Impingement Conference, San Francisco, California, May 4–7, 1980, (Session Chairman); American Society for Limnology and Oceanography, June Meeting, Knoxville, Tennessee, June 16–17, 1980 (Session Chairman); Environmental Effects of Photovoltaic Energy Development, Brookhaven National Laboratory, June 18–20, 1980; Energy, Ethics, and Governance, EPRI Summer Seminar, Aspen, Colorado, August 11–15, 1980 (Session Chairman); Cherokee Interagency Task Force, Knoxville, Tennessee, August 19–20, 1980; Workshop on Hydroelectric Development: Ecological Issues at the River Basin Level, Oak Ridge, Tennessee, September 15–17, 1980; American Fisheries Society, Annual Meeting, Louisville, Kentucky, September 22–24, 1980 (Session Moderator).

Faculty: Adjunct Associate Professor, University of Tennessee, Knoxville, and Adjunct Professor at Tennessee Technological University, Cookeville.

Advisor: Research advisor for B. A. Schaich, M.S., University of Tennessee, Knoxville; Research advisor for T. E. Cheek, M.S., Tennessee Technological University, Cookeville; Graduate committee member for M. Tisa and J. W. Minton, M.S. University of Tennessee, Knoxville, and M. Bruner, Ph.D., University of Tennessee, Knoxville; Research advisor for K. Zachmann and B. Pearman, undergraduate research participants.

Ad hoc reviewer: Proposals: NSF, Maryland Power Plant Siting Program, and EPRI. *Canadian Journal of Fisheries and Aquatic Sciences, Transactions of the American Fisheries Society, Environmental Science and Technology*, and Symposium on Water Chlorination.

Other: Editor, Underwater Telemetry Newsletter. Secretary-Treasurer, East Tennessee Chapter of the American Fisheries Society. Southeast regional lecturer for the Society of the Sigma Xi.

CRAIG, R. B.

Member: Technical Program Committee, American Nuclear Society, Power Division; Program Committee, Ecological Society of America; Buell Award Committee, Ecological Society of America; Technical Committee, Alternative Fuels Source Evaluation Board.

Participant: ANS Topical Meeting on Technical Assessment of Nuclear Power and Its Alternatives, Los Angeles, California, February 27–29, 1980; ICEUM Meeting on Changing Energy Use Futures, Los Angeles, California, October 1979; Annual Meeting, American Institute of Biological Sciences, Tucson, Arizona, August 1980; Earthday 1980, University of Tennessee, Knoxville, Tennessee, April 22, 1980; Working Group, Oak Ridge National Energy Perspective.

Other: Recruiter, University of California, Berkeley, November 1979; Associate Editor, NEPA Theory and Practical Application Section, Environmental Impact Assessment Review.

Chairman: Small Mammal Ecology Session, Annual Meeting, American Institute of Biological Sciences, Tucson, Arizona, August 1980.

CUSHMAN, J. H.

Member: ORNL Ad Hoc Committee on Energy and Water; State Reclamation Committee, Tennessee Rural Abandoned Mine Program, Soil Conservation Service, USDA.

Participant: Ecology Task Force, Office of Environmental Assessment, Department of Energy; Bioenergy '80 World Congress and Exposition, Atlanta, Georgia, April 1980; Workshop facilitator, 1980 Solar Update–Tennessee, Knoxville, Tennessee, May 1980; Southern Forest Biomass Working Group, Raleigh, North Carolina, May 1980; Preparation of Technology Assessment of Solar Energy Summary Volume, Technology Assessment Division, Department of Energy.

Advisor: Douglas A. Crandall, M.S., Miami University, Miami, Ohio.

CUSHMAN, ROBERT M.

Participant: Preparation of: Solvent Refined Coal-II; Demonstration Project DEIS, SRC-I; Demonstration Project PDEIS, Conoco; Demonstration Project PDEIS, ICGG; Demonstration Project PDEIS, W. R. Grace; Demonstration Project PDEIS, MLGW; Demonstration Project PDEIS; Second International Conference on Energy Use Management, Los Angeles, California, October 1979; Annual Meeting, American Institute of Biological Sciences, Tucson, Arizona, August 1980.

Advisor: Michael I. McKamey, ORAU Student Research Participant, University of Tennessee, Knoxville.

CUTSHALL, N. H.

Ad hoc reviewer: *Estuaries*, Ecological Stress and the New York Bight: Science and Management (Symposium Proceedings), *Science*, *Deep Sea Research*; proposals: NSF, DOE, Sea Grant College Program, National Oceanic and Atmospheric Administration.

Participant: Water Pollution Control Federation Annual Conference, Houston, Texas, October 1979. American Society of Civil Engineers Environmental Engineering Division Specialty Conference, New York, New York, July 1980.

DeANGELIS, DONALD L.

Faculty: Adjunct Professor, Department of Mathematics, University of Tennessee.

Advisor: Margaret E. Cochran, M.S., University of Tennessee. (Ms. Cochran was awarded prize for best contributed paper by a student by the Society for Industrial and Applied Mathematics, Annual Southeastern Section Meeting, Birmingham, Alabama, for a presentation based on this work.) Martha A Turner, Indiana University; Master's Student Intern at ORNL.

Ad hoc reviewer: *Science*, *American Naturalist*, *Mathematical Biosciences*, *Journal of Mathematical Biology*, *Journal of Theoretical Biology*.

DELCOURT, HAZEL R.

Participant: 1980 Geobotany Conference, Bowling Green State University, Bowling Green, Ohio, March 1, 1980.

Ad hoc reviewer: *Journal of Biogeography*, *Ecology*, and *Ecological Monographs*; proposals: NSF.

Other: Secretary, Paleoecology Section, Ecological Society of America, 1978–1980; Vice-Chairperson, Paleoecology Section, Ecological Society of America, 1980–1981; Co-organizer for the United States Participation in the International Geological Correlation Programme (IGCP) Project 158, Subproject B (Paleohydrological changes in the temperate zone in the last 15,000 years; lake and mire environments), 1980–present.

EDDLEMON, G. K.

Participant: Workshop on Comparative Reservoir Research, Oak Ridge, Tennessee, October 1979; Public Scoping Meeting for Mount Taylor Uranium Mill Project, Grants, New Mexico, October 1979; Annual Meeting, American Society of Limnology and Oceanography, Knoxville, Tennessee, June 1980; preparation of: Draft Environmental Assessment for Dow Parcperdue Geopressure Project, 1980; Draft Environmental Report Guidelines for Department of Energy Projects, 1980; Environmental and Health Program for Pike County Coal Gasification Facility, 1980; Draft Environmental Guidance for Proposals on Oil Shale Projects, 1980; Draft Environmental Readiness Document for indirect Coal Liquefaction, 1980.

EDWARDS, NELSON T.

Participant: Workshop on Methods for Measuring Effects of Chemicals on Terrestrial Ecosystem Properties, ORNL, Oak Ridge, Tennessee, January 1980; Whole Tree Harvest Workshop, University of Florida, Gainesville, Florida, January 1980.

Ad hoc reviewer: *Journal of Environmental Quality*; proposal: NSF.

ELWOOD, J. W.

Member: Program Committee of the Ecological Society of America Review team, Electric Power Research Institute Project, Lawler, Matusky and Skelley Engineers, Pearl River, NY, March 1980

Participant: Workshop on Methods for Measuring Effects of Chemicals on Aquatic Ecosystem Properties, Oak Ridge, Tennessee, February 1980. Session chairman, American Society of Limnology and Oceanography, Knoxville, Tennessee, June 1980.

Faculty: Adjunct Assistant Professor, Graduate Program in Ecology, University of Tennessee.

Advisor: Martin Silver, M.S., University of Tennessee, Knoxville; Robert W. Stark, M.S., University of Tennessee, Knoxville; Carole Hom, M.S., University of Tennessee, Knoxville; Linda Neff, B.S., Carrol College, Helena, Montana.

Ad hoc reviewer: Proposals: NSF, EPRI, *Canadian Journal of Fisheries and Aquatic Science*.

EMANUEL, W. R.

Participant: DOE Research Conference on CO_2 and Climate, Washington, D.C., April 1980.

Advisor: Eric Kostilich, B.S., University of North Carolina, Raleigh.

Ad hoc reviewer: Proposals: NSF, EPA, DOE.

FARRELL, M. P.

Chairman: Managing Data for Energy and Environmental Research Session, American Statistical Association.

Participant: Fifth Annual SAS Users Group Internatonal Conference, San Antonio, Texas, February 1980; American Institute of Biological Sciences Annual Meeting, Tucson, Arizona, August 1980; American Statistical Association Annual Meetings, Houston, Texas, August 1980; American Society of Quality Control Meetings, Tulsa, Oklahoma, October 1980; DOE Statistical Symposium, Berkeley, California, October 1980.

Faculty: Adjunct Professor of Zoology, Miami University, Oxford, Ohio.

Advisor: H. N. Polovino, M.S., Miami University, Oxford, Ohio; J. C. Waternouse, Ph.D., University of Tennessee, Knoxville.

FITTS, R. B.

Member: DOE Shallow Land Burial Steering Committee (Secretary), DOE Waste Management Facilities Operator Working Group (Secretary).

Participant: DOE National Low-Level Waste Management Program (NLLWMP), Strategy Task Force Meeting, San Francisco, California, December 1979; National LLWMP Information Meeting, Las Vegas, Nevada, December 1979; DOE Waste Management Facilities Operator Working Group, Las Vegas, Nevada, January 1980; Waste Management '80, Tucson, Arizona, March 1980; presentation of the DOE NLLWM program plan to Nuclear Regulatory Commission staff, Silver Spring, Maryland, March 1980; NLLWM Program Plan Development Meeting, Des Moines, Iowa, June 1980; American Nuclear Society, Las Vegas, Nevada, June 1980, (Session Chairman); preparation of Technology Development Plan for the DOE NLLWMP.

Ad Hoc Reviewer: Proposals: DOE NLLWMP from various DOE sites and commercial vendors.

FLORAN, R. J.

Participant: Attended workshop on Alternative Nuclear Waste Forms, Gatlinburg, Tennessee, May 1980.

FRANCIS, C. W.

Chairman: DOE-sponsored Workshop: Management of Solid Wastes from Energy Producing Technologies, Washington, D.C., June 30–July 2, 1980.

Participant: Task 4, Third Contractor Information Meeting, Waste Isolation Assessment Program, Seattle, Washington, October [illegible], 1979.

Ad Hoc Reviewer: *Journal of Environmental Quality*, *Soil Science Society of America Journal*, *Environmental Science and Technology*, *Health Physics*; proposals: NSF.

GARDNER, R. H.

Participant: EPA Workshop: Mathematical Models Useful in Toxicity Assessment, January 8–9, 1980.

Advisor: D. E. Weller, Ph.D., University of Tennessee, Knoxville.

Ad hoc reviewer: *Science*; proposal: NSF.

GARTEN, CHARLES T., JR.

Member: DOE Panel on Actinide Modeling.

Participant: Conference on Analytical Chemistry in Energy Technology, Gatlinburg, Tennessee, October 1979; Environmental Decontamination Workshop, ORNL, December 1979; Workshop on Environmental Chemistry of Transuranics, Savannah River Plant, South Carolina, April 1980; Beginner Mapper Course (M-330), ORNL, January 1980; Annual Health Physics Society Meeting, Seattle, Washington, July 1980.

Ad hoc reviewer: *Journal of Environmental Quality*, *Environmental and Experimental Botany*, *Ecology*.

Other: Section Editor, *Nuclear Safety*.

GEHRS, C. W.

Chairman: Session chairman, 43rd Annual Meeting of American Society of Limnology and Oceanography, June 1980; Task Force on Ecological Effects of Synthetic Fuels: Advisory Committee to Federal Interagency Committee on Health and Environmental Effects of Energy Technologies.

Faculty:	Adjunct Associate Professor: University of Tennessee, Knoxville; Adjunct Lecturer, University of Tennessee, Graduate Biomedical School.
Advisor:	John D. Cooney, Ph.D., University of Tennessee, Knoxville; S. O. Ullrich, Associate Advisor on the Graduate Research Committee, Ohio State University, Columbus, Ohio.

GIDDINGS, J. M.

Chairman:	ORNL Workshop on Assessment and Policy Requirements of Multispecies Toxicology Testing Procedures, Oak Ridge, Tennessee, November 1979; ORNL Workshop on Methods for Measuring Effects of Chemicals on Aquatic Ecosystem Properties, Oak Ridge, Tennessee, February 1980; ORNL Workshop on Methods for Measuring Effects of Chemicals on Aquatic Population Interactions, Oak Ridge, Tennessee, March 1980.
Participant:	Third International Symposium on Aquatic Pollutants, Jekyll Island, Georgia, October 1979; Symposium on Process Measurements for Environmental Assessment, Atlanta, Georgia, February 1980; American Society of Limnology and Oceanography Annual Meeting, Knoxville, Tennessee, June 1980 (session chairman); Symposium on Health Effects Investigation of Oil Shale Development, Gatlinburg, Tennessee, June 1980; Symposium on Environmental Aspects of Fuel Conversion Technology, St. Louis, Missouri, September 1980.
Advisor:	Michele Ricard, M.S., University of Tennessee, Knoxville; Mary Ashley, B.S., Kenyon College, Gambier, Ohio.
Ad hoc reviewer:	*Environmental and Experimental Botany*, Savannah River Ecology Laboratory, Environmental Protection Agency; proposals: NSF, EPRI, NOAA.
Other:	Ph.D. recruiter, Cornell University.

GOUGH, S. B.

Member:	Seminar Committee, Environmental Sciences Division; founding member of the International Association of Crenobiologists.
Chairman:	Session chairman, Annual Meeting, American Society of Limnology and Oceanography, Knoxville, Tennessee, June 1980.
Participant:	Bio-Energy '80, International Conference, Atlanta, Georgia, April 1980; Conference on Research in the National Parks of the Southeastern Region, Gatlinburg, Tennessee, September 1980; preparation of: Fusion Energy Programmatic Workplan for the Magnetic Fusion Energy Environmental Project; Oak Ridge Gaseous Diffusion Plant DES and DEA; the Aquifer Thermal Energy Storage EIA; Monitoring Guidelines for DOE Facilities; PDEIS for the Alabama Nuclear Fuel Fabrication Plant.
Advisor:	A. Sasson, Masters of Environmental Science, Miami University, Oxford, Ohio.
Consultant:	ORNL environmental control officers and the Chemical Technology Division regarding sewage oxidation pond upgrading.
Ad Hoc Reviewer:	Proposals: NSF, EPRI, ORNL Seed Money Community; *Journal of Applied and Environmental Microbiology*, *Botanical Gazette*, *Limnology and Oceanography*.
Other:	Ph.D. recruiter, University of Minnesota and University of Wisconsin.

HAASE, C. S.

Participant: Annual Meeting of the Geological Society of America, San Diego, California November 1979; Annual Spring Meeting of the American Geophysical Union, Toronto, Ontario, Canada, May 1980.

Ad hoc reviewer: *Journal of Geology*.

HARRIS, W. FRANKLIN

Faculty: Adjunct Assistant Professor, University of Tennessee, Knoxville.

Advisor: Laboratory Advisor for P. D. Parr and D. A. Weinstein (temporary), Graduate Program in Ecology, University of Tennessee.

Ad hoc reviewer: *Science, Ecology, Canadian Journal of Forest Research; Journal of Experimental and Environmental Botany*; proposals: Smithsonian Institution, NSF; DOE (Office of Health and Environmental Research).

HERBES, S. E.

Participant: DOE Workshop on Research Needs for Synthetic Fuels: Water Quality, Quantity, and Aquatic Ecology, Oak Ridge, Tennessee, May 1980.

Advisor: Timothy A. Whitley (Summer Research Internship Program), Ph.D. (Chemistry), University of Tennessee, Knoxville.

Ad hoc reviewer: *Archives of Environmental Contamination and Toxicology; Applied and Environmental Microbiology*.

Other: Undergraduate Student Coordinator for ESD.

HILDEBRAND, S. G.

Chairman: Environmental Workshops at Waterpower 79, An International Symposium on the Potential for Small Scale Hydropower, Washington, D.C., October 1979; DOE TVA EPRI Workshop: Hydroelectric Development: Ecological Issues at the River Basin Level, Oak Ridge, Tennessee, September 1980; Session 25, Freshwater and Marine Pollution, Annual Meeting of the American Society of Limnology and Oceanography, Knoxville, Tennessee, June 1980.

Member: ORNL Ad Hoc Committee on Energy and Water.

Ad hoc reviewer: Proposals: NSF.

Other: Ph.D. recruiter, The University of Michigan, fall, 1979.

HUFF, D. D.

Member: ORNL Geosciences Committee; ORNL Committee on Water and Energy; Associate Board of Editors, Water Resources Monographs, American Geophysical Union.

Participant: DOE Workshop on Hydroelectric Development.

Faculty: Adjunct Associate Professor, University of Tennessee, Knoxville.

Advisor: James J. Sledz, M.S., University of Tennessee, Knoxville.

Ad hoc reviewer: *Water Resources Research; Transactions of the American Society of Agricultural Engineers*; proposals: NSF.

JOHNSON, DALE W.

Participant:	TIE Workshop on Acid Rain Effects on Soils, Indianapolis, Indiana, February 21–22, 1980.
Ad hoc reviewer:	*Science; Soil Science Society of America Journal; Journal of Environmental Quality; Ecological Monographs; Water Resources Research;* EPA Corvallis Lab (Report); *Pedobiologia;* proposals: NSF, Central Institute for Industrial Research, Royal Norwegian Council for Scientific and Industrial Research; papers from final report of SNSF-pr ·iect.

KANCIRUK, PAUL

Member:	Environmental technical advisor, DOE's Source Evaluation Board for Alternative Fuels Proposal, 1980.
Participant:	Bio-Energy '80 Conference, Atlanta, Georgia, April 1980; Earthday 1980, University of Tennessee, Knoxville, April 1980; Oceanic Law and the Environment, short course, Cornell and University of New Hampshire, Isle of Shoals Marine Laboratory, July 1980; preparation of: Draft Environmental Guidance for Preparing Major Acquisition Project Proposals Solicited by DOE; Draft Environmental Guidelines for Department of Energy Projects; Draft Technology-Specific DOE Guidance for Oil Shale Proposals; expert witness testimony for the Nuclear Regulatory Commission on the aquatic impacts of marine biomass as a substitute energy source for the Allens Creek Nuclear Generating Station, Texas, September 1980; PDEIS, Virgil Summer Nuclear Generating Station.
Witness:	Expert witness, testimony for the Nuclear Regulatory Commission on the aquatic impacts of the Virgil Summer Nuclear Generating Plant in South Carolina, 1979.
Ad Hoc Reviewer:	National Marine Fisheries Service, *Fisheries Bulletin;* proposals: NSF.
Other:	Invited scientist on oceanographic cruise, *R/V Islin* (Miami University), October 1979.

KIRK, B. L.

Participant:	Time Series, ORNL In-House Course, April 10–June 26, 1980; Conference on Matrix Computations and Optimization in Energy Activities, U.T. Math Department and DOE, October 16, 1979; Conference on Time Series Analysis, U.T. Math Department and DOE, October 9, 1979; MAX IV Batch Users' Course: Introduction to the MOPCOMP CLASSIC IV, ESD for Computer Support Group, October 22–26, 1979; Computer Methods for Math Computations, ORNL In-House Course, September 10–December 3, 1979; Statistical Analysis System (SAS) Course, ESD for Computer Support Group, January 22–23, 1980.

KITCHINGS, J. THOMAS

Participant:	Bobcat Research Conference, Front Royal, Virginia, October 1979; Association of Southeastern Biologist 41st Annual Meeting, Tampa, Florida, March 1980; Conference on Use of Multivariate Statistics in Analyzing Wildlife Habitat, Burlington, Vermont, April 1980; Workshop on Use of IMGRID in Data Storage and Handling, TVA, Norris, Tennessee, December 1979; Workshop on Long-Term Ecological Research in the Southern Appalachian Region, University of Tennessee, Knoxville, January 1980.
Advisor:	Douglas Levy, B.S., Earlham College, Richmond, Indiana; Amy Kretchman, B.S., Emory University, Atlanta, Georgia; William Galbraith, B.S., University of Wisconsin-Stevens Point.

KLOPATEK, J. M.

Chairman: Planning committee member and topical coordinator for Ecology and Environment, Second International Conference on Energy Use Management, Los Angeles, California, October 22–26, 1979.

Participant: Second Life Sciences Symposium, Potential Environmental and Health Consequences of Atmospheric Sulfur Deposition, Gatlinburg, Tennessee, October 14–18, 1979; American Institute of Biological Sciences–Ecological Society of America Annual Meetings, Tucson, Arizona, August 3–8, 1980.

Advisor: R. J. Wilk, B.S., University of Wisconsin-Stevens Point; D. A. Weinstein, Ph.D., University of Tennessee, Knoxville; R. D. Roop, Ph.D., University of Tennessee, Knoxville.

Ad hoc reviewer: *Environment International, Environmental Conservation;* U.S. Fish and Wildlife Service, U.S. Forest Service.

KROODSMA, R. L.

Participant: Preparation of: PDEIS, Memphis Light, Gas and Water Division, Industrial Fuel Gas Demonstration Plant Program; PDEIS, W. R. Grace and Company Synthesis Gas Demonstration Plant; DEIS, Solvent Refined Coal—II Demonstration Project; PDEIS, SRC-I Solvent Refined Coal Demonstration Plant; PDEIS, The Illinois Coal Gasification Group Pipeline Gas Demonstration Plant; PDEIS, Conoco Coal Development Company Pipeline Gas Demonstration; Plant Technology Assessment of Production of Low Btu Gas from Coal for Industrial Use; Environmental Report Guidelines for Department of Energy Projects.

KRUMMEL, J. R.

Participant: Discussion leader on issues of the loss of farmland in the Northeast, sponsored by New Jersey Conservation Foundation, Princeton, New Jersey, May 1980.

Consultant: National Resource Council, National Academy of Sciences, Washington, D.C.

Other: Secretary/Treasurer for the Society for Human Ecology.

LEE, S. Y.

Participant: Waste Rock Interaction Technology Information Meeting, Seattle, Washington, October 1979.

Ad hoc reviewer: *Journal of Environmental Quality, Nuclear Safety.*

LINDBERG, S. E.

Chairman: Sessions on Atmospheric Chemistry and Deposition, Second ORNL Life Sciences Symposium on Potential Environmental and Health Consequences of Atmospheric Sulfur Deposition, Gatlinburg, Tennessee, October 1979.

Member: Committee on Data Analysis and Interpretation, National Atmospheric Deposition Program.

Participant: EPA Workshop on Dry Deposition Methodology, Argonne, Illinois, December 1980; Session on data acquisition needs in vegetation–air pollution interaction studies, International Conference on Air Pollutants and Their Effects on the Terrestrial Ecosystem, Alberta, Canada, May 1980; Gordon Research Conference on Aerobiology, Meridan, New Hampshire, July 1980.

Ad hoc reviewer: *Geophysical Research Letters, Journal of Environmental Quality, Journal of Geophysical Research, Water, Soil, and Soil Pollution, Environmental and Experimental Botany;* Council on Environmental Quality report; proposals: NSF.

LUXMOORE, R. J.

Member:	S-124 Regional Technical Committee, Rural Abandoned Mines Program Committee for Morgan County, Tennessee.
Participant:	S-124 Regional Technical Committee Meeting, Lexington, Kentucky, April 1980; International Symposium, Effects of Air Pollutants on Mediterranean and Temperate Forest Ecosystems, University of California, Riverside, California, June 1980; Low-Level Waste Environmental Modeling Workshop, Bethesda, Maryland, July 1980.
Advisor:	Mary H. Ward, M.S., University of Tennessee, Knoxville; Lily Fong, M.S., and Henry R. Appelbaum, M.S., MIT School of Chemical Engineering Practice at ORNL, Oak Ridge; Paul A. Hausman, B.S., Wilkes College, Wilkes-Barre, Pennsylvania.
Consultant:	Highlander Research and Education Center, New Market, Tennessee.
Ad hoc reviewer:	USDA-SEA; *Agronomy Journal; Forest Science; Soil Science Society of America Journal;* proposals: NSF.

MANN, L. K.

Chairman:	Co-chairperson: Roane County Board of Supervisors, Soil Conservation Service.

MATTICE, J. S.

Member:	Program Committee, Third Conference on Water Chlorination, Colorado Springs, Colorado, October 28–November 2, 1979. Program Committee, Comparative Reservoir Research Workshop, Oak Ridge, Tennessee, October 9–10, 1979. Project Review Teams (2), Electric Power Research Institute.
Participant:	Session Chairman, Third Conference on Water Chlorination, Colorado Springs, Colorado, October 28–November 2, 1979; Session Chairman, Annual Meeting of American Society of Limnology and Oceanography, Knoxville, Tennessee, June 16–19, 1980; Discussion Leader, Comparative Reservoir Research Workshop, Oak Ridge, Tennessee, October 9–10, 1979; Course on Environmental Toxicology Data Interpretation, University of Tennessee, Knoxville, Spring, 1980.
FACULTY:	Adjunct Assistant Professor, Tennessee Technological University, Cookeville, Tennessee.
Advisor:	Nancy Dailey, M.S., Tennessee Technological University, Cookeville; Donna Buffum, B.S., GLCA/ACM Science Semester, Denison University, Granville, Ohio.
Ad hoc reviewer:	*Canadian Journal of Fisheries and Aquatic Sciences, Water Research;* proposals: EPRI.
Other:	Briefing for John Galloway, Staff Director, Subcommittee on Environment, Energy, and Natural Resources Committee on Government Operations, U.S. House of Representatives, on "Potential for increase in production and impacts of chlorinated organics due to impoundment of the Duck River by Columbia Dam." June 26, 1980; Editor, *Corbicula* Newsletter; proposal: Interagency Agreement between ORNL, DOE, and EPA.

McBRAYER, J. F.

Member:	ORNL-Information Center Complex review team for establishing Basic Ordering Agreements; PL 96-126 proposal review team, U.S. Department of Energy; Buell Awards Judging, Ecological Society of America, Tucson, Arizona, August 1980.

Participant: Bio-Energy '80 Conference, Atlanta, Georgia, April 1980; Earthday 1980, University of Tennessee, Knoxville, April 1980; Aquifer Thermal Storage Programmatic Environmental Assessment, (Final); Biomass Energy Systems Programmatic Environmental Assessment, (Final); Defense Wastes Processing Facility Environmental Impact Statement (Draft).

Ad Hoc Reviewer: *American Midland Naturalist, Annals of the Entomological Society of America, Applied and Environmental Microbiology, Canadian Journal of Zoology, Ecology, Ecological Monographs, Pedobiologia;* proposals: DOE Biomass Energy Systems Division, ORNL Seed Money Committee, NSF Division of Policy Research and Analysis and NSF Ecosystem Studies Program.

McCONATHY, R. K.

Participant: Second Life Sciences Symposium on Potential Environmental and Health Consequences of Atmospheric Sulphur Deposition, Gatlinburg, Tennessee, October 14–18, 1979.

McLAUGHLIN, S. B.

Participant: Annual Air Pollution Workshop, Fort Collins, Colorado, May 7–9, 1980; Session Moderator for "Effects of Gaseous Pollutants on Terrestrial Vegetation," International Symposium on Air Pollutants and Their Effects on the Terrestrial Ecosystem, Banff, Alberta, Canada, May 10–16, 1980; Session Moderator for "Use of Simulation Models to Study Effects of Chronic Air Pollution Stress on Plant Processes and Plant Community Dynamics," International Symposium on Effects of Air Pollutants on Temperate and Mediterranean Forest Ecosystems, Riverside, California, September 17-22, 1980; 31st Meeting of AIBS, Tucson, Arizona, August 7–8, 1980; invited speaker, APCA Specialty Conference on the Air Quality Standard for Particulate Matter and Sulfur Dioxide, Atlanta, Georgia, September 16, 1980.

Ad hoc reviewer: *Science, Environmental and Experimental Botany;* proposals: EPRI.

Advisor: Roger Walker, Ph.D., University of Tennessee, Knoxville.

McLEAN, R. B.

Chairman: Session chairman, American Society of Limnology and Oceanography, June 16–19, Knoxville, Tennessee.

MILLEMANN, R. E.

Member: Graduate Student Selection Committee.

Faculty: Professor, University of Tennessee, Knoxville.

Advisor: Graduate Student Coordinator, Environmental Sciences Division; Chairman Graduate Student Selection Committee, Environmental Sciences Division; Michele Ricard, M.S., University of Tennessee, Knoxville; Sterling O. Ullrich, Jr., M.S., Ohio State University, Columbus.

Ad hoc reviewer: Proposals: NSF, EPRI.

MORAN, MARY S.

Member: ORNL Committee for the Establishment of Environmental Guidelines for Radioactive Waste Disposal.

Participant:	National Water Well Association Ground Water Technology Division, Education Session, Oklahoma City, Oklahoma, October 1979; preparation of FEIS, Geothermal Demonstration Program, 50-MWe Power Plant, Baca Location, Sandoval and Rio Arriba Counties, New Mexico, January 1980; Waste Management '80 Symposium, Tucson, Arizona, March 1980.
Ad hoc Reviewer:	Proposals: DOE.

MULHOLLAND, P. J.

Participant:	Preparation of draft environmental impact statement related to the operation of Bison Basin Project, Ogle Petroleum, Inc., June 1980; Draft Environmental Guidance For Peat Utilization Proposals, submitted to DOE, NEPA Affairs Division, April 1980. National Research Council Workshop on the Flux and Fate of Organic Carbon in the World's Rivers, Woods Hole, Massachusetts, September 22–24, 1980.
Ad Hoc Reviewer:	Proposals: DOE.

NEWBOLD, J. D.

Participant:	Workshop on Methods of Measuring Effects of Chemical on Aquatic Ecosystem Properties, Oak Ridge, Tennessee, February 1980; Session Chairman, American Society of Limnology and Oceanography, Knoxville, Tennessee, June 1980.
Ad hoc reviewer:	Proposals: NSF.

NUNGESSER, M. K.

Participant:	Fifth Annual SAS Users Group International Conference, San Antonio, Texas, February 1980; 1980 Annual Meeting, American Institute of Biological Sciences, Tucson, Arizona, August 1980.

OAKES, KATHLEEN M.

Participant:	Conference on Energy "Fast-Track" Legislation, Washington, D.C. March 1980; Technical assistance to the DOE Source Evaluation Board for the major Alternative Fuels Solicitation by reviewing proposals for alcohol fuels cooperative agreements; preparation of: Final Environmental Impact Statement for the Geothermal Demonstration Program 50-MWe Power Plant, Baca Ranch, Sandoval and Rio Arriba Counties, New Mexico, January 1980; Draft Environmental Impact Assessment for the Heber Geothermal Binary-Cycle Demonstration Project, Imperial County, California, July 1980; Environmental Guidance for Proposals on Tar Sands Development for DOE N.E.P.A. Affairs Division, June 1980; Environmental Effects of Natural Gas Production and of Geothermal Energy for the ORNL National Energy Perspectives.
Member:	ORNL Ad-Hoc Committee for Unconventional Natural Gas.
Advisor:	William Rusin, M.S., Miami University, Oxford, Ohio.
Other:	Coordinator for the ORNL Colloquia Series for 1980.

OLSEN, CURTIS R.

Member:	Panel on Geophysics of Estuaries (National Academy of Sciences, National Research Council).
Participant:	NOAA Workshop on Sediment Transport on the Inner New Jersey Shelf, Gaithersburg, Maryland, March 1980; DOE Mid-Atlantic Bight Contractors' Meeting, Harper's Ferry, West Virginia, October 1980.
Other:	Proposals: NOAA, EPA, NRC.

OLSON, J. S.

Member:	National Academy of Sciences; Climate Research Board, Committee on International Programs on Climate; NSF coordination team at Duke University, Phytotron Program on Response of Plans and Ecosystems to Increased CO_2 Fertilization, March 3–5, 1980; National Academy of Sciences review team of Savannah River Plant and University of Georgia Savannah River Ecology Laboratory research programs.
Participant:	Workshop composing AAAS-DOE project workplan document on "Environmental and Societal Consequences of CO_2-induced Climate Change," Duke University, March 5–7, 1980.
Faculty:	Professor, University of Tennessee, Knoxville, Special course lecturer, J. F. McCormick's State Department short course for foreign environmental scientists, August 1980; briefed NIH team on Environmental Toxicology Program developing at University of Tennessee.
Advisor:	Richard Busing, M.S., University of Tennessee, Knoxville.
Ad hoc reviewer:	*Ecology.*

OLSON, RICHARD J.

Chairman:	Planning Committee, Integrated County-Level-Data User's Workshop.
Member:	DOE Ecological Task Force.
Participant:	AutoCarto IV, Reston, Virginia, November 4–8, 1979; Harvard Computer Graphics Week, Boston, Massachusetts, July 28–31, 1980; Multivariate Statistics in Studies of Wildlife Habitat, Burlington, Vermont, April 23–25, 1980.

O'NEILL, R. V.

Faculty:	Adjunct Associate Professor, University of Tennessee, Knoxville.
Ad hoc reviewer:	Proposals: NSF, EPA; *Ecology*, University of Chicago Press.
Other:	Associate Editor, *Ecology*.

PARR, PATRICIA D.

Participant:	EPA Vegetation Damage By Air Pollution Workshop, Minneapolis, Minnesota, December 1979.
Other:	Biology Division Judge for St. Mary's School Science Fair, Oak Ridge, Tennessee, May 1980.

POWERS, C. D.

Chairman:	Aquatic Ecology Section (ESD) Personnel Search Committee.
Member:	ORNL review team at DOE, Washington, D.C., for Alcohol Fuels Program proposal evaluation.
Participant:	Environmental Impact Statement Workshop, University of Wisconsin-Madison, June 16–20, 1980; Geothermal Resources Council Annual Meeting, Salt Lake City, Utah, September 9–11, 1980; preparation of: Federal-American Partners (Gas Hills District, Wyo.) DES; and Rorabaugh Lease Development Geothermal Loan Guaranty (Sonoma County, California) DEA.
Other:	Recruiter, ORNL Ph.D. recruiting visit to the University of Michigan, October 2–3, 1980.

RANNEY, J. W.

Chairman:	Woody Biomass Program Contractors' Workshop, Rhinelander, Wisconsin, September 1980; Woody Biomass Program Annual Technical Review, Atlanta, Georgia, March 1980.
Member:	Southern Forest Biomass Working Group, Raleigh, North Carolina, June 1980.
Participant:	Institute for International Education-Forest Energy, Atlanta, Georgia, April 24–30, 1980; University of Tennessee, Graduate Program in Ecology, guest lecturer on Ecological Principles in Forest Energy Development, Great Smoky Mountain National Park, Tennessee, July 21, 1980; Alabama A&M University, Summer Forest Practicum—Energy from Forests, June 1980.
Advisor:	John Schutt, Ph.D., University of Tennessee, Koxville.
Ad hoc reviewer:	Forest Products Research Society; Department of Energy's Division of Biomass Energy Systems; American Institute of Biological Sciences—Ecological Society of America Buell Award judge, Tucson, Arizona, August 4–6, 1980.

REED, R. M.

Participant:	Preparation of: Draft Environmental Guidance for Preparing Major Acquisition Project Proposals Solicited by DOE; Draft Environmental Guidelines for Department of Energy Projects; Draft Technology-Specific Guidance for Coal Liquefaction/Gasification Proposals.

REICHLE, D. E.

Chairman:	World's Fair Committee, Oak Ridge National Laboratory.
Member:	Associateship Selection Panel, National Academy of Sciences; Committee on Alternative Programs for Beltwide Cotton Insect Management, Board on Agriculture and Renewable Resources, National Academy of Sciences; Committee on Federal Research on Biological and Health Effects of Ionizing Radiation (FREIR), National Academy of Sciences/National Research Council radiation ecology program review, Colorado State University; Advisory Subcommittee for the Applied Physical, Mathematical and Biological Section of the Division of Applied Research, National Science Foundation; Committee on the Effects of Funding Changes upon the Rate of Growth of Scientific Knowledge, Division of Policy Research and Analysis, National Science Foundation; MAB Project 2 Directorate, U.S. Department of State; Admissions Committee, Graduate Program in Ecology, University of Tennessee.
Participant:	The Institute of Ecology (TIE) Tenth Annual Meeting, Indianapolis, Indiana, March–April 1980; The Institute of Ecology general review of Experimental Ecological Reserves (EER) Project and discussion panel "Present Programs and Future Needs," Washington, D.C., May 1980; ORNL Technical Seminar Series, 1979 and 1980.
Faculty:	Adjunct Professor, University of Tennessee, Knoxville.
Ad hoc reviewer:	*Science, Ecological Bulletin;* proposals: National Sea Grant College Program, National Oceanic and Atmospheric Administration.
Other:	Editorial Board, *Pedobiologia;* Consulting Environmental Editor, Springer-Verlag, Inc.

SALK, M. S.

Participant: Second Symposium on Environmental Concerns in Rights-of-Way Management, Ann Arbor, Michigan, October 16–18, 1979; coordinator for the preparation of background papers on the environmental impacts of conventional and unconventional energy technologies for the Oak Ridge National Energy Perspective steering group.

SHARPLES, F. E.

Member: Review team for DOE's Alternative Fuels Production Source Evaluation Board.

Participant: Geothermal Resources Council Management Survey Course, Geothermal Environmental Problems, Control Technology, and Mitigation Measures, San Francisco, California, February 1980; U.S. Environmental Protection Agency, Region IV, Environmental Impact Statement Conference, Atlanta, Georgia, June 1980; Preparation of final Supplementary Staff Testimony on Site Selection Alternatives for the Douglas Point Nuclear Power Plant; FEA Oregon Trail Mushrooms, Geothermal Loan Guaranty Application, Malheur County, Oregon, April 1980; DEA Biomass Energy Systems Program, April 1980; Draft, Environmental Guidance for Preparing Major Acquisition Project Proposals Solicited by DOE; Draft, Environmental Guidance for Proposals on Biomass Energy Systems; Draft, Environmental Report Guidelines.

Ad Hoc Reviewer: *American Naturalist.*

SHRINER, D. S.

Member: Technical Council, TE Agricultural Effects Committee, Air Pollution Control Association; Scientific Advisory Board, National Atmospheric Deposition Program; technical advisor: NAS/NRC Committee on Atmospheric and the Biosphere, Sulfur Oxides Subcommittee; Pollution Effects on Plants Committee, American Phytopathological Society.

Participant: International Symposium on Air Pollution Effects on Terrestrial Ecosystems, Banff, Alberta, Canada, May 1980; Annual Meeting, Air Pollution Control Association, Montreal, Quebec, Canada, June 1980 (Session Chairman).

Faculty: Adjunct Professor, Department of Plant Pathology and Physiology, Virginia Polytechnic Institute and State University, Blacksburg.

Advisor: Bowler Anderson, B.S., Emory University, Atlanta, Georgia; Matthew Mahoney, Ph.D., VPISU, Blacksburg, Virginia.

Ad hoc reviewer: *Science, Journal of the Air Pollution Control Association, Journal of Environmental Quality, Environmental and Experimental Botany;* EPA; proposals: NSF, DOE, USDOE, EPRI.

Other: Editor, Effects Division Environmental Report, Air Pollution Control Association.

SHUGART, H. H.

Chairman: Workshop on Forest Succession, Mountain Lake, Virginia, June 8–14, 1980.

Faculty: Part-time Associate Professor, Department of Botany and Graduate Program in Ecology, University of Tennessee, Knoxville, Tennessee.

Advisor: T. M. Smith, Ph.D., University of Tennessee, Knoxville; T. R. Doyle, Ph.D., University of Tennessee, Knoxville; D. A. Weinstein, Ph.D., University of Tennessee, Knoxville.

Ad hoc reviewer:	*Science, Ecology, American Naturalist.*
Other	Ad hoc editor: *Ecology/Ecological Monographs.*

SIGAL, L. L.

Participant:	Environmental Impact Statement Conference, Atlanta, Georgia, June 1980; International Symposium on Effects of Air Pollutants on Mediterranean and Temperate Forest Ecosystems, Riverside, California, June 1980; Botany '80 Conference, Vancouver, British Columbia, July 1980; EPA/EPRI Joint Symposium on Stationary Combustion NO_x Control, Denver, Colorado, October 1980; preparation of: Environmental Guidelines for Use of Municipal Solid Waste as an Alternative Fuel; Data Base Outline for Coal Combustion Solid Waste Disposal; Preliminary Draft of environmental statement for conversion of Arthur Kill power plant to coal firing.
Ad Hoc Reviewer:	*The Bryologist*

SOLOMON, ALLEN M.

Participant:	Geological Society of America Meeting, American Quaternary Association Council Meeting, San Diego, California, November 1–4, 1979 (ex-officio member); USDOE/NSF Workshop on Forest Succession (invited participant), Mountain Lake, Virginia, June 8–13, 1980; Fifth International Palynological Conference (invited participant), Cambridge, England, July 1–6, 1980; Ecological Society of America Meeting (M. F. Buell Award Committee Chairman), Tucson, Arizona, August 3–8, 1980; American Quaternary Association Meeting (poster presentation), Orono, Maine, August 18–21, 1980; Oak Ridge Associated Universities, Workshop on Nuclear Energy (instructor), June 23, 1980; preparation: Final Environmental Impact Statement, Bison Basin Uranium Mine, Sweetwater Station, Wyoming, USNRC Office of Nuclear Material Safety and Safeguards (DES, June 1980; FES pending); Final Environmental Impact Statement, Operating License, Virgil Summer Nuclear Plant, Columbia, South Carolina, USNRC, Office of Nuclear Reactor Regulation (DES, June 1979; FES pending); Final Environmental Impact Appraisal, Oak Ridge Gaseous Diffusion Plant, Oak Ridge, Tennessee, Department of Energy, NEPA Affairs Division (DEIA, August 1979; EIA pending).
Consultant:	University of Arizona, College of Medicine, Tucson, Arizona.
Ad hoc reviewer:	Proposals: NSF—Ecosystem Studies Program and Polar Studies Program (2).
Other:	Editor: American Quaternary Association Newsletter, 1979–; Chairman, M. F. Buell Award Committee, Ecological Society of America, 1978–1980; Secretary, Paleoecology Section, Ecological Society of America, 1980–1982.

SOUTHWORTH, G. R.

Participant.	Fifth Annual ASTM Symposium on Aquatic Toxicology, Philadelphia, Pennsylvania.
Advisor:	Lynelle Golden, B.S., Emory University, Atlanta, Georgia.
Ad hoc reviewer:	*Archives of Environmental Contamination and Toxicology.*

SPALDING, B. P.

Member:	USDA Technical Committee No. 59.
Participant:	USEPA Workshop on methods for measuring effects of chemicals on terrestrial ecosystem properties, Oak Ridge, Tennessee, January 1980.
Ad hoc reviewer:	*Soil Science Society of America Journal, Journal of Environmental Quality*; proposals: NSF.

STOW, S. H.

Faculty:	Part-time Full Professor, Department of Geological Sciences, The University of Tennessee, Knoxville.
Member:	International Geologic Correlation Program on Volcanic Rocks; ORNL Materials Recommendation Committee; ORNL Unconventional Gas Committee.
Participant:	National Geological Society of America Annual Meeting, San Diego, California, November 1979; Southeastern Geological Society of America Annual Meeting, March 1980; Annual Alabama Geological Society Field Trip (Co-Leader), November 1979.
Advisor:	L. Long, D. Whittington, R. McDonald, B. Hayes-Davis, J. Holmes, P. Hubbard, L. Bundschu, M. Steltenpohl, M.S., University of Alabama, Tuscaloosa.
Ad hoc reviewer:	Geological Society of America; *Science*.
Other:	Secretary-Treasurer, Southeastern Section, Geological Society of America.

STRAND, R. H.

Chairman:	Statistical Computing Section, American Statistical Association, Program Chairman-elect 1980; Program Chairman, Statistical Computing Section, American Statistical Association, 1980–1981.
Member:	Environmental Sciences Division, Computing Executive Committee, SAS Users Group International.
Participant:	Applied Regression and Modeling Course, Miami, Florida, January 1980; SAS Statistics Methods Course, Oak Ridge, Tennessee, July 1980; American Statistical Association, Session Chairman, Research Data Management, Statistical Computing Section, Houston, Texas, August 1980.
Advisor:	H. N. Polovino, M.S., Miami University, Oxford, Ohio; J. C. Waterhouse, Ph.D. University of Tennessee, Knoxville.

SUTER, G. W.

Chairman:	Workshop on Methods for Measuring Effects of Chemicals on Terrestrial Ecosystem Properties, Oak Ridge, Tennessee.
Participant:	Workshop on Methods for Measuring Effects of Chemicals on Terrestrial Ecosystem Properties, Oak Ridge, Tennessee; preparation of: Draft EIS, W. R. Grace and Co., Synthesis Gas Demonstration Plant; Draft EIS, Illinois Coal Gasification Group, Pipeline Gas Demonstration Plant; Draft EIS, Conoco Coal Development Co., Pipeline Gas Demonstration Plant; Draft EIS, Memphis Light Gas and Water Division, Industrial Gas Demonstration Plant; and Oak Ridge National Energy Plan.
Advisor:	Partricia Gregory, M.S., Miami University, Oxford, Ohio.
Ad Hoc Reviewer:	*Pedobiologia*

SWITEK, J.

Reviewer: (with others) Uranium Resource Evaluation Project Reports, "Hydrogeochemical and Stream Sediment Reconnaissance Basic Data," Union Carbide Corporation, Nuclear Division, Oak Ridge Gaseous Diffusion Plant (ORGDP), Oak Ridge, Tennessee; and U.S. Department of Energy, Grand Junction (GJ), Colorado: Beeville NTMS Quadrangle, Texas; Laredo NTMS Quadrangle, Texas; Hot Springs NTMS Quadrangle, South Dakota; Lemmon NTMS Quadrangle, South Dakota; Wichita Uplift Region, Oklahoma; Beaumont NTMS Quadrangle, Texas; Dickinson NTMS Quadrangle, North Dakota; Marquette NTMS Quadrangle, Michigan; Iron River NTMS Quadrangle, Michigan.

TAMURA, T.

Member: EPRI Solid Waste Advisory Committee; UMTRAP/DOE Liners Task Group.

Participant: DOE/ET Workshop on Modeling Needs for Low-Level Radioactive Waste, Bethesda, Maryland, July 1980; DOE/EV Workshop on Nonnuclear Waste Disposal, Dulles Airport, Maryland, June 1980 (Session Chairman); IAEA Review of Shallow Land Burial Criteria, Vienna, Austria, December 1979.

Faculty: Adjunct Professor, Graduate Program in Geology, University of Tennessee, Knoxville.

Advisor: Donald V. Crider, M.S., University of Tennessee, Knoxville; Janine J. Sledz, M.S., University of Tennessee, Knoxville.

Witness: Expert witness for DOE (on soil plutonium contamination at Rocky Flats, Colorado), Denver, Colorado, 1978 and continuing.

Ad hoc reviewer: *Journal of Environmental Quality*; proposals: EPRI.

TAYLOR, F. G., JR.

Member: Board of Directors, Tennessee Native Plant Society, 1980.

Participant: Annual Meeting of the Cooling Tower Institute, Houston, Texas, January 1980; 13th National Air Pollution Workshop, Fort Collins, Colorado, May 1980; Union Carbide Corporation Nuclear Division and Goodyear Atomic Waste Management Seminar, Friendship, Ohio, April 1980; 32nd School of Agricultural Sciences, "Effects of Gaseous Air Pollution in Agriculture and Horticulture," Nottingham, England, September 1980.

Ad hoc reviewer: *Bulletin of the Torrey Botanical Club.*

Other: Recording Secretary, Tennessee Native Plants Society, 1980.

TAYLOR, G. E., JR.

Member: Steering Committee, Air Pollution Workshop

Participant: 12th Annual Air Pollution Workshop, Fort Collins, Colorado, May 1980 (session chairman); 'Botany 80'--Botanical Society of America annual meeting, Vancouver, British Columbia, July 1980; 32nd Annual School of Agriculture entitled "Effects of Gaseous Air Pollutants in Agriculture and Horticulture," Sutton Bonington, United Kingdom, September 1980.

Faculty:	Adjunct Assistant Professor, Oregon State University, Corvallis, Oregon.
Advisor:	Eloise B. Carter, Ph.D., Emory University, Atlanta, Georgia.
Consultant:	USEPA, Criteria Assessment Office, Research Triangle Park, North Carolina.
Ad hoc reviewer:	*Bulletin of the Torrey Botanical Club;* Ecological Research Series Publications, USEPA; proposals: USEPA.
Other:	Editor: Physiological Section Newsletter, Botanical Society of America.

TOLBERT, V. R.

Chairman:	Committee to develop handbook of personnel and strip-mining research capabilities within Tennessee.
Member:	Rural Abandoned Mines Program (RAMP) state implementation committee.
Participant:	Tennessee Surface Mining Aquatic Research Needs, Tennessee Wildlife Resources Agency, Crossville, Tennessee, December 1979; Symposium on Surface Mining Hydrology, Sedimentology, and Reclamation, Lexington, Kentucky, December 1979; Geothermal Resources Council Workshop, San Francisco, California, February 1980; North American Benthological Society, Savannah, Georgia, March 1980; Annual Meeting, American Institution of Biological Sciences, Tucson, Arizona, August 1980; technical assistance to DOE Source Evaluation Board for review of proposals in response to Alcohol Fuels program solicitations, Washington, D.C., May 1980; Judge, annual Murray F. Buell Award, Ecological Society of America, Tucson, Arizona, August 1980; preparation of: Draft Environmental Assessment for Heber 45-MWe binary demonstration project; Environmental guidance for sources of aquatic biota and water quality information for response to Major Acquisition Project solicitations by DOE Division of NEPA Affairs, February 1980; Aquatic habitat alteration selection for Environmental Report Guidelines for DOE Division of NEPA Affairs, July 1980.
Ad Hoc Reviewer:	Entomological Society of America.

TRABALKA, J. R.

Member:	ORNL Seed Money Proposal Review Committee; Environmental Sciences Division Hazardous Mterials Advisory and Seminar Committees.
Participant:	Workshop on Measurements and Interpretation of Actinide Accumulation by Man, Snowbird, Utah, October 1979; Environmental Decontamination Workshop, Oak Ridge, Tennessee, December 1979; Silver Anniversary Meeting, Health Physics Society, Seattle, Washington, July 1980; Annual Bluegrass Chapter Meeting, Health Physics Society, Slade, Kentucky, September 1980; Preparation of Scientific Projection Paper for NIH Subcommittee to Develop Federal Strategy for Research into the Biological Effects of Ionizing Radiation.
Ad hoc reviewer:	*Science.*

TSAI, S. C.

Participant:	Session Chairman, Fisheries Section (11/18/79), Agriculture Division, National Construction Seminar, Taipei, Taiwan, November 4–19, 1979; American Fisheries Society, 110th Annual Meeting, September 22–24, 1980, Louisville, Kentucky; Third Conference on Water Chlorination: Environmental Impact and Health Effects, October 28–November 2, 1979, Colorado Springs, Colorado; biostatistics course at ORAU and two courses of English pronunciation at The University of Tennessee.

Consultant:	Taiwan Fish Culture Station of the Taiwan Fisheries Research Institute, Taiwan, on the population manipulation of milkfish pond community with chemical and biological agents.

TURNER, R. R.

Member:	ESD Seminar Committee, ORNL Quality Assurance Audit Committee (for mass spectrometer).
Participant:	Second Life Sciences Symposium on Potential Environmental and Health Consequences of Atmospheric Sulfur Deposition, Gatlinburg, Tennessee, October 14–18, 1979; Meeting of DOE Contractors Conducting Coal Ash Research, Chicago, Illinois, November 9, 1979; Symposium on Urban Stormwater and Combined Sewer Overflow: Impact on Receiving Water Bodies, Orlando, Florida, November 26–28, 1979.
Reviewer:	*Water, Air, and Soil Pollution;* Chesapeake Bay Research Consortium; proposals: NSF, EPRI.

TYNDALL, R. L.

Participant:	Invited speaker for the Third Conference on Chlorination at Colorado Springs, Colorado, October 28–November 1, 1979; Pathogenicity of Small Free-Living Amoeba, Gainesville, Florida, March 23–25, 1980.
Faculty:	Research Associate Professor, Zoology Department, University of Tennessee, Knoxville, Tennessee.
Advisor:	Audrey Nicholson, Ph.D., and Lycurgus Muldrow, Ph.D., University of Tennessee, Knoxville.
Consultant:	Northern States Power, Minneapolis, Minnesota; Minnesota Power and Light Company, Duluth, Minnesota and Duke Power Company, Charlotte, North Carolina
Ad hoc reviewer:	*Science.*

VAN HOOK, ROBERT I.

Ad hoc reviewer:	Proposals: NSF.
Member:	ORNL Graduate Selection Panel; ORNL Technical Seminar Group.

VAN WINKLE, W.

Chairman:	Committee to Review Technician Performance Review Forms and Procedures, Environmental Sciences Division, Oak Ridge National Laboratory; In-House Comparative Reservoir Research Workshop, Oak Ridge Associated Universities, Oak Ridge, Tennessee, October 1979.
Member:	Program Committee for Fifth Entrainment and Impingement Workshop, sponsored by Ecological Analysts, Inc.
Participant:	Annual Research Coordination Meeting, Tennessee Valley Authority - U.S. Fish and Wildlife Service, Pickwick Dam, Tennessee, November 1979; Population Dynamics Workshop, State Federal Striped Bass Management Project, National Marine Fisheries Service, Washington, D.C., December 1979 and February 1980; Hudson River Power Plant Case Technical Meeting, Blue Hill, New York, April 1980; Chairman: Leadership Skills for Project Managers, American Management Association, Boston, Massachusetts, May 1980.

Faculty:	Adjunct Professor, Department of Ecology, University of Tennessee, Knoxville.
Ad hoc reviewer:	*Journal of the Fisheries Research Board of Canada, Science;* proposals: NSF.
Consultant:	Electric Power Research Institute, Palo Alto, California (subprogram on "Aquatic Resource Utilization and Management"); Martin Marietta Corporation, Environmental Center, Baltimore, Maryland.

VAUGHAN, DOUGLAS S.

Participant:	Workshop on Comparative Reservoir Research, Oak Ridge, Tennessee, October 9–10, 1979; Workshop on Feasibility of Basing Regulatory Actions on the Achievement of Mitigation Criteria, ORNL, October 23–24, 1979; Workshop on Applications of Mathematics to Environmental Problems, University of Tennessee, Knoxville, December 4, 1979; 43rd Annual Meeting, American Society of Limnology and Oceanography, University of Tennessee, Knoxville, June 16–19, 1980; International Symposium of Inland Waters and Lake Restoration, Portland, Maine, September 8–12, 1980; 110th Annual Meeting, American Fisheries Society, Louisville, Kentucky, September 21–24, 1980; preparation of Supplementary NRC Staff Testimony Regarding the Criteria Used to Select Alternatives to the Douglas Point Site and the Examination of Site Alternatives to Douglas Point, before the Atomic Safety and Licensing Board; proposal on Effects of Multiple Stress on Fish Populations, National Power Plant Team, U.S. Fish and Wildlife Service; An Introduction to Time-Series Analysis, ORNL In-house Course, Spring 1980.
Ad hoc reviewer:	Electric Power Research Institute; Environmental Protection Agency (Region V); proposals: Sea Grant (NOAA), ORNL Seed Money.
Other:	Organizer, Module on Age Structure Models in Fishery Science, 110th Annual Meeting, American Fisheries Society, September 21–24, 1980.

VATH, J. E.

Member:	Technology Assessment of Uranium Enrichment Processes (DOE-UCCND/PNL); Nonproliferation Alternatives Systems Assessment Program (DOE); ORNL National Energy Perspective (Contributor).
Participant:	NLLWMP Site Review, Mound Facility, Miamisburg, Ohio, May 21, 1980; NLLWMP Site Review, Brookhaven National Laboratory, Upton, New York, May 29, 1980; NLLWM Program Planning Seminar, Des Moines, Iowa, June 3–4, 1980; NLLWM Program Current Year Plans meeting, Idaho Falls, Idaho, September 17–18, 1980.
Ad hoc Reviewer:	Proposals: DOE.

VAUGHAN, NANCY D.

Chairman:	Environmental Sciences, General Session at the American Nuclear Society Winter Meeting in San Francisco, California, November 11–16, 1979.

VOORHEES, L. D.

Member:	Committee on Roadside Maintenance, Transportation Research Board for the National Research Council.

Participant: Association of Systematic Collections Center for Biosystematics Resources Workshop, Lawrence, Kansas, October 1979; Annual Meeting of the Transportation Research Board, Washington, D.C., January 1980; Sixth Annual Scientific Research Meeting, The Upland Areas of the Southwest Region National Park Service, Gatlinburg, Tennessee, June 1980; Annual Meeting, American Institute of Biological Sciences, Tucson, Arizona, August 1980; Transportation Research Board Summer Meeting, Roadside Vegetation Management and Manipulation Program, San Antonio, Texas, August 1980; preparation of draft DOE Procurement Guidelines, draft DOE Environmental Report Guidelines, and PDES for the Alabama Nuclear Fuel Fabrication Plant, Prattville.

Advisor: Bill Rusin, M.S., Miami University, Oxford, Ohio.

WAIDE, JACK B.

Member: Environmental Biology Review Panel, EPA; Ecological Systems Review Group for the Controlled Ecological Life Support System Program, NASA-AIBS.

Advisor: Ginger Ellis, M.S., Clemson University, Clemson, S.C.; Yetta Jager, M.S., University of Tennessee, Knoxville; Daniel Pettigrew, M.S., Clemson University, Clemson, S.C.; Lawrence Schissel, M.S., Clemson University, Clemson, S.C.

Ad hoc reviewer: *Ecology, Ecological Monographs, Limnology and Oceanography*; proposals: EPA, NASA, NSF.

WALTON, B. T

Participant: Society of Toxicology Annual Meeting, Washington, D.C., March 1980; Second Chemical Congress of the North American Continent, Las Vegas, Nevada, August 1980; Entomological Society of America Annual Meeting, Denver, Colorado, November 1979.

Advisor: Michael B. Lustig, B.S., Emory University, Atlanta, Georgia.

Ad hoc reviewer: *Environmental Entomology, Journal of Economic Entomology.*

WATTS, J. A.

Participant: IMGRID, Version 2.5 Workshop, Tennessee Valley Authority, Norris, Tennessee, December 5–6, 1979; IMGRID, Version 3.5 Workshop, Tennessee Valley Authority, Norris, Tennessee, March 26, 1980; Time Series Analysis Short Course, ORNL Inhouse Continuing Education Program, Oak Ridge National Laboratory, Oak Ridge, Tennessee, April 24–June 26, 1980; SAS Statistics Short Course, SAS Institute, Inc., Cary, North Carolina, held at Oak Ridge National Laboratory, Oak Ridge, Tennessee, July 9–10, 1980.

Advisor: Secondary advisor to G. W. Bowen, M.S., University of Tennessee, Knoxville.

Other: Affirmative Action Representative from ESD, October 1979–April 1980.

WEBB, J. W.

Participant: Canopy Arthropod Workshop, University of Georgia, Athens, Georgia, May 1980; Entomology Subgroup (co-chairman), Workshop on effects of chemicals on terrestrial population interactions, Oak Ridge, Tennessee, February 1980; preparation of: PDES, Federal American Partners Uranium Mill Project; DEA, Dow Geopressure Project (project manager); DEA, Rorabaugh Geothermal Project (project manager).

Advisor:	Christopher Craft, M.S., University of Tennessee, Knoxville.
Ad Hoc Reviewer:	Proposals: NSF; *Annals of the Entomological Society of America, Environmental Entomology*.

WRIGHT, L. D.

Participant:	Workshop on Ecology of Mollusca in the Tennessee Valley Region, Tennessee Tech University, Cookeville, Tennessee, June 2–4, 1980.

YEH, G. T.

Chairman:	Ground-Water Hydrology, International Conference on Water Resources Development, Taipei, Taiwan, May 12–14, 1980. Coastal Flooding (Session 7), The National Symposium on Urban Storm-water Management in Coastal Areas, Blacksburg, Virginia, June 19–20 1980. NSF Heat Transfer Program.
Member:	Environmental Effects Committee of the ASCE's Energy Division.
Participant:	Workshop on Low-Level Waste Environmental Model.
Ad hoc reviewer:	ASCE Committee on Hydrologic Transport and Dispersion.