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ABSTRACT

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Aquatic ecology activities reported include results from the growing projects on reservoir and stream studies and on Legionnaires' Disease Bacterium. Also included are the final results from the two long-term projects on analysis and modeling of aquatic populations and ecosystems and on toxicant formation in condenser cooling systems.

Research in the Environmental Resources Section included regional pattern analysis, large waterway regional analyses, regional analysis of likely impacts of coal production and use in the Western Kentucky area, regional wildlife habitat analysis, acidic deposition, and evaluation of potential conflicts between mineral deposits and renewable resources in the conterminous United States. Modeling studies included ecosystem risk analysis, the study of aggregation problems in ecology, and work on positive feedback in natural systems. Environmetrics emphasized organization, management, and reporting for several large data sets used for examining the effects of by-products of synthetic fuel manufacture on various biota; reporting lower Mississippi River impacts studied by the U.S. Army Corps of Engineers; reporting gasifier research data from the University of Minnesota; studying global carbon issues; and correlating information in the Geoecology data base with country-wide issues. Research park activities emphasized characterization of Oak Ridge Reservation communities, habitat studies for wildlife on an interagency basis, management of softwood plantations, and management and research on reservation wildlife populations.

Earth Sciences research efforts included nonnuclear solid waste technology, an outreach activity involving liner evaluation for disposal of uranium mill tailings, and studies of sediment and contaminants in the New York Bight. The solid waste activity emphasized the evaluation of procedures to remove organics from selected wastes, and the liner study was concerned with bench-scale tests of organic grouts to reduce permeability. The New York Bight study summarized trace metal and radionuclide distribution in the sediments.

Terrestrial ecology activities reported address the effects of air pollution on vegetation (including effects on carbon allocation, regulation of gaseous uptake, and fluoride exposure), modeling whole plant systems with respect to water and nutrient utilization, forest dynamics, acid rain (including effects on forest soils and agricultural crops), and studies of global carbon cycling.

Emphasis within the Advanced Fossil Energy Program continued to shift toward microcosm or field studies. Initiation of a risk assessment project provided a mechanism for utilizing data in the decision-making process while identifying areas where funding requires enrichment or can be decreased.

The Toxic Substances Program continued to develop new information on the behavior of radionuclides (the transuranium elements, ^{99}Tc and ^{95}Nb) in the environment. New research and test protocol development was initiated for the U.S. EPA-Office of Toxic Substances, and substantial progress on model development in the areas of transport and bioaccumulation of xenobiotics was accomplished.

In addition to preparing environmental impact statements and assessments on a variety of energy production facilities (e.g., uranium mines and mills, nuclear generating stations, geothermal plants, oil-to-coal fuel-conversion projects), several new activities were initiated in the Environmental Impacts Program. These studies focused on (1) environmental risk assessment of direct and indirect coal liquefaction and oil shale production and (2) regional environmental characterization of granitic formations in the Southern Piedmont that are potentially suitable for the permanent disposal of high-level nuclear wastes. Technical assistance

was also provided to DOE on the significant environmental issues associated with development of various alternative energy sources (e.g., tar sands, peat lands, Chattanooga Shale, alcohol fuels, and small-scale hydropower).

Biomass studies centered on short-rotation woody crops production at 30 sites across the United States, ecological effects of whole-tree harvesting in the major forest products regions of the United States, and fertility and tilth effects of agricultural residue removal.

Activities in the Low-Level Waste Research and Development Program included site characterization at the experimental burial site for low-level radioactive waste and initiation of waste emplacement, field-scale chemical treatment of an old burial trench to reduce ^{90}Sr migration, and recommendation of a strategy for correcting the escape of ^{90}Sr from Solid Waste Storage Area 4. Geologic studies in the area of the Melton Valley waste management complex were resumed. Seasonally variable radionuclide concentrations in the "^{60}Co-seep" near ILW Trench 7 were found to be correlated with pH fluctuations. It appears that groundwater intercepts the zone of chemical and radionuclide contamination near this liquid waste disposal site.

The Low-Level Waste Management Program Office developed technology development program plans for FY 1981 through FY 1983 and outlying years, prioritized the FY 1982 through FY 1983 budgets to implement these plans, monitored the activities of the participating DOE contractors in implementing the funded FY 1981 tasks, and coordinated the DOE Low-Level Waste Management Program Second Annual Information Meeting and issued the meeting proceedings.

Work in the Waste Isolation Program involved continued research on geologic and geochemical aspects of disposal of high-level nuclear waste in a deep geologic repository. Projects of special interest included study of the response of different rocks to heat, recrystallization of salt from migrating brine, and an environmental assessment of granitic areas in the southern Appalachians as possible repository sites.

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PART I. ENVIRONMENTAL SCIENCES DIVISION SECTIONS

1. AQUATIC ECOLOGY

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Introduction

The Aquatic Ecology Section is involved in basic and applied research that focuses on environmental problems and on gaining a better understanding of the structure and function of aquatic ecosystems. In addition to interacting with the programs and other sections of the Environmental Sciences Division (ESD), the Aquatic Ecology Section interacts with several other Oak Ridge National Laboratory (ORNL) divisions (e.g., Analytical Chemistry, Energy Health and Safety Research, and Information), with the Union Carbide Corporation Nuclear Division (UCC-ND) Computer Sciences Division, and with several outside research organizations in the Southeast [e.g., Tennessee Valley Authority (TVA), The University of Tennessee, Tennessee Technological University, and the National Reservoir Research Program of the U.S. Fish and Wildlife Service (FWS)]. Research in the section for FY 1981 was funded by the Department of Energy (DOE) (22%), the National Science Foundation (NSF) (22%), the Electric Power Research Institute (EPRI) (20%), the Environmental Protection Agency (EPA) (19%), the Nuclear Regulatory Commission (NRC) (12%), and the FWS (6%).

System-level studies of streams and ecosystems continue to be a major emphasis in the section. The NSF-funded project on material spiralling in stream ecosystems has been renewed for a second three-year period. One of the current areas of study is the controlling influence of benthic macroinvertebrates on phosphorus spiralling.

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The field study of effects of reducing macroinvertebrate density indicates that the mechanism through which macroinvertebrates influence nutrient turnover in woodland streams indirectly results from the macroinvertebrates' control of microconsumer density, which, in turn, regulates the turnover of nutrients and microbial biomass associated with detritus. The study in artificial streams of the effects of variation in grazer density showed that the uptake length of inorganic phosphorus increases and that the apparent turnover time of phosphorus in aufwuchs decreases as the standing stock of grazers increases.

The DOE-funded Reservoir Studies Project is still in transition from research on the effects of power plants per se to a more holistic approach to reservoir research. The study of prey-spawning dynamics in southeastern reservoirs indicates that the timing of ovulation resulting in synchronous spawning of the dominant forage fish, threadfin shad, may contribute to the ability of this population to expand rapidly following mass mortality during cold winters. The study of predator-prey dynamics in reservoirs suggests that largemouth bass that do not attain a certain minimum size by the end of their first growing season are less likely to survive during cold winters because of the inability of small bass to store sufficient energy reserves during winter and the unavailability of prey of appropriate size (e.g., threadfin shad) in the spring. Efforts are continuing to develop a sound conceptual basis for reservoir ecological research that will be applicable to effective impact prediction, benefit/risk assessment, and decision making regarding energy technologies and river-reservoir ecosystems.

The project on analysis and modeling of aquatic populations and ecosystems involves development and application of quantitative methods designed to assess a variety of man-made impacts. The areas of research highlighted in this annual report are (1) the effect of stochastic variation on estimates of entrainment mortality and (2) the effects of multiple stress on fish populations. A computer simulation program was developed to aid in designing field sampling programs and in evaluating the bias of estimates of entrainment mortality and how estimates can be best corrected. A synthesis and evaluation of existing information and modeling approaches on the effects of multiple stress indicate that dynamic pool models, Leslie matrix models, and bioenergetic models are the most promising approaches—the choice of approach depending on the amounts and types of data available. This second area reflects an evolution in our research toward the development of methods for assessing the effects of stresses other than entrainment and impingement, such as toxic substances and acid precipitation, not only on single populations but also on communities and ecosystems.

Research on impacts associated with power plants continues to be prominent. Pathogenic microorganisms in artificially heated waters are a growing area of concern. Our research is now focused on determining the distribution, viability, and infectivity of Legionnaires' Disease Bacterium (LDB) and on defining the conditions promoting its proliferation. Our study of toxicant formation in condenser cooling systems, which ends with FY 1981, is directed toward determining optimum chlorination procedures at power plants. Current research focuses on equivalent toxicity and additive toxicity of residual chlorine, lipophilicity and fish toxicity of residual halogen species, and bioaccumulation of chlorinated organic compounds by the Asiatic clam.

Controlling Influence of Benthic Macroinvertebrates on Phosphorus Spiralling in Stream Ecosystems

Studies of nutrient and carbon dynamics in many aquatic and terrestrial ecosystems indicate that consumers can have an important controlling effect on the uptake, remineralization, and retention of these materials in ecosystems. Similar studies in streams, however, show that macroinvertebrates (e.g., aquatic insects, mollusks, and amphipods) account for only a minor fraction of the uptake and turnover of nutrients; these studies suggest that the direct effects of these consumers on nutrient dynamics are relatively small. The indirect effects of benthic macroinvertebrates on other ecosystem components that play a major role in the uptake and turnover of nutrients in streams have not been studied. To examine the controlling influence of macroinvertebrates on phosphorus dynamics in stream ecosystems, two studies involving the experimental manipulation of consumer density were conducted.

Effects of Reducing Macroinvertebrate Density

In the first experiment, the density of macroinvertebrates was reduced in a small, first-order woodland stream by the controlled addition of the pesticide methoxychlor. This treatment removed most of the macroinvertebrate functional groups (e.g., shredders and scrapers), but it had no direct toxic effect on microbial populations in the stream. The uptake and turnover of phosphorus in the treatment stream and in an adjacent control stream were measured both before and after the pesticide addition by adding a solution of carrier-free $^{32}PO_4$ to the streams over a 30-min period in February 1980.

The uptake length of phosphorus, defined as the average or expected travel distance of PO_4-P in water before being sorbed by particles in suspension or on the stream bottom, was 7 m in the treatment stream and 15 m in the control stream prior to adding the pesticide. Since the two streams were similar in size, discharge, and temperature and appeared to have comparable standing stocks of benthic organic matter (BOM), this difference in uptake length is probably a result of differences in the extent of mixing of $^{32}PO_4$ with stream sediments.

About three months after the pesticide treatment, the uptake length in the treated stream had changed only slightly, increasing from 7 m in February to 9 m in May. Over the same period, the uptake length of phosphorus in the control stream had increased by about 70%, from 15 m to 25 m. This difference in the incremental change in uptake length between the two streams after the pesticide treatment suggests that benthic macroinvertebrates increase the uptake length of phosphorus. Differences between the two streams that could explain the mechanism of this apparent effect include a fivefold higher standing stock of BOM and a sixfold higher biomass of microbes per unit weight of fine particulate organic matter (FPOM) in the treated stream in May. Either alone could account for both the difference in uptake length between the two streams and the insignificant increase of the uptake length in the treated stream after the pesticide addition. The greater standing stock of BOM in the treated stream is a result of the reduced processing and transport of detritus following the removal of most benthic macroinvertebrate functional groups. Uptake of $^{32}PO_4$ per unit weight of FPOM was significantly greater in the treated stream than in the control stream, most likely because of the greater biomass of microbes associated with FPOM in the treated stream. Because microbial biomass is based on measurements of adenosine triphosphate (ATP) extracted from detritus samples and ATP content per cell varies with cell growth, greater biomass of microbes in the treated stream may reflect increased turnover of microbial biomass resulting from the reduced grazing pressure after removal of macroinvertebrates.

Subsequent turnover of ^{32}P taken up by detritus was faster in the treated stream than in the control stream, thus indicating that macroinvertebrates also reduce the turnover rate of phosphorus associated with detritus. This apparent effect of macroinvertebrates on phosphorus turnover appears to contradict results of several laboratory studies that have demonstrated bacterial uptake and turnover of phosphorus in detrital systems to be lower in the absence of consumers. This apparent contradiction, however, can be explained by differences in available nutrients between closed laboratory systems and open stream systems and differences in the trophic structure between the laboratory systems and the natural streams used in our experiment. In the laboratory systems, the consumers used were protozoans and other microconsumers that tend to feed more selectively on bacteria and fungi than do shredders and collectors. Removal of microconsumers from closed systems would be expected to result in microbial populations becoming senescent as available nutrients are increasingly sequestered in microbes. As a consequence, turnover of both nutrients and microbial biomass decreases. In our experiment, reduction of macroinvertebrate consumers in the treated stream resulted in an increase in the density of oligochaetes, microcrustaceans (e.g. copepods), and other microconsumers that feed on bacteria and fungi. This response was probably caused by the reduced predation of and/or competition from macroinvertebrates following the pesticide treatment. As a consequence of this increase in microconsumer density, grazing pressure on microbes probably increased, thus resulting in an increase in the turnover rate of phosphorus and microbial biomass in the treated stream. The mechanism through which macroinvertebrates influence nutrient turnover

in woodland streams thus appears to result indirectly from the macroinvertebrates' control of microconsumer density, which, in turn, regulates the turnover of nutrients and microbial biomass associated with detritus.

Effects of Variation in Grazer Density

In a second experiment designed to examine the effects of consumers on nutrient spiralling, phosphorus uptake and turnover were measured in four replicate stream channels, three containing a simplified community of aufwuchs and different densities (low = 156/ m^2, medium = 311/ m^2, and high = 622/ m^2) of a snail, *Goniobasis clavaeformis*, which grazes on aufwuchs. The fourth channel, which served as an ungrazed control, contained no macroinvertebrates. About three weeks after introducing the snails, the uptake and turnover of phosphorus were measured in each of the four channels using $^{32}PO_4$.

The uptake length of phosphorus, based on the loss of $^{32}PO_4$ from stream water, increased with increasing grazer density (Fig. 1.1). Both the standing stock of aufwuchs and the amount of ^{32}P taken up per unit area of stream bottom were inversely related to grazer density, thus indicating that grazers control the uptake length of

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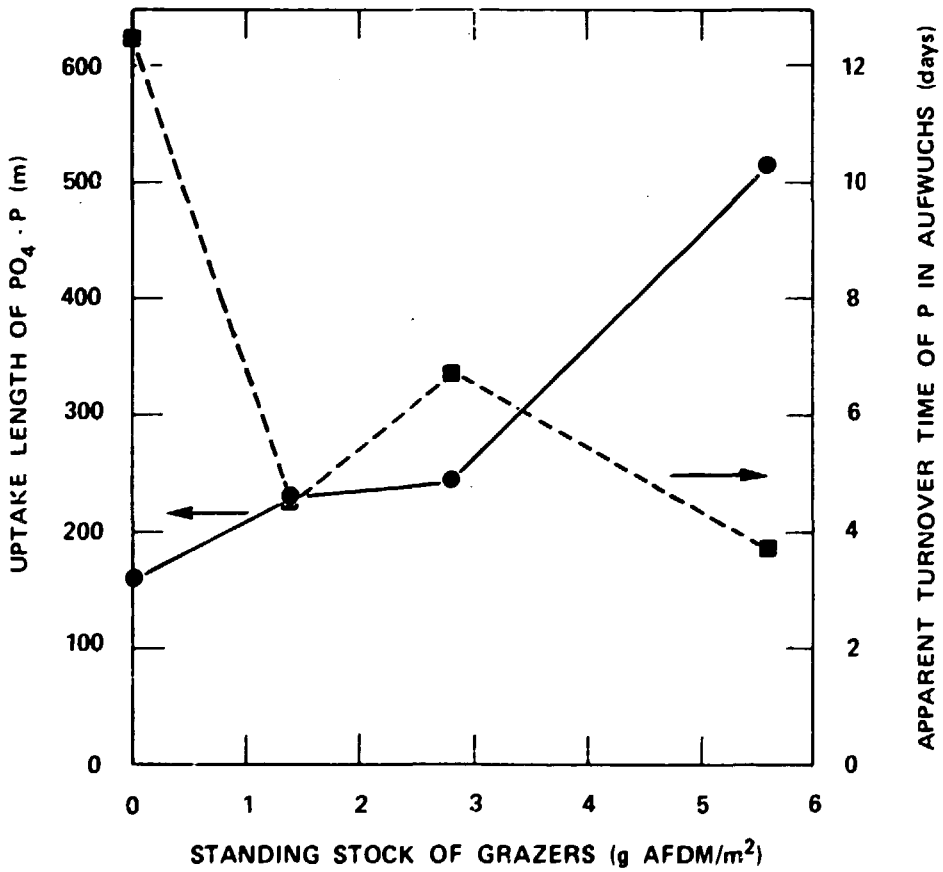

Fig. 1.1. Uptake length of PO_4-P (solid line) and apparent turnover time of phosphorus in aufwuchs (dashed line) as a function of the standing stock of grazers, *Goniobasis clavaeformis*, in artificial streams. The uptake length of phosphorus is based on the loss of ^{32}P from stream water during a 30-min release of carrier-free $^{32}PO_4$, and the turnover time is based on the estimated change in ^{32}P concentration in aufwuchs following the release. (AFDM = ash-free dry mass.)

phosphorus through their influence on aufwuchs biomass. The increase in the uptake of ^{32}P per unit biomass with increasing grazer density suggests that grazers also control the uptake rate of phosphorus from water by enhancing the turnover rate of phosphorus in algal cells and/or by reducing the self-limiting effect of aufwuchs' biomass on the uptake rate. The effect of aufwuchs' biomass on phosphorus uptake length is consistent with that observed in the preceding experiment and indicates that consumers can influence the uptake of nutrients through their control of microbial biomass and/or substrate area available for microbial growth.

The apparent turnover time (= inverse of turnover rate) of phosphorus taken up by the aufwuchs, as estimated from the rate of change in ^{32}P concentration per unit weight of aufwuchs, is lower in the grazed channels than in the channel containing no snails (Figure 1.1), thus indicating that grazing increases the turnover rate of phosphorus in aufwuchs. This turnover rate, however, may not be a true measure of the regeneration rate of phosphorus from aufwuchs back to water because dilution from cell growth also contributes, over time, to the reduction in ^{32}P concentration. Irrespective of whether the decrease results primarily from growth or from regeneration of phosphorus back to water, these results show that either one or both of these processes increase in the presence of grazers. Results of carbon fixation measurements should provide an indication of whether the increased turnover rate of phosphorus in the presence of grazers results from both the increased productivity of aufwuchs biomass and the increased remineralization of phosphorus.

Reservoir Studies Project

The research emphasis of the Reservoir Studies Project is in transition. Historically, ORNL research efforts related to reservoirs have focused on (1) thermal effects of power plant releases on aquatic biota (1970–1978) and (2) impacts of cooling systems operation, including intake-related entrainment and impingement problems (1973–1978). During 1978 and 1979, investigation of the effects of energy-related stresses on selected ecological interactions in reservoirs (trophic dynamics of reservoir benthos, interaction of reservoir forage fishes with predator species, and habitat selection by predators) was emphasized. Recent DOE-ORNL evaluations of current and long-term research priorities have resulted in the rescoping of our reservoir research efforts (1) to address generic stresses and impacts on river-reservoir systems associated with multiple energy technologies, (2) to identify specific characteristics indicative of the relative ability of river-reservoir systems to accommodate energy-related impacts, and (3) to provide technical information, expertise, and ecologically sound criteria applicable to a variety of energy-related impacts on river-reservoir systems.

In this section, we summarize three lines of research that have received emphasis during the past year. The first two have evolved from previous studies related to cooling system entrainment and impingement problems, and the third is fundamental to the application of a holistic approach to reservoir research. All three represent links between the past and future research of the Reservoir Studies Project.

Prey-spawning Dynamics in Southeastern Reservoirs

The threadfin shad *(Dorosoma petenense)*, which is normally restricted in its geographical range to areas where temperatures do not go below about 4°C, has been stocked as a forage fish throughout the southern United States (i.e., below a latitude of 39° N). Massive mortalities occur when the temperature drops abruptly and large numbers of threadfin shad are then impinged at steam electric generating plants. However, the adverse ecological consequences of this mortality are often minimized by the ability of a small number of surviving threadfin shad to produce a population explosion. The reproductive strategies responsible for this phenomenon are largely unknown; thus, reasonable assumptions or predictions regarding the ability of the forage base to rebound each year cannot be made.

We have observed that threadfin shad spawn synchronously between 5:40 and 7:30 AM. Initiation of spawning is governed by the last phases of oocyte maturation as indicated by a bimodal distribution of follicles in the ovary, groups of eggs near the vent portion of the lumen, and parallel development of spawning condition in fish isolated from the field population. The time of day and duration of the spawn are important (1) in missing the major feeding periods of largemouth bass; (2) in relieving predation pressure by sauger, which feed uniformly over 24 h; (3) in increasing zygote number by ensuring fertilization; and (4) in possibly increasing zygote survival by missing the feeding period of the yellow bass, a predator of shad eggs. In summary, the timing of ovulation resulting in synchronous spawning may contribute to the ability of a threadfin shad population to expand rapidly following mass mortality.

Predator-prey Dynamics in Reservoirs

In many freshwater systems of the United States and particularly in temperate areas, threadfin and gizzard shad, the primary prey of several predators, undergo drastic temporal fluctuations in abundance because of winter-cold kills and impingement at electrical generating stations. Response of predator populations to extreme seasonal or yearly fluctuations in prey abundance is not well documented. The objectives of this research were (1) to quantify the response of largemouth bass, a major predator in reservoirs, to this fluctuating prey availability; (2) to investigate strategies employed by a predator to partition consumed energy in the face of prey shortages; and (3) to develop and validate a bioenergetics model for predicting the behavior of predators in reservoir ecosystems.

Growth, mortality, and food consumption were the functional responses we measured to investigate the regulating effects of a fluctuating prey base on predator population structure. Predator response to prey availability was compared between two years when temperature and prey availability were radically different, and the relationship between prey availability and predator growth and mortality was established through field measurements of consumed energy. Relatively small differences in winter water temperatures between years can have a major influence on predator population structure because of the threshold relationship between temperature and the lower lethal limits of shad. Temperature indirectly controls the structure of a predator population by regulating the abundance and size of prey. Growth and consumption of bass in Watts Bar Reservoir were lower in 1979 than in 1980 because of the lower winter water temperature in 1979, which reduced the abundance and availability of prey of adequate size. Depending on the severity of the winter, bass that do not attain 25 ± 5 cm by the end of their first growing season do not survive to annulus I formation because of the inability of small bass to store sufficient energy reserves over winter and the unavailability of prey of appropriate size in the spring.

Allocation of consumed energy by largemouth bass was also determined to investigate strategies employed by this predator to maintain condition in a system with a temporally fluctuating prey base. Consumed energy is partitioned into growth energy storage and reproduction, according to temporal prey availability, metabolic demand, and reproductive strategy. Throughout minimum feeding periods in the winter and early spring, bass utilize energy from visceral fat and body protein for standard metabolic demands and gonad development. The calculated activity metabolism in largemouth bass ranged from 18 to 144% of standard metabolism, depending on sex and time of year. Activity metabolism and consumption were directly correlated throughout the year, thus suggesting that foraging costs may constitute a large fraction of activity metabolism. Catabolism of energy from body tissue during the winter was less than 33% of standard metabolic demands, thereby indicating that some consumption had to occur during the winter. To maintain condition in a system where their primary prey undergoes drastic fluctuations in temporal abundance, bass maximize growth in the fall, feed in warm water refuges in the winter, and both store visceral fat and minimize standard and active metabolic demands in the winter and spring.

A bioenergetics model that predicts the response of largemouth bass to various levels of prey availability and temperature has been developed and validated with field data. Experiments with the model have revealed that consumption and growth are sensitive not only to prey abundance but also to size distribution of prey. Field measurements of growth and consumption have confirmed that predictions of the model fall within the range of observed values. Also, the gross conversion ratio (growth/consumption) obtained for various age classes of bass (0.22 for age I, 0.20 for age II, 0.16 for age III, and 0.10 for age IV) indicates that consumption predicted by the model produces realistic estimates This trend of decreasing ratios with increasing age is consistent with field and laboratory values for predators of similar sizes and life styles. We believe that further development of the bioenergetics approach to evaluate predator-prey interactions will permit insights into reservoir ecosystem structure and function and will provide a mechanism for evaluating the relative sensitivity of various types of reservoirs to man-induced perturbations.

Development of a Conceptual Basis for Reservoir Ecological Research

Despite their widespread distribution and economic importance, reservoirs as aquatic ecosystems have received limited scientific attention relative to that given streams, rivers, and natural lakes. In fact, U.S. reservoirs have never received coordinated ecological study, and little basis exists for predicting (1) the environmental impacts on river-reservoir systems, (2) the relative sensitivity or resistance of reservoirs to perturbation, or (3) the fate of specific compounds (e.g., essential nutrients and toxic contaminants) in reservoirs. Most research efforts concerning U.S. reservoirs have focused on fisheries management, water quality, or siltation, and the efforts have been so specifically problem oriented as to preclude comparative or system-level synthesis. However, existing ecological knowledge of riverine and lacustrine systems may provide an initial conceptual basis for examining man-made impoundments as ecological systems.

We are attempting to (1) synthesize existing ideas concerning reservoir ecology and (2) apply ecological knowledge of riverine, lacustrine, estuarine, and oceanic systems to our conceptualization of reservoir ecosystem structure and function. Our goal is to provide a sound scientific foundation applicable to effective impact prediction, benefit/risk assessment, and decision making regarding energy technologies and river-reservoir ecosystems.

Analysis and Modeling of Aquatic Populations and Ecosystems

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

The first project described in this section, a Monte Carlo simulation model for comparing the accuracies of two formulas for estimating entrainment mortality, represents one of the last remaining tasks in our research on entrainment and impingement. The second project described is a comprehensive review of empirical data, theory, and modeling techniques related to assessing the effects of multiple stresses on fish populations. This review is the first effort in what we hope will be a continuing line of research.

The Effect of Stochastic Variation on Estimates of Entrainment Mortality

The probability that live fish eggs or larvae entrained in cooling water will be killed is an important element in projecting the effects of power plants on fish stocks. This probability — the entrainment mortality factor,

or *f* factor — is commonly estimated with one of several relatively simple formulas that use data collected from intake and discharge water. Such biological phenomena as gear avoidance, gear-induced mortality, extrusion through nets, and the presence of dead organisms in ambient water introduce error into the estimates. An additional difficulty is that, because of small sample sizes, it is usually necessary to combine data from many samples, taken under different conditions, before estimating the *f* factor. A computer simulation program, ENTRAN, was developed to aid in the design of field sampling programs and in the analysis of reliability of entrainment mortality factor estimates.

The model simulates both the entrainment mortality sampling process and the estimation of the *f* factor by either of two equations: an "ORNL" formula and an "OTHER" formula. Different equations could be substituted for these, if desired. The entrainment process is repeatedly simulated as key variables are allowed to vary randomly. In each repetition, the true value of the entrainment mortality factor (*f* factor) is selected, and the value is compared with estimates of this factor obtained from the two alternate formulas. The reliability of each formula can then be evaluated by comparing the estimates of the *f* factor with the corresponding true values. ENTRAN enables an examination of the magnitude and variance of error as a function of variability introduced by various sampling phenomena.

We intend for the program to be viewed as flexible because the biological assumptions built into the present version may not best describe, or even adequately describe, a particular sampling situation or species. When suitably modified to reflect what is known or suspected about the biology of the sampling situation, the designer of the sampling program can make good use of ENTRAN to address needs in several areas. The exercise of providing ranges of values for the parameters will likely indicate to the biologist where uncertainty about these parameters is greatest. In conjunction with this exercise, sensitivity analysis of the model will indicate profitable areas for further research that will be helpful in improving the reliability of estimates.

ENTRAN can also aid in determining how to design the sampling program and how to interpret the results. The program can be used to study the relative effects of estimating the *f* factor from many small samples vs fewer larger samples, and it can indicate how reliability is influenced by small sample sizes, given uncertainty in the parameters. ENTRAN can also be used in a general way to evaluate the reliability of *f*-factor estimates calculated from sample data. Depending on the degree of confidence in the input parameters, the program will be useful in evaluating the bias of estimates and in indicating how estimates calculated with a particular formula can best be "corrected."

Effects of Multiple Stress on Fish Populations

Fish populations in nature are subjected to a variety of anthropogenic stresses such as fishing, thermal and chemical pollution, and mortality at power plant intakes. The effects of each new stress on the health of a population are determined in part by the level of preexisting natural or man-induced stress. The cumulative effects of many stresses can possibly cause the collapse of a population even when the effects of each individual stress appear insignificant. The objectives of this research were to synthesize and evaluate existing information (task I) and modeling approaches (task II) that address the effects of multiple sources of stress on fish populations and to assess research needs (task III).

The specific objectives of task I were to (1) highlight the importance to fisheries management of considering the effects of multiple stress on fish stocks and (2) provide a focus for the evaluation of available modeling approaches studied in task II. Task I entailed a synthesis of literature related to field observations, experimental work, and theory concerning population responses to the combined effects of multiple stresses. Empirical data on effects of multiple stress and methods of quantifying interactions among stresses were examined. Case studies based on field observations in which adverse changes in fish populations have been attributed to the effects of multiple stresses were reviewed and summarized. Experimental studies that focused on chronic effects

of single and multiple stresses were evaluated and synthesized. Although the primary emphasis was on fish populations, supplemental information on higher invertebrate taxa (crustaceans and mollusks) was considered where relevant. Our evaluation of the experimental data illustrates that the problem of multiple stress is more complex than simple acute toxicity experiments alone would indicate. Widening our purview to include sublethal responses to chronic exposures, which are not often examined, decreases our ability to make generalizations about responses to multiple stresses. Theoretical problems center upon (1) mathematically specifying the manner in which stresses and the variety of environmental factors influence basic biological processes and (2) correctly translating across trophic levels.

Task II entailed an analysis of existing population-modeling approaches useful for quantifying the combined effect of noncommensurate sources of stress on population processes. Modeling approaches evaluated included

1. surplus production models,
2. dynamic pool models,
3. stock-recruitment models,
4. Leslie matrix models modified to incorporate growth, and
5. bioenergetic models.

Deterministic, rather than stochastic, models were emphasized. For each model type, we assessed assumptions, parameter estimation procedures, complexity, and dynamic behavior as these factors related to the predictive capability of the model type. We also evaluated the types of validation and verification required to apply each model, and we compared the model types with respect to data requirements and robustness. The modeling approaches were compared and contrasted on the basis of the following: (1) data needs, (2) model assumptions, (3) parameter estimation, (4) sensitivity of model to errors in parameters, and (5) ability and level at which the effects of stress can be incorporated into model structure. We concluded that dynamic pool, Leslie matrix, and bioenergetic models are the most promising approaches. Dynamic pool models provide a relatively simple and easy approach to assessing the effects of multiple stress when resources are limited. A Leslie matrix model combined with a bioenergetic approach allows greater detail in modeling the effects of multiple stress, but it requires a much greater amount of data.

Presence of Pathogenic Microorganisms in Power Plant Cooling Waters

Our study on the presence of pathogenic *Naegleria* in power plant cooling water showed that artificial heating of water by power plants can facilitate the propagation and/or persistence of these pathogens. Recent studies also indicate an association of Legionnaires' Disease Bacterium (LDB) with cooling systems. The source of infection of some Legionnaires' Disease outbreaks has implicated cooling towers associated with air conditioning systems as the dispersal vehicle. The largest cooling tower systems (i.e., those of electrical generating stations) had not been previously examined as a source of LDB. A detailed study of such cooling towers was thus warranted to determine whether LDB is present in and is dispersed by cooling towers of electric generating stations. In addition, further testing of the distribution of the encephalitic ameba *Naegleria fowleri* was advisable.

The levels of LDB and the predominant LDB 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. To test for *Naegleria*, water samples (100 to 400 mL) were filtered through cellulose membranes having a pore size of 1.2 μ. These filters were inverted and placed onto nonnutrient agar plates seeded with live *Escherichia coli*. The plates were incubated for 3 to 7 d or until growth of ameba was observed. Ameba that grew out at 45° C were tested for

their ability to flagellate. All amebo-flagellates were tested for pathogenicity by intranasal inoculation into weanling ICR mice.

While all but one of the sites tested were positive for the presence of thermophilic ameba, only two sites were positive for pathogenic *Naegleria*. The *Naegleria* isolates were pathogenic for mice, and all inoculated animals succumbed within 7 d after intranasal inoculation. The ameba were readily reisolated from infected brain tissue. Pathogenic *Naegleria* were not detected in control source water.

Thus far, infectious LDB has been demonstrated in four of ten test sites. Infectious LDB was demonstrated as positive in the source water of two of the four test sites. Various serotypes of infectious LDB were isolated. These include the Knoxville, Bloomington, Los Angeles, and Chicago serotypes as well as a new species of *Legionella* (OR 10). The newly isolated species is being jointly studied by ORNL personnel and personnel at the Center for Disease Control in Atlanta. The latter have shown that the new *Legionella* species has a unique fatty acid composition and, unlike other *Legionella*, does not require cystine or iron for growth. This finding suggests that the isolate, while definitely a new species, may also represent a new genus as well.

Preliminary air sampling using an impinger-type sampler has indicated that LDB can be detected in the air downwind from cooling towers. These preliminary samples indicate that the number of LDBs per liter of air is decreased by 10^5–10^6 relative to the number per liter of tower basin water. Considering the small numbers of LDBs that can infect guinea pigs via aerosolization, however, these preliminary findings of positive air samples indicate the need for more extensive air sampling.

Toxicant Formation in Condenser Cooling Systems

This EPA-funded project, which ends with FY 1981, has been highly productive over the past six years in providing sound chemical and toxicity information relating to determining optimum chlorination procedures at power plants. Current research focuses on examining (1) the two assumptions of equivalent toxicity and additive toxicity of residual chlorine species, (2) the structure-toxicity relationship of monochloramines to see if their toxicity can be predicted from their lipophilicity, and (3) the bioaccumulation of halogenated hydrocarbons and fatty acids by *Corbicula*. In addition, the fourth in the series of conferences on water chlorination focused on environmental impact and health effects.

Equivalent Toxicity and Additive Toxicity of Residual Chlorine

Inherent in the choice of total residual chlorine (TRC) as a basis for establishing water quality criteria or effluent guidelines for chlorine are assumptions that components of TRC are roughly equivalent (on a milligram per liter basis) in toxicity to aquatic species and that the toxicities of these components are additive. In view of the continuing controversy that has focused on the levels of residual chlorine that can be discharged without deleterious impact on receiving waters, we examined each of these two assumptions using mosquito fish, *Gambusia affinis*, as test organisms.

The assumption that residual chlorine species are about equally toxic is not tenable (Table 1.1). In most previous toxicity studies, organisms have been exposed to free residual chlorine (hypochlorous acid, hypochlorite ions) or inorganic chloramines (monochloramine, dichloramine). These compounds differed in toxicity by sixfold (Table 1.1). The ratio of toxicity of $NHCl_2$ to NH_2Cl for mosquito fish (3.5), which is similar to that found for three other fish species by two previous investigators, suggests that the sixfold range may be representative for these four chemical species for short exposure periods. In real situations (e.g., in sewage and power plant effluents), however, organic amines probably form significant fractions of the residual chlorine species. Information is not available on the species composition of organic amines in natural or sewage waters; thus, products cannot be predicted, but inclusion of the toxicities of a selected series of organic chloramines in the

Table 1.1. Median lethal concentrations (LC50) of residual chlorine compounds for mosquito fish exposed for 1 h[a]

Compound	Chemical formula	LC50[b] (mg/L)
Dichloramine	$NHCl_2$	0.366
Hypochlorous acid	HOCl	0.455
Cyclohexylmonochloramine	$C_6H_{11}NHCl$	0.547
Ethylmonochloramine	C_2H_5NHCl	0.646
N-propylmonochloramine	C_3H_7NHCl	0.673
Methylmonochloramine	CH_3NHCl	0.799
Monochloramine	NH_2Cl	1.31
N-chloroethylglycinate	$C_2H_5COOCH_2NHCl$	1.70
Hypochlorite ions	OCl^-	2.21
Ethanolmonochloramine	$HOCH_2CH_2NHCl$	15.4
N-chlorotrisamine	$(HOCH_2)_3CNHCl$	90.4
N-chloroglycine	$COOHCH_2NHCl$	575.0

[a]Mortality assessed 48 h postexposure.
[b]Expressed as total residual chlorine.

comparison of species toxicity increases the differential in toxicity to about 1600-fold. More importantly, several organic monochloramines (cyclohexylmonochloramine, ethylmonochloramine, N-propylmonochloramine, and methylmonochloramine) are more toxic than inorganic monochloramine. Whether these chemical species represent the full range of toxicities of the residual chlorine species that may be formed (and persist) is conjectural. However, these data indicate (1) the need for identification of the components resulting from chlorination of natural and waste waters and (2) the dependence of toxicity on species composition of the chlorinated products measured as TRC.

Three lines of evidence suggest that the assumption of additive toxicity is valid. First, predictions of LC50 values for mosquito fish exposed to mixtures of hypochlorous acid, hypochlorite ions, and inorganic monochloramine and dichloramine over a range of pH values from 6 to 8.5 fit very well the actual values observed. This model was derived by assuming additivity and dissociation of hypochlorous acid according to pH; thus, the close fit provides support for both of these assumptions.

Second, we evaluated the additivity assumption using an additivity index. This index is based on the assumption that the toxicity of a mixture equals the sum of the toxicities of the individual components, both expressed as their fractional LC50 values:

$$\frac{\sum_{i=1}^{n} \text{Concentration of compound } i}{\text{LC50 of the mixture}} = \sum_{i=1}^{n} \frac{\text{Concentration of compound } i}{\text{LC50 of compound } i}$$

When the sum of the concentrations of the compounds in a mixture equals the LC50 value for the mixture, the left side of this equation is equal to unity. Then the hypothesis of additivity can be tested by evaluating the right side of the previous equation, that is,

$$\text{Additivity index} = \sum_{i=1}^{n} \frac{\text{Concentration of compound } i}{\text{LC50 of compound } i} ,$$

and comparing this calculated additivity index to unity. Values of the additivity index equal to unity indicate simple additivity, values significantly greater than unity indicate less than additive interaction (i.e., antagonism), and values significantly less than unity indicate more than additive interaction (i.e., synergism).

We found that additivity indexes of three mixtures of inorganic chloramines and/or free residual chlorine were 1.10, 1.06, and 0.68, respectively. The first two strongly support additivity, while the latter suggests synergism. However, the latter mixture may also have contained some trichloramine that appears to be more toxic than the other two chloramines. Nonetheless, even in this case, the assumption of additivity would not lead to a large error.

Finally, the relationship between toxicity and octanol/water partition coefficient (see section below) of three chlorinated natural waters matched rather well with that found for a series of individual organic chloramines. Since all of these chlorinated waters contained mixtures of residual chlorine species, the close correspondence would not be expected unless the toxicities of these chlorine species were additive.

A preponderance of the evidence thus supports additivity. Studies of other organisms and a wider range of mixtures are needed before the additivity hypothesis can be accepted as generic.

Lipophilicity and Fish Toxicity of Residual Halogen Species

Because of the large number of potential organic chloramines, obtaining sufficient data for each one would be a toxicologist's nightmare. However, if the toxicities of residual chlorine compounds are found to be generally additive, development of structure-activity relationships would offer one way to avoid this problem.

We studied the structure-toxicity relationship of monochloramines to see if toxicity of monochloramines (and free halogen species) could be predicted from their lipophilicity. Median lethal concentrations (LC50s) were determined by exposing mosquito fish to each compound for 1 h at pH 8.5. Partition coefficients (PCs) were determined in the *n*-octanol/water system. Monochloramines selected retained ≥90% of their initial concentrations for 1 h.

Our data indicate that lipophilicity affects the toxicity of halogen species to mosquito fish. Partition coefficients and LC50s, respectively, were 0.0072 and 650 mg/L for N-chloroglycine, 0.049 and 150 mg/L for N-chlorotrisamine, 0.22 and 1.9 mg/L for monochloramine, and 0.72 and 1.43 mg/L for free chlorine. The classic Meyer-Overton equation provides an excellent description of these data: $\log \frac{1}{LC50} = a \log PC + b$, where $a = 1.48$ and $b = 0.220$ ($r^2 = 0.91$; $P = 0.05$). However, the increase in toxicity leveled off for compounds of $PC \geq 1.0$. Partition coefficients and LC50s, respectively, were 1.48 and 0.08 mg/L for methylmonochloramine, 4.4 and 0.73 mg/L for ethyl monochloramine, 34.8 and 0.71 mg/L for free bromine, and 145 and 0.60 mg/L for cyclohexyl monochloramine. The Meyer-Overton equation for these four lipophilic compounds is: $\log \frac{1}{LC50} = 0.162 \log PC - 0.0719$, ($r^2 = 0.75$; $P = 0.025$). Cyclohexyl monochloramine was 2.4 times more toxic and N-chloroglycine 455 times less toxic than free chlorine.

This study shows that (1) lipophobic monochloramines drastically reduce the toxicity of total residual chlorine, (2) lipophilic nitrogenous bases potentiate the chlorine toxicity and can contribute to environmental impacts of chlorinated discharges, and (3) the partition coefficient provides a reliable estimate of the acute toxicity of monochloramines and free halogen species.

Cooling Water Pollutants: Bioaccumulation by *Corbicula*

Chemical analysis of tissue extracts of *Corbicula* samples collected at coal-fired and nuclear-powered electric generating power plants has resulted in the identification of a variety of chemical compounds (e.g., fatty acids, hydrocarbons, polysaccharides, alcohols, esters, and sterols). Several halogenated hydrocarbons and fatty acids were tentatively identified both in control samples collected upstream from power plants and in the samples exposed to the chlorinated cooling water effluents. These preliminary experimental results obtained with limited samples indicate that *Corbicula* may bioaccumulate pollutants and that a need exists for further research to corroborate and more thoroughly investigate possible bioaccumulation.

Fourth Conference on Water Chlorination: Environmental Impact and Health Effects

Approximately 200 scientists participated in the Fourth Conference on Water Chlorination: Environmental Impact and Health Effects, Asilomar Conference Center, Pacific Grove, California, Oct. 18–23, 1981. In 12 oral and 7 poster sessions, 121 technical papers were presented. Among the session topics were Organic Chemistry Basis for Chlorine Demand; Chemical and Biological Effects of Cooling System Chlorination; Mutagenicity Studies; Epidemiology; Oxidant Analysis; Interaction of Aquatic Ecosystem Components with Chlorination; Toxicology; and Risk Assessment: Issues and Answers. The conference proceedings are scheduled for publication in June 1982. Sponsoring agencies were EPRI, ORNL, DOE, EPA, NRC and TVA.

2. ENVIRONMENTAL RESOURCES

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Introduction

Five groups comprise the Environmental Resources Section: Regional Studies Group, Modeling and Systems Analysis Group, Environmetrics Group, Computer and Statistical Services Group, and Environmental Research Park Group. The staff members are assigned either to projects within the section or to those elsewhere in the Environmental Sciences Division (ESD) where expertise in regional studies, modeling, environmetrics, or research park activities is needed.

Changes within the section during the past year have been the addition of the Environmental Research Park and the bifurcation of research data management activities. The Environmetrics Group has been established to handle the larger multidisciplinary research projects where organization of the information bases, statistical testing, and computer-oriented display of results are of paramount importance. For other projects requiring analyses, a statistical consulting service aided by staff assigned to ESD from the Computer Sciences Division provides this service.

Major research reported for the past year included regional pattern analysis, extension of regional activities into large-waterway regional analyses (the Tennessee-Tombigbee project), regional analysis of likely impacts of coal production and use in the Western Kentucky area, development of methods for regional environmental analysis, regional wildlife habitat analysis, acidic deposition, and evaluation of potential conflicts between mineral deposits and renewable resources in the conterminous United States.

Modeling studies included considerable effort in ecosystem risk analysis; the study of aggregation problems in ecology, an extension of work done previously on error analysis; and continued work on the subject of positive feedback systems in ecology.

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Environmetrics emphasized the organization, management, and reporting of several large data sets, such as the establishment of data systems for research projects examining the effects of by-products of synthetic fuel manufacture on various biota, the lower Mississippi River data base for the U.S. Army Corps of Engineers, and the continued management of the gasifier research data base, the global carbon projects, and the Geoecology Data Base. Research park activities emphasized (1) continuing efforts to characterize habitats of the Oak Ridge Reservation, (2) habitat studies for wildlife on an interagency basis, (3) management of softwood plantations, and (4) management and research on reservation wildlife populations, not all of which is reported on in this annual report.

Regional Ecological Studies

Society's increased demands for food, fiber, energy, and minerals place continued pressure on the nation's renewable resource base. The spatial distribution of these resources requires that issues such as optimal land use and multipurpose management be addressed with a regional perspective. The inherent broad geographic scale introduces dimensions of spatial heterogeneity and landscape patterning that are becoming more and more demanding in terms of problem solving. Associated links in renewable resource use (i.e., agricultural patterns and habitat variables) require a scientific basis for understanding the connections and interdependence of these resources. Many of the regional studies conducted by ESD staff utilize the Geoecology Data Base (Olson et al. 1980) to integrate environmental resource data and to portray spatial patterns. The national county-level system contains approximately ten million data values, with new data and updates continually being added.

Regional ecological studies in the Environmental Resources Section involve research of landscape-scale problems associated with anthropogenic perturbations and natural processes. Work in this area includes a large variety of subjects covered in subsequent sections of this report.

Pattern Analysis

This study was designed to describe quantitatively the various aspects of regional distribution patterns of forest islands and to relate these patterns to other landscape features (Bowen and Burgess 1981). Several maps showing the forest cover of various counties in Ohio were selected as representative examples of forest patterns to be quantified. Ten-thousand-hectare study areas (landscapes) were delineated on each map. A total of 15 landscapes representing a wide variety of forest island patterns was chosen for the study.

Measurements of number, perimeter size, area, and distances between woodlots, as well as topography, soil type, glacial history, original vegetation, and potential natural vegetation were recorded.

The variables were used in a factor analysis to describe variation of forest island pattern among landscapes. Most of the variation was accounted for by two factors. One factor was strongly related to the portion of the study area covered by forest, as measured by the variable-percent forest cover. The other factor was the degree of forest fragmentation as measured by either the total number of woodlots in a landscape (island density) or landscape dissection index (a function of forest perimeter area ratio).

Discriminant analysis showed that forest island patterns are related to topography and various environmental features correlated with topography. Landscapes with smooth topography and arable land had a small amount of forest coverage divided among a relatively low number of small woodlots. With increasing topographical roughness, the size and/or density of forest islands increased. The greatest degree of forest fragmentation was associated with a 20–30% forest cover in hilly topography. Because forest pattern is a result of the cumulative effects of land use over time, these results were interpreted to mean that the patterns of land use in Ohio were somewhat dependent on topography and related factors.

The ability to quantify landscape pattern on a regional basis has applications to regional ecology. Mathematical models can be developed to predict changes in landscape pattern for given land-use scenarios, and parameters of landscape pattern can be analyzed as indicators of habitat and resource distribution and long-term ecosystem stability. The ability to measure forest island pattern and other aspects of landscape pattern can be one part of quantitative approaches to solving regional ecological and land use problems.

Tennessee-Tombigbee Corridor Study

The purpose of the Tennessee-Tombigbee Corridor Study, which is supported by the U.S. Army Corps of Engineers, is to define and characterize environmental resources in the region affected by completion of the Tennessee-Tombigbee Waterway. This region consists of 51 counties from the junction of the Tennessee and Ohio rivers in Western Kentucky south through Tennessee and Mississippi to the mouth of the Tombigbee River at Mobile, Alabama. Results of the study will be used by local and regional planners to address environmental issues of economic development in their counties. Environmental resource data were integrated with economic development, human resources, and water availability data to produce an overall development plan for the corridor.

The task of the corridor study was to collect, summarize, and interpret environmental data for each planning district and county in the corridor. Eleven reports were compiled that organized planning district boundaries and addressed the following resources: (1) land use, (2) water quality, (3) air quality, (4) physiography and mineral resources, (5) natural areas and recreation sites, (6) free-flowing streams, (7) endangered and threatened species, and (8) cultural resources. Information was presented with text, tables, and figures in a concise form. When relevant, brief discussions of legislation were included. Data were collected primarily from state and federal sources.

The approach used in this study serves as a general framework for regional characterizations. The purpose of the study guided the approach and format. Existing data were compiled and summarized at an appropriate scale of resolution. This approach can be used whenever development issues conflict with environmental issues in a complex geographic and socioeconomic milieu. The corridor study is a unique effort for the ESD because it addresses regional environmental planning on a scale rarely attempted. For example, a particularly difficult aspect was characterizing water quality, usually viewed as a point-source phenomenon, on a broad, regional basis.

Extension of Regional Models

The objective of this project is to formulate a comprehensive conceptual framework for regional environmental analysis adaptable to a broad range of environmental conflicts. A hypothesis has been constructed which states that three classes of state variables are necessary and sufficient for addressing a broad spectrum of regional environmental conflicts. These classes are (1) renewable and nonrenewable resources, (2) environmental patterns, and (3) cultural responses within a region (Klopatek et al., submitted). In addition, variables external to the system that act as forcing functions independent of the state of the regional system are defined. This approach implies that major relevant aspects of the regional system are included and that one can study the dynamic links between the classes of state variables.

This approach has been utilized to study the implications of a food acquisition problem in a highly variable environment in East Africa (Krummel et al., submitted). In this problem, the links between food supply, precipitation amounts, cultural aspects of cattle management, government food subsidy, and human population fluctuations were analyzed in detail. The analysis suggested that government food subsidies do not alter drought-induced population function and that, contrary to popular belief among human ecologists, cattle populations serve a valuable role as food storage mechanisms when crop failures occur.

Problems associated with the multiple siting of coal combustion and liquefaction facilities in a 60-km radius within Western Kentucky have also been addressed with this conceptual framework. As a first step in this regional environmental analysis, current ambient air quality levels were defined, and projected changes in air quality from the proposed coal utilization facilities were determined for a variety of situations. Current patterns of agricultural and forest vegetation that could be sensitive to perturbations associated with changes in air quality levels were used to define potential impacts.

Large, economically important areas of soybeans occur within the air shed defined by the proposed facilities. Background levels of SO_2 and ozone already occur at chronic and, during certain periods, acute levels at which effects on sensitive species have been demonstrated. Based on the analysis of this study to date, projected changes in air quality levels that can further perturb primary productivity will result mainly from coal combustion facilities.

Regional Wildlife Habitat Evaluation

A generic regional model of wildlife distribution based on land-use and vegetation patterns has been developed to predict the consequences of land management schemes on the occurrence and relative abundance of faunal species. Discriminant function analysis was used to construct a linear decision scale that subsequently could be used to create county-level maps to reflect the occurrence of suitable habitat for three avian species.

All data included in the analysis were expressed on a county basis; that is, vegetation type and land-use categories were expressed as the proportion of each type or category within a particular county. Abundance statistics for the three main avian species were based on the 1973–1974 average counts from the annual breeding bird survey conducted by the U.S. Fish and Wildlife Service (USFWS).

The utility of this method is illustrated by a discussion of the results obtained on the analysis of pine warbler distribution. Geographically, the pine warbler is distributed across the 12 southeastern states of the United States. Categories of pine warbler abundance were determined by using data taken from 243 routes in a similar number of counties and assigning each route's count to one of the three groups. Thirty counties fell into the absence category (group 1); 178 in the 1–10 abundance-level group (group 2); and 35 in the >10 abundance group (group 3). Reduction of variables by eliminating redundant or nonsignificant ones resulted in a final set of five vegetation types. Oak-hickory, pine, and southern mixed forests were correlated ($P < 0.001$) with the occurrence of pine warblers; the greater the abundance of these habitat types, the larger the potential for pine warblers within the county. Conversely, the higher percent of oak-hickory, mixed mesophytic, and floodplain forests, the fewer the birds in the censuses.

A linear decision scale also was calculated for this species, and the county score was compared to the decision scale and mapped (Fig. 2.1). Consequently, 340 counties were classified as group 1; 322 counties as group 2; and 481 counties as group 3.

Subsequently, the data were manipulated to indicate how the distribution of the species might change with a change in the county's vegetation patterns.

Two scenarios involving the selective reduction in the two vegetation types correlated with the occurrence of the species; oak-hickory-pine and southern mixed forests were undertaken to demonstrate the effects on the pine warbler. A combination of a 20% reduction in oak-hickory-pine forests and a 50% reduction in southern mixed forests resulted in an increase in the species-absence group (group 1) from 340 to 558 and a corresponding decrease in the other two groups group 2, 322 to 318, and group 3, 481 to 267. The second removal scheme, 50% of oak-hickory-pine and 30% of southern mixed, elicited an even greater reduction in Group 3 counties, from 481 to 98. However, group 1 remained the same as in scenario 1, 558, with group 2 increasing from 322 to 487. From these studies, one can see the utility of developing various management-oriented land-use scenarios using these community indices to obtain estimates on how ecological associations may be altered.

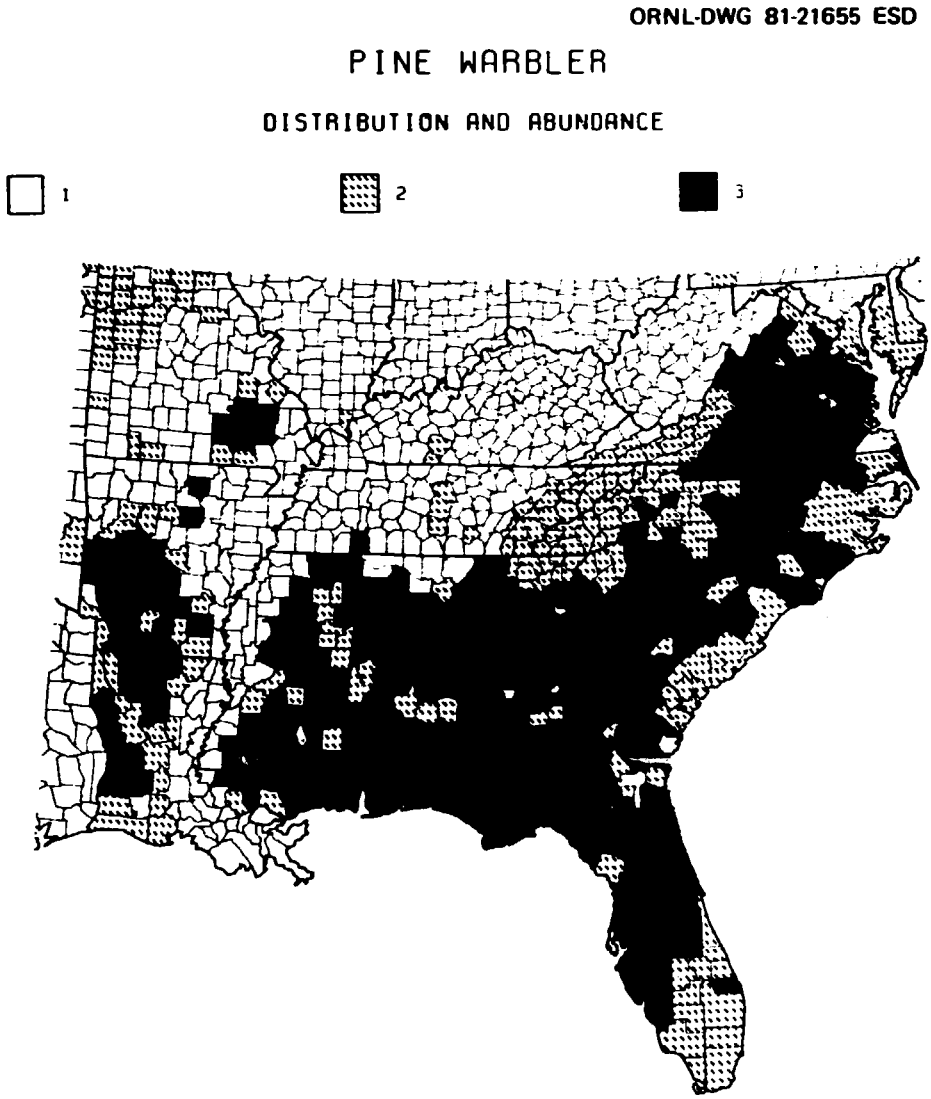

Fig. 2.1. Potential species abundance levels and distribution of the pine warbler based on a linear decision scale. Group 1 = absence of species; group 2 = species abundance levels of one to ten individuals; group 3 = species abundance levels of greater than ten individuals.

Regional Studies in Acidic Deposition

Soils, geology, and land use were used to classify counties in the eastern United States for their potential sensitivity to acid precipitation. Both the potential for changes in the nutrient status of forest soils and the potential for transfer of acid inputs to aquatic systems were included as indices of soil sensitivity. Surface soil properties, including exchangeable bases, pH, cation exchange capacity, clay content, and base saturation, were combined with the criteria developed by the Canada United States Transboundary Working Group to classify counties. Sulfate absorption capacity was used to further define the type of potential impact because sulfate absorption has been shown to prevent leaching of nutrient cations or the transport of acid to aquatic ecosystems. The resulting sensitivity maps are useful in showing broad regional patterns of the hypothesized soil sensitivity criteria, but because the maps may not reflect all conditions within individual counties, caution is urged in making interpretations that may depend on higher resolution than the county-level information will support.

Of the 1658 counties in the eastern 27 states, 28 and 18% were in moderate and high sensitivity classes, respectively, for potential changes in nutrient status resulting from acid rain (Fig. 2.2). Another 38% of the counties had sensitive surface soils characteristics but high sulfate absorption capacity of the subsurface horizons. Counties with predominantly Ultisols, which occur in most of the southeastern states, have subsurface horizons that are efficient sulfate adsorbers and that, consequently, would resist cation leaching by acid rain.

The second class of sensitive areas is defined as areas having the potential to transfer acid inputs to aquatic systems. These areas were classified considering total exchangeable base contents, sulfate adsorption capacity, soil depth, and bedrock sensitivity. The analysis indicated that 83% of the 1658 counties had low potential for transfer of acid to aquatic systems, 13% had moderate sensitivity, and the remaining 4% had high sensitivity.

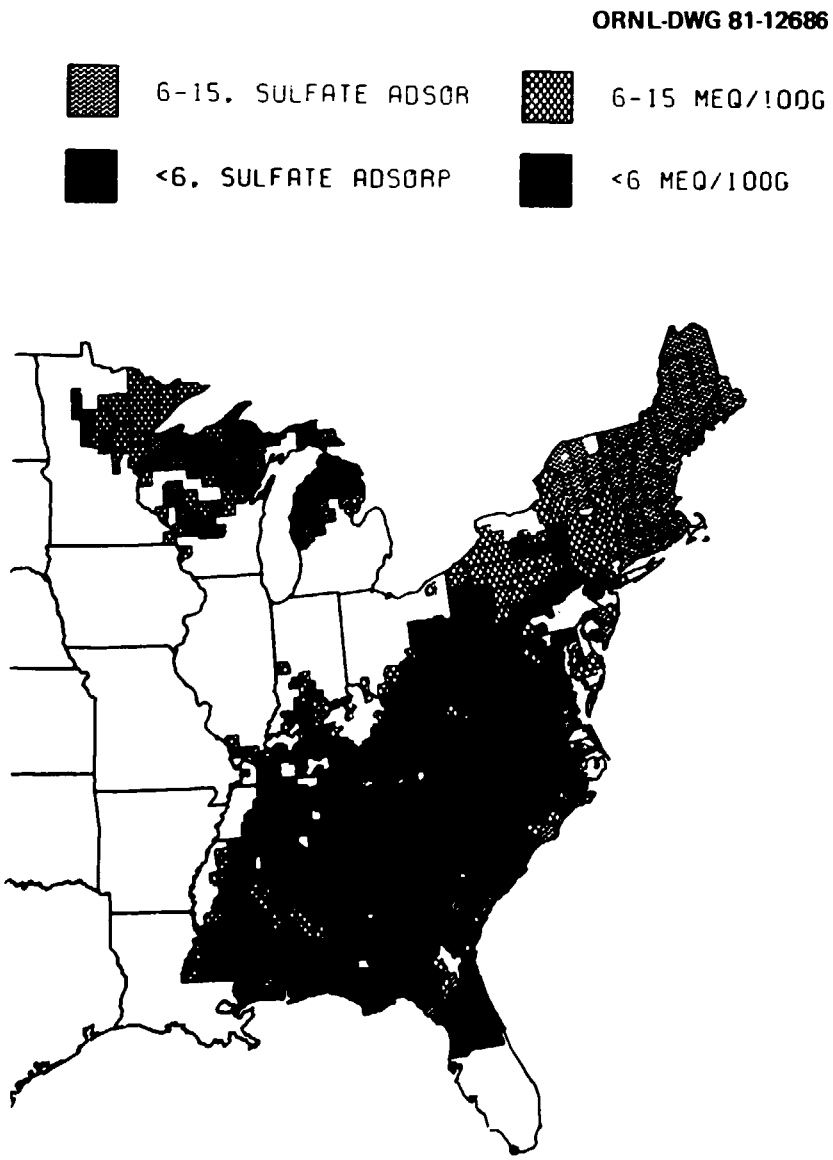

Fig. 2.2. Soil sensitivity to acid rain: forest areas with potential for changes in soil nutrient status based on exchangeable bases and sulfate adsorption.

Conflicts Atlas

A collaborative effort with the USFWS produced an atlas (Honig et al. 1981) that examined regional potential environmental conflicts. This atlas highlights areas in the conterminous United States of potential concern involving coal and minerals development activities and fish and wildlife resources, in particular the Important Resource Problem areas (IRPs), designated in 1980 by the USFWS as areas of emphasis in policy making. National and regional administrators and planners need such information because of several national, state, and local laws that currently require landowners to minimize disturbances and adverse impacts on fish and wildlife resources and protect and enhance these resources where practicable. This atlas serves as an initial screening tool for planners and administrators to help define areas that may require further analysis prior to development.

The atlas consists of two parts. The first part is a series of twenty 1:7,500,000-scale, county-level resolution maps of the conterminous United States that depict deposits of selected mineral resources (i.e., coal, copper, geothermal resources, gold, iron, molybdenum, nickel, oil shale, tar sands, peat, phosphate, silver, and uranium), USFWS IRPs, federal endangered and threatened animal species, and county names. By overlaying a wildlife map onto a mineral map, counties containing both mineral and wildlife resources will be identified. The maps can also be used with a variety of other 1:7,500,000-scale maps, such as those in *The National Atlas of the United States of America* (U.S. Geological Survey 1970). The second part of the atlas is a text that serves to orient the reader to the use of the 20 maps and that contains background information on IRPs, mineral commodities, and environmental impacts of mineral mining activities, as well as appendices that tabulate the information found in the 20 maps.

Modeling and Systems Analysis

Ecosystem Risk Analysis

Accurate prediction of ecosystem effects of toxic substances is currently impossible. The data describing toxic effects are limited to single-species laboratory tests that are designed inadequately for extrapolation to the field. In addition, the relevant effects of toxic substances involve complex ecological interactions that are poorly understood. Thus, the development of methods for making accurate predictions is critical, especially for new technologies such as synthetic fuel processes. In spite of these problems, if the relevant effects can be specified (e.g., such as eutrophication of a lake or reduction in catchable fish), then risk-assessment methods can provide an estimated probability of a given effect occurring.

We have tested this approach by explicitly considering ecosystem processes, the uncertainties of measurements, and the problems of extrapolation of lab data to field conditions. SWACOM, an aquatic ecosystem model (O'Neill and Giddings 1979), was used as a synthesis of relevant ecosystem processes. SWACOM mimics the pelagic portions of a lake by explicitly considering the abiotic environment, physiological mechanisms, competitive interactions, and trophic relationships of ten phytoplankton, five zooplankton, three planktivorous fish, and one top carnivore. The process-specific and species-specific effects of a toxicant can be affected by adjustment of an individual parameter of the model. The adjustment caused by toxic effects of all parameters can be described by an effects matrix. Uncertainties associated with the effects matrix can be simulated by repetitive solution of the model with randomly varying values in the effects matrix. Thus, the effects matrix describes the factors that contribute to ecosystem risk: (1) the explicit nature and magnitude of a toxic effect and (2) the uncertainty associated with the measurement and extrapolation to field conditions. Repeated solutions of SWACOM then synthesize these effects in terms of probabilities of observing the relevant ecological consequences.

Tests of this method demonstrate that uncertainties often dominate the effect on risk, that is, the risk associated with releasing certain toxicants may have more to do with our lack of understanding than the actual toxicity of the chemical. The complexity of ecosystem interactions can also produce unexpected results. For example, at some combinations of toxicity and uncertaintly, the zooplankton seem to prosper, while their food supply (phytoplankton) remains nearly constant. This phenomenon occurs because of a combination of events, including reduced competition between phytoplankton species for available nutrients and decreased predation by forage fish.

Toxicity effects are difficult or impossible to predict without the intervention of an ecosystem model, but the exclusive use of deterministic models to predict ecosystem effects often gives misleading results. The calculation of risks in the form of probabilities is more helpful and informative. Inclusions of uncertainty in the analysis and the statement of the probabilities of a result should become a part of environmental assessment procedures.

Aggregation Problems in Field Ecology

Because ecological processes are so complex that no system can be completely described, all measurements must be made on components of the system that are aggregates of many subcomponents and processes. We know that in nearly all cases aggregate behavior will differ from the sum of the component parts (Cale and Odell 1979, 1980; O'Neill and Rust 1979; Zeigler 1976, 1979; Cohen in press). Thus, the aggregation problem requires that the nature of ecosystems be described without being able to make direct measurements.

The task then is to determine from many possible situations what information can be extracted reliably from the behavior of aggregates and then to determine if the error resulting from the aggregation process will be less than the general noise in the system. The task can be stated in question form: When can we ignore the aggregation problem, and when will the problem be largely responsible for determining the results?

We devised 40 models that describe a variety of aggregation patterns of ecological relationships (Fig. 2.3). The patterns included parallel (Fig. 2.3a), triangular (Fig. 2.3b and 2.3c), and serial (Fig. 2.3d) aggregations. For each diagram, varieties of mathematical functions were considered that included state-independent inputs, linear and/or quadratic outputs, and donor, recipient, cross-product, or Michaelis-Menton interactions.

The necessary theoretical conditions that describe zero error are extremely restrictive, but establishing criteria that keep errors within acceptable bounds and that are robust across a broad range of system structures is possible. For instance, the results of theoretical considerations state that if the rate constants are exactly equal, there will be zero error. For the triangular and parallel cases (Fig. 2.3a 2.3c), the aggregate models gave 10% maximum error if the mortality/respiration coefficients did not differ by a factor less than 0.3 or greater than 3.0. The series aggregation (Fig. 2.3d) was very sensitive, with errors small only when the components were very similar and when the mortality/respiration coefficients were independent and the interactions were donor controlled.

If it is possible to measure parameters of the aggregated system at a different level of resolution than the disaggregated, then an aggregated system might possibly show less overall error. Figure 2.4 is a general view of the results in nomogram form. The expected uncertainty (coefficients of variation) associated with the parameters of the disaggregated model is shown on the abscissa. The ordinate is the percent increase in maximum relative error associated with the aggregate system. The three shaded areas represent 10, 20, and 30% coefficients of variation on the parameters of the aggregated system. Results show that the effects of aggregation are not lessened by parameter uncertainty but that when the aggregated system can be measured at higher resolution than the disaggregated, then the total system uncertainty can be less.

Analysis of Positive Feedbacks in Systems

A popular view among theoretical ecologists has been that an ecosystem normally resembles a homeostatic cybernetic system, that is, one where negative feedback mechanisms predominate and act to restore equilibrium

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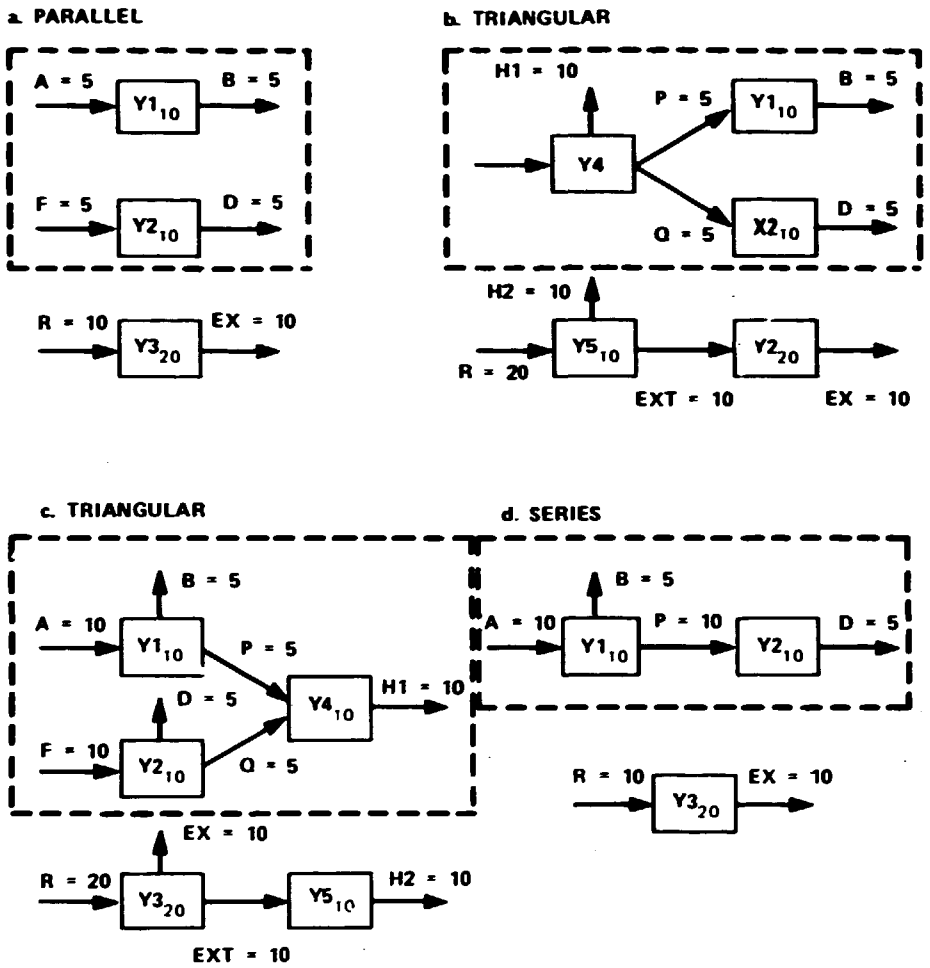

Fig. 2.3. Four system configurations in which Y1 and Y2 are aggregated into Y3. Numbers refer to equilibrium fluxes and standing crops. Because all calculations in the paper are based on relative error, the values selected are arbitrary and have no effect on the conclusions reached.

conditions following a perturbation. A few ecologists, however, have argued that positive feedbacks are as ubiquitous in nature as negative feedbacks and that positive feedbacks drive such processes as ecological succession.

We have collected or developed mathematical models for a large variety of ecological systems characterized by important positive feedback loops. Analyzing the stability of such models is important to determine whether the positive feedbacks are strong enough to lead to "deviation-amplifications" that change the state of a system. We have used theorems from matrix theory (in particular, the theory of M-matrices) to provide simple and convenient criteria for stability (e.g., Travis and Post 1979; DeAngelis, Travis, and Post 1980). Two examples of the use of these criteria are given below.

Coevolution of Mutualists. Mutualism provides striking examples of coevolution. Association of marine fish and cleaner organisms, ants and acacias, and yuccas and their pollinators, for example, probably began as

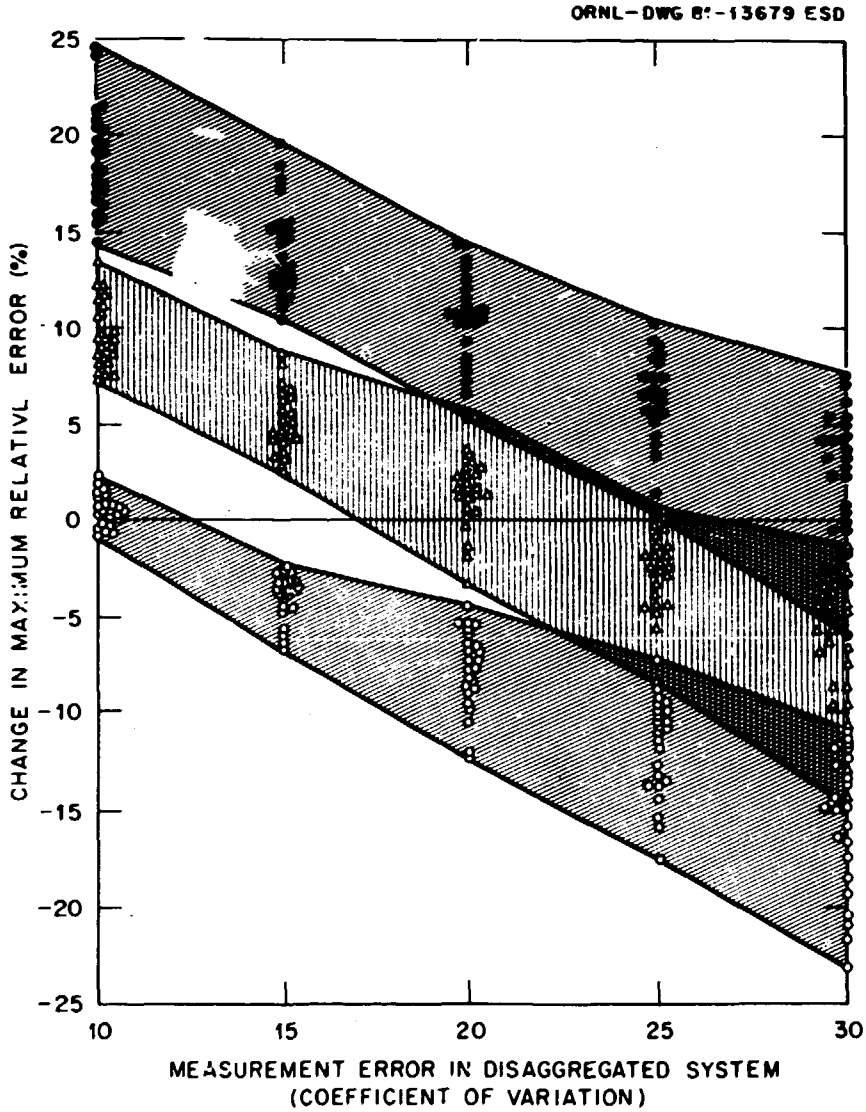

Fig. 2.4. Change in maximum relative error when using an aggregate model with measurement errors of 10% (lower regions), 20% (middle region), or 30% (upper region) to describe a disaggregated system that is also subject to measurement error (abscissa).

casual commensal association that was subsequently strengthened by coevolutionary positive feedback. Figure 2.5 depicts a hypothetical commensal association into which a new guest phenotype (phenotype 3), competing with the original guest phenotype (phenotype 2), has been introduced. If phenotype 3 affects the host positively in turn (mutualism), the commensal relationship will increase the host's fitness and, indirectly, its own. However, by aiding the host, phenotype 3 also increases the fitness of its competitor, phenotype 2, by the same increment it increases its own fitness. Thus, there would be little coevolutionary force toward mutualism. Spatial isolation may change this situation. If host-guest pairs involving phenotypes 2 and 3, respectively, are spatially isolated so that the mutualism of phenotype 3 does not indirectly help phenotype 2, then the mutualism could strengthen through evolutionary time.

To determine if such isolation actually is important, the literature was surveyed to tabulate all the obligate mutualistic interactions (where there are certainly mutual benefits) that could be located (Table 2.1). Many of

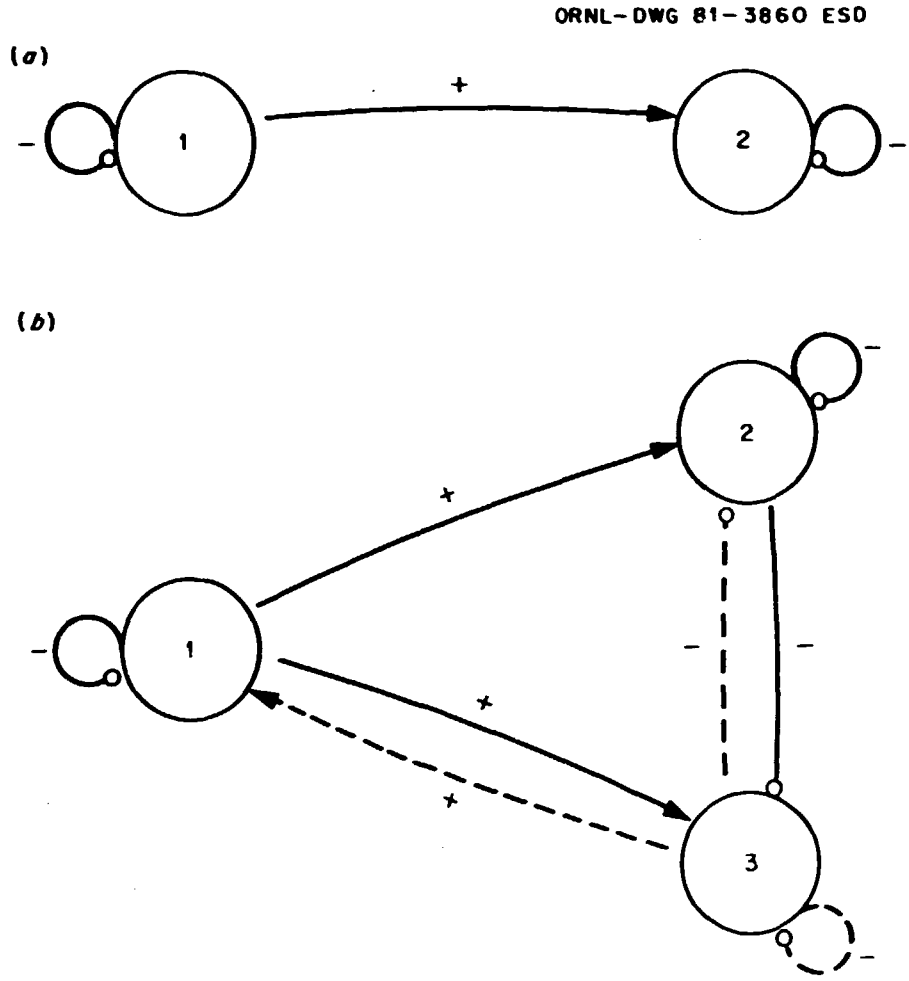

Fig. 2.5. ***(a)* depicts an ancestral commensal relationship between host species 1 and guest species 2, and *(b)* shows the three population systems when a new phenotype, population 3, invades.** Population 3 is similar to population 2 except that it is capable of providing benefit to species 1. Dashed arrows indicate interactions that are nearly zero when population 3 is small as it would be when invading.

the obligate mutualistic interactions do, in fact, involve isolation of mutualist pairs. Others such as the aphid interaction may also be counted as examples if the definition of individual is stretched to include populations of genotypically identical individuals or evolutionary individuals (Janzen 1977). Information is lacking on the natural history of other cases (e.g., moth-yucca). Therefore, while the hypothesis that isolation of mutualist pairs is necessary for obligate mutualism has some support, it is still tentative at this point.

Spread of Disease. The spread of disease in a population depends on the rates of contact between susceptible individuals in a local population and infected individuals both within that local population and in other populations that may be reservoirs of disease. Occasional transmissions between semiisolated populations can form positive feedback loops that continually reintroduce the disease in local populations and prevent it from ever disappearing over a large region.

Standard models describing the spread of infectious diseases divide the host population into susceptibles *(X)*, infecteds *(Y)*, and immunes *(Z)*. Members of the host population move from one class to another at rates specified by the rate of infection, $f(X, Y)$; rate of recovery, V; and loss of immunity, γ. Newborn individuals are

Table 2.1. Obligate mutualists

Organisms	Benefits provided
Endosymbionts	
Lichens (fungus-algae)	Favorable environment sugars
Coelenterates-zooxanthellae	Favorable environment sugars
Animals (ruminants, termites) - bacteria	Favorable environment proteins
Cells-organelles	Favorable environment food, organization
Higher plants-bacteria	Favorable environment nitrates
Insects-fungi, bacteria	Favorable environment various organic compounds
Algae-protozoa	Favorable environment nutrients
Coelenterate-fish	
Sea anemone-damselfish	Protection food, habitat
Pollination systems	
Figs-wasp	Larval food pollination
Yucca-moth	Larval food pollination
Obligately outcrossed plants-insects	Nectar pollination
Ant-plant associations	
Ant plants-ants	Domicile nutrients, germination
Various trees *(Acacia, Cecropia, Barteria, Ochroma)* - ants	Domicile, food protection, "allelopathy"
Insect-insect	
Ant-aphid	Dispersal, reproduction, protection food

introduced at a rate $g(X, Y, Z)$. Death rates for infecteds and others are, respectively, $b + \alpha$ and b. All the gains and losses for a given local population i may be combined into a set of differential equations:

$$\frac{dX_i}{dt} = g_i(X_i, Y_i, Z_i)(X_i + Y_i + Z_i) - b_i X_i - \sum_j f(X_i, Y_j) + \gamma_i Z_i \quad ,$$

$$\frac{dY_i}{dt} = \sum_j f(X_i, Y_j) \quad (\alpha_i + b_i + V_i) Y_i \quad ,$$

$$\frac{dZ_i}{dt} = V_i Y_i - (b_i + \gamma_i) Z_i \quad ,$$

where the summations represent the interactions between susceptibles in one local population and infecteds in others.

The dynamics of each population in isolation from others are well known. If the population size is below a certain threshold, the rate at which new susceptibles contact those infecteds will be too low to maintain the disease in the local population. However, if there is a mixing between local populations, each of which is below this maintenance threshold, the contact rate may be high enough for the disease to remain endemic in the total population made up of these subpopulations. Analysis of the entire positive feedback network demonstrates that if the transmission rate of the disease is linearly proportional to the length of time susceptibles and those infected are in contact, then mixing between local populations under these conditions will not lead to endemism. If, however, the infection rate is a concave function of the length of time an individual spends in a given local population (Fig. 2.6), the disease may become endemic.

Environmetrics

University of Minnesota-Duluth (UMD) Gasifier Data Management

The U.S. Department of Energy's (DOE's) Gasifiers in Industry Program is part of a large-scale activity to develop and improve technologies for conversion of coal into clean gaseous fuels that can be used as substitutes

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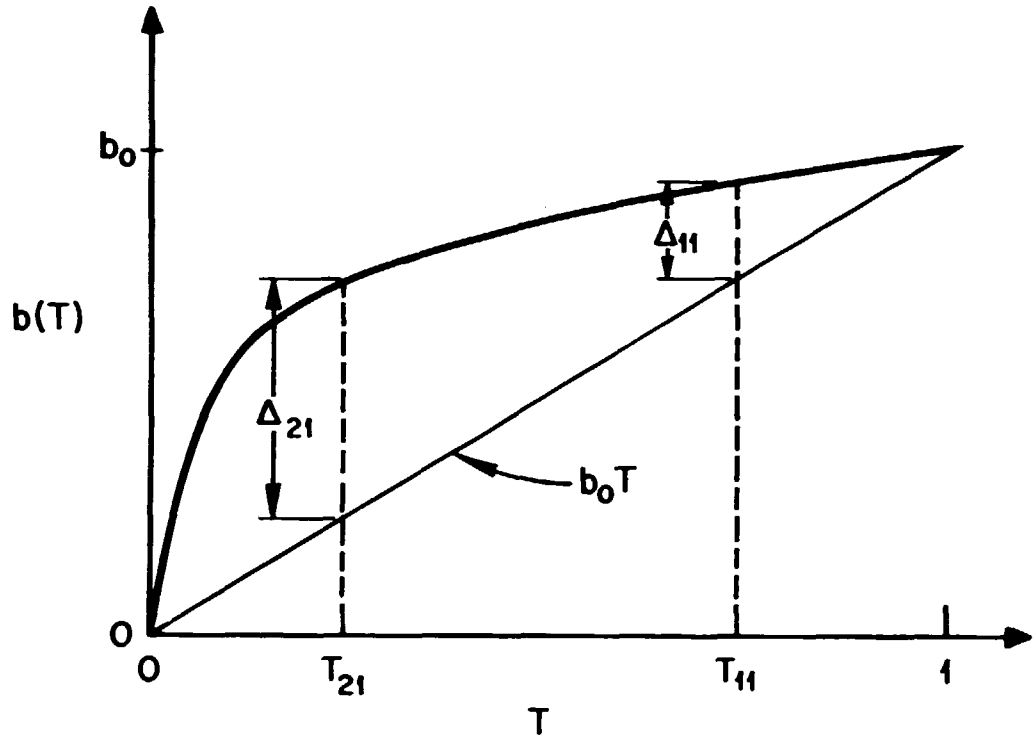

Fig. 2.6. Example of an infection rate function *b(T)* with values Δ_{21} and Δ_{11} ($\Delta_{11} < \Delta_{21}$) representing enhancement of infectibility resulting from mixing between the two population centers. $T_{11} + T_{21} = 1$.

for oil and natural gas. This program involves the demonstration and evaluation of existing technology for low-Btu coal gasification in several different industrial, commercial, and institutional settings. An integral part of the demonstration effort is the assessment of potential health and environmental hazards associated with coal gasification. For this work an approach had to be developed to manage the research information.

Since the late 1960s, the ESD has been involved with data management of large, interdisciplinary scientific projects. The International Biological Program (IBP), funded by the National Science Foundation, contained a data management component that aided in the integration of field and laboratory experimental data. From the IBP came an understanding of how to organize, computerize, and synthesize projects using the tools of computers and statistics. These experiences guided the UMD gasifier data management effort.

Automated monitoring of the gasification process parameters began in January 1979; detailed discussion of the process-monitoring techniques and computer software are reported in Million, Brand, and Ruenger (1981) and Strand et al. (1981). The total data file constituted about 3.5 million records taken during eight test runs of the gasifier over a three-year period.

Several environmetrics tools were developed to organize and account for the research results from UMD. A computerized tracking system can identify what samples were taken during the three-year period, where they were taken, and what were the results from the testing and evaluation performed on each of the samples. The system allows for status and summary reports to be created as research results are received.

A series of graphical display capabilities were developed to allow statistical analyses, development of charts, and plotting of time traces of combinations of the process parameters or three-dimensional projections of the parameters in terms of time or sampling location. This work allowed for selection of time periods that

represented appropriate sampling intervals for various statistical comparisons. Also, these graphical capabilities provided for the ability to inspect the data rapidly for outliers by presenting the large volumes of data on the output screens.

With the computerized procedures for collating, merging, and modifying each of the various data components from UMD, comparisons across time and location within the gasifier were possible. These comparisons were the main objective of the data management project. Integration of the process parameters with effects and test data provided for a synthesis of the data for final assessment.

H-Coal Data Management

Similar to the UMD assessment project, a coal liquefaction process assessment (H-Coal) was implemented in 1980 to evaluate potential environmental and health effects. The three-year H-Coal project has focused this past year on process monitoring and sampling and then examining the products and effluents for possible occupational exposures and environmental impacts. The data management project has dealt with the sampling design and organization and tracking of the samples. The computerized tools used for these efforts have necessitated only slight reconfiguration of the tools developed in the UMD project. As results from the H-Coal sample characterizations become available, statistical and graphical tools developed for the UMD project also will be modified for the needed analyses.

Research Data Base Management for the U.S. Army Corps of Engineers

Research has been initiated to develop computerized models for analyzing, integrating, and synthesizing summaries of aquatic communities in the Mississippi River with the Waterways Experiment Station (WES) and the Lower Mississippi Valley Division (LMVD). In the WES study, benthic, fish, and zooplankton species in several habitats have been studied to characterize species composition and to evaluate changes over time. Physical and chemical properties of the habitats were related to changes in community structure.

In the LMVD study, relationships between physical and chemical habitat characteristics and biological productivity have been examined on a statistical basis. Currently, geographic coverage includes the Mississippi riverine habitats between Cairo, Illinois, and Venice, Louisiana.

Carbon Cycling and CO_2 Research Data Management

Mapping of major world ecosystem complexes using computerized cartographic techniques has continued with the additional definition of 6 ecosystem classes, for a total of 48 classes. The data base underwent extensive editing and refinement as new information became available. The map was presented at a number of national and international meetings, with suggestions resulting from these critiques being incorporated into the data base. Efforts are now under way to finalize the map for publication in early 1982.

During the year, the GEOSECS data base was obtained from the Scripps Oceanographic Institute and was implemented on the ORNL computer system so that it can be accessed in an efficient and fast manner to retrieve selected data.

The U.S. Forest Service Continuous Forest Inventory (CFI) county summary data base was mapped by individual species as a part of the forest mapping (FORMAP) project. This data base is also being utilized to determine transfer flux values as a part of the bioclimatology subproject of the carbon cycling program. In several states, the summaries are provided only on a unit basis. Efforts are under way to build subsets of the unit data for county-level representation so that the data can be mapped on a county level for the entire eastern United States.

The CO_2 information project sponsored by DOE, through collaboration with the Oak Ridge Associated Universities (ORAU) CO_2 assessment team, was defined and implemented on the DEC-System 10 interactive computer system, an on-line data base containing numeric data being utilized by the assessment team. A "history" file for each data set contains information on formatting, updating, and other features unique to the data set. A "directory" file contains information on what data are included in the on-line data base. A review of the CO_2 issues, to be published as the *CO_2 Annual Review, 1982*, will contain a chapter on evaluated numeric data of special significance and utilization to the CO_2 research community. Eight data sets were selected for inclusion, and all data are presented in tabular summaries and graphic displays. The pathway for obtaining additional information or detailed data is spelled out in the report. Schematics of the radiation balance, carbon cycle, and climatic history drawn to scale for each compartment are also included, with the idea that these definitive diagrams will become the standards of the CO_2 community.

National Environmental Research Park (NERP)

Establishing a Regional Data Base for NERP at Oak Ridge

Two major objectives of the NERP are to provide research sites for long-term ecological research, and to compile a regional resource data base for evaluating potential effects of developing energy technologies. Extensive natural resource data, including soils, surface geology, forest inventories, and surveys of other biota, have been collected at Oak Ridge for a number of years on the lands administered by the DOE. Establishment of the NERP at Oak Ridge emphasized the need for a natural resource data system that would include storage, retrieval, and spatial modeling capabilities. Such a data system can be useful for analyzing energy technology impacts on two scales: (1) in the southeastern region of the United States and (2) locally on the Oak Ridge NERP. Initially, we have used extant data available for the Oak Ridge Reservation and surrounding areas.

IMGRID (Holmes and Jolly 1980) — a data storage, retrieval, and modeling system — was selected for use because it was readily available, was simple to use, was suitable for most applications, and could be utilized at minimal cost. IMGRID utilizes a coordinate system for data storage and retrieval and allows overlaying and comparing data values from different sources such as geology and soils as well as allowing evaluation of data from surrounding coordinates such as distance to roads or streams. Data were digitized on 0.5-ha grid cells. Soils, surface geology, slope aspect, slope angle, slope steepness, and land use are currently included in the data base, and forest inventory data are now being added. The utility of this data system is demonstrated in the following example.

An assemblage of plants, many of them ordinarily found in the prairie states, occurs throughout the ridge and valley on shallow limestone-derived soils. These plants occupy areas known as barrens (DeSelm et al. 1969) and are similar to those in the cedar glades of Middle Tennessee. Since several species that occur in the glades are under review for protection under the Endangered Species Act (USFWS 1980) and others that occur in the barrens at Oak Ridge have been suggested to be protected (Parr and Taylor 1978), we were interested in locating those soil units that are representative of barrens as they have been mapped in the soil surveys. These soils are currently mapped as Gladeville soils. The occur on undulating to rolling bare or nearly bare rocky places with slopes of 2 to 20%. These soils are lithic Rendolls formed in residuum weathered from thin-bedded flaggy limestone and probably would have been previously classified in the Rendzina great soil group. Most older surveys would have classified these soils as "rockland" although some would have been designated Colbert, Fairmount or Colbert/Talbott complex (National Cooperative Soil Survey, series description).

By combining slope information with series designations, we printed soil map units from the older survey in the Colbert and Colbert/Talbott complex that are possibly barren/glade soils as well as the Gladeville soils. From this analysis on the Comparative Animal Research Laboratory (CARL) lands, we located one large barren

area, now in pasture, that was not previously identified and a smaller area west of the Clinch River near several barren areas that had been previously surveyed.

Forest Resources Management

The timber inventory prior to 1974 was based on continuous inventory data that were of limited extent. A new inventory and mapping system was devised in 1974 to describe the forests on the Oak Ridge Reservation by timber stands within a designated compartment. The revised forest compartment system contains 28 management units and 7 alternates (in the ORNL, K-25/Y-12 plant facility buffer zones). During the past year the last compartments were cruised, thus completing the reinventory process that was designed to update and document the changes that have occurred over the past seven years. These data are currently being placed into the IMGRID data storage and retrieval system.

In compartment 2, a 50.6-ha area located on a ridge top was planted in loblolly pine. This area was the only effort at site preparation and planting during the year.

Wildlife Resources Management

During 1980, 98 white-tailed deer were killed by vehicles on the Oak Ridge Reservation roads, an increase of 25 over the number killed in 1979. As in the past, the majority of fatalities occurred during the rutting season (November and December), with approximately 41% of the kills reported during this time. The geographical distribution of road kills was similar to that reported in 1979. However, the increase in road kills in the eastern part of the Oak Ridge Reservation, first noticed in 1979, continued in 1980. While 6 deer were killed in this part of the Oak Ridge Reservation during 1979, 21 were killed during 1980.

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3. EARTH SCIENCES SECTION

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Introduction

Contributions of scientists in the Earth Sciences Section pervade every program activity in the Environmental Sciences Division (ESD). At the same time, staff scientists of the section are continually exploring new areas and accepting new challenges where the scientists' talents may be employed. The reader is referred to the major sections of this report for the variety of contributions by earth scientists in the following areas of discipline: rocks, soils, air, water, and sediments and the interactions of all of these with biota.

A growing interest is in the support area of nonnuclear solid waste technology. As in the past, the contributions are divided into two segments: research related to the biological aspects is reported in the Advanced Fossil Energy Program, and research bearing on the Resource Conservation and Recovery Act (RCRA) is reviewed in this section.

Developing information for one activity frequently becomes useful and needed in other related activities. Thus, the hydrologic efforts performed for the Low-Level Waste Research Program have been extended to assist the Operations and the Industrial Safety and Applied Health Physics divisions; similarly, geochemical interactions have proved valuable to the Health and Safety Research Division. A brief summary of those activities is included.

Finally, a synopsis is provided on programs where the lead group or the focus of attention is outside the Oak Ridge National Laboratory (ORNL). Four separate outreach activities are described; these activities represent the highly specialized talents of those who have been able to complement and supplement other programs of broader scope.

Nonnuclear Solid Waste Technology

Nonnuclear solid wastes generated by energy technologies include wastes with a wide range of physicochemical properties. Management of these wastes involves either utilization or disposal practices. In an ecological sense, in terms of both material and energy conservation, utilization of the waste in a resource recovery process or as a material in land reclamation, building, or road construction projects is preferred. However, because of prevailing economic conditions, most solid wastes from energy-producing technologies will be disposed of in either ashponds or landfills. Disposal of some energy-related wastes will have serious long-term health and environmental effects. The principal goals of the nonnuclear solid waste research are to evaluate what these effects might be and how they might be mitigated. Research is centered on the following objectives:

1. to assess the environmental impact of disposing of energy-related solid wastes;
2. to determine the characteristics of solid waste that may represent a potential environmental impact;
3. to evaluate the transport and effects of pollutants from solid waste disposal sites;
4. to develop appropriate environmental control technologies (pre- and postdisposal) for energy-related solid wastes, including fixation/stabilization of wastes and conceptual designs of landfills; and
5. to establish environmental monitoring requirements for solid waste disposal sites.

Stored Solids Study

Research relative to the characterization and environmental implications of the disposal of coal conversion solid wastes has been conducted over the past three years. The work represents the most comprehensive evaluation done to date of the leaching characteristics of gasifier ash/slags from six proposed coal conversion processes: Cogas, British Gas/Lurgi, Grace/Texaco, U-Gas, SRC-I/Koppers-Totzek, and SRC-II/Texaco.

The major solid waste in coal conversion is ash or slag from the gasification process. A commercial-scale liquefaction or gasification plant (capacity of 50,000 bbl/d or 8×10^3 m^3/d will generate more than 4000 tons of ash/slag a day.

Coal gasification ash/slags are often of larger particle size and more glassy in appearance than fly ashes from modern direct-fired coal combustion processes (Francis et al. 1981, Turner and Lowry 1980). These characteristics are acquired in slagging-type gasifiers where temperatures exceed the fusion point of the mineral matter in the feed coal and the molten slag is rapidly quenched in water. Elemental analysis of the ash/slags indicates that they can be generally characterized as ferroaluminosilicates (e.g., iron and aluminum concentrations of approximately 10% and silicon concentrations of approximately 20%). Carbon contents are usually less than 5%. Exceptions to this are the fine fractions of some gasification processes. Sulfur contents are usually less than 1%; however, some processes indicate that sulfur concentrations in the range of 2–3% are typical.

Work at ORNL during 1980 and part of 1981 was aimed at characterizing the ash/slags that would be generated in future coal conversion plants from the standpoint of RCRA regulations. Leaching studies on the ash/slags of six coal conversion processes revealed that these wastes would be classified as nonhazardous wastes under RCRA. These wastes, even though classified as nonhazardous relative to such toxic wastes as pesticides, dye wastes, and polychorobiphenyls (PCBs), will very likely contaminate ground-water aquifers around landfills in which the wastes are disposed. For example, some of the ash/slag leachates were found to be highly acidic (pH <3.5) and to contain levels of contaminants that exceeded water quality criteria concentrations of SO_4^{2-} greater than 5000 mg/L and excessive concentrations of cadmium, nickel, and zinc. The main problem is not the acute toxicities of these wastes but the persistent long-term release of specific elements and compounds from the high volume of discarded wastes.

To assess how effectively soils attenuate the hydrologic transport of contaminants to ground-water aquifers, waste/soil lysimeters were constructed using disposal-site soil and the ash/slag. Continuous-flow lysimeters containing waste I and its disposal-site soil revealed that this soil did not adequately attenuate the transport of sulfate nor did it neutralize the acidic character of the solid waste leachate (Table 3.1). Leachate from the waste/soil lysimeters was much more acidic (pH 4.3) than that from the lysimeter containing only soil (pH 6.0). To date, toxic trace elements have not been measured in the leachate or in the adjacent soil layers from these lysimeters. The high sulfate concentration (about 2000 mg SO_4^{2-}/L) in the leachate from the waste/soil lysimeter would also be a serious threat to ground-water quality in the vicinity of a landfill containing waste I. Taking into consideration the quantity of these wastes to be generated at a commercial coal conversion facility (2700×10^3 to 4500×10^3 kg/d), it is conceivable that ground-water aquifers that may be needed or used for human consumption will be contaminated if disposal is carried out in nonsecure landfills. To avoid such an occurrence, which would not likely be detected until years after commercial operations had started, a disposal plan should be directed at mitigating or eliminating the undesirable characteristics of the solid waste leachates. Such a plan would entail a method for neutralizing the leachates and containing the sulfates.

Solid Waste Extraction Project

The purpose of this work is to determine the degree of migration of organic and inorganic constituents of solid wastes into the environment using two extracting procedures, one established by the U.S. Environmental Protection Agency (EPA-EP) and one proposed by the American Society of Testing Materials (ASTM-Method A). The work is in support of the Solid Waste Sampling and Characterization Program managed by the Laramie Energy Technology Center (LETC). The solid waste samples are representative of various fossil energy technologies. The wastes are extracted in duplicate by two procedures: the EPA-EP and the ASTM-Method A. This research defines the limits of precision for organic and inorganic contaminants in solid waste extracts relative to the extraction procedures and addresses the associated analytical methods.

Table 3.1. Leachate quality from continuous-flow waste/soil lysimeters containing waste I[a]

	Site soil[b]		Ash/slag[c]		Ash/slag over site soil[d]		
Time (d)	pH	SO_4^{2-} (mg/L)	pH	SO_4^{2-} (mg/L)	pH	Electrical conductivity (μS/cm)	SO_4^{2-} (mg/L)
7	6.5	12	4.0	e	6.0	104	18
14	5.5	13	e	e	5.7	118	28
21	6.2	12	4.1	6130	5.5	1182	719
28	6.1	12	4.0	3790	3.8	2170	1100
35	6.7	9	3.7	2360	4.2	2800	1435
42	5.5	<1	3.6	1890	4.2	2875	1910
49	6.2	<1	3.7	1980	4.4	2740	1990
56	5.9	<1	3.7	1960	4.3	2825	2035
63	5.0	<1	3.6	1870	4.3	2775	2040
70	6.1	<1	3.5	1860	4.2	2735	2080
77	6.2	<1	3.5	1800	4.3	2640	1975
84	6.1	<1	3.6	1880	4.3	2545	1935

[a]Flow rate of 1 L/d of distilled water into 56-cm-diam columns.
[b]Subsurface soil taken at the proposed waste I disposal site, 3 cm (20 kg).
[c]Waste I, 13 cm (50 kg) under 3 cm (20 kg) of site soil.
[d]Data are average values from two replicates; the ash/slag (13 cm, 50 kg) is between two soil layers, 3 cm (20 kg) on top and 15 cm (50 kg) on the bottom.
[e]Measurement not made.

Toxicity of Solid Waste Leachates

To evaluate the potential toxicity of a leachate from an industrial waste that has been codisposed of with a municipal waste, a laboratory extraction procedure is needed that models the leaching action the waste would undergo when disposed of along with a municipal waste. Currently, under the RCRA, toxicity is determined by the extraction procedure toxicity test (EPA 1980), henceforth referred to as EPA-EP. Toxicity criteria are based on the concentrations of eight elements in the Primary Drinking Water Regulations (As, Ba, Cd, Cr, Pb, Hg, Se, and Ag), four pesticides (Endrin, Lindane, Methoxychlor, and Toxaphene), and two herbicides (2,4-D and 2,4,5-TP Silvex) observed in the extract. The EPA-EP is used as a regulatory test to classify a waste relative to a landfill management scenario. The EP, however, has a number of limitations, the most important one being that a waste containing other toxicant materials is not included in the present criteria. For example, the EPA-EP does not model the effects that higher molecular weight organics present in a municipal leachate have on the leaching of a solid waste. Other experimental factors not addressed in the current EPA-EP include such variables as the effectiveness of extraction, the deficiency of expressing kinetic relationships of components extracted, and the relevancy to real-world leachates. In terms of applying biological testing to EPA-EP extracts, the EP is severely limited in that the acetic acid used in the procedure interferes with aquatic toxicity- and phytotoxicity-testing protocols (Epler et al. 1980).

The primary objective of the 1981 research was to assess the capabilities of five selected aqueous extractions to remove organics from 11 solid wastes known to contain significant quantities of organic compounds. A desirable, relevant extraction needs to simulate disposal conditions but not to be overly complicated in protocol nor to contain constituents that would interfere in biological assays. Of the five extractions selected for this study, four were batch-mode extractions using the following extractants: (1) acetic acid (EPA-EP), (2) distilled deionized water, (3) distilled deionized water with a sodium displacement resin, and (4) citrate buffer. The fifth procedure was an upward flow column extraction using distilled deionized water. Both the EPA-EP and the

citric acid media are intended to simulate leachates derived from codisposal of industrial wastes with municipal wastes. The remaining three extractions do not simulate such a disposal regime but reflect disposal conditions dominated by the chemical and physical characteristics of the waste per se.

Solid waste extracts (final liquid-to-solid ratio of 20:1) produced from the five extractions were compared in two ways. First, the total area of the gas chromatogram (excluding the solvent peak) was compared as a measure of the total mass extracted by the leaching medium. Because of the low levels of organics present in the extracts, gravimetry was not useful. Under these chromatographic conditions, 15–20% of the total mass might be expected to be accounted for (i.e., 80–85% would not be chromatographable). Second, the quantities of individual compounds extracted by the leaching media were compared using gas chromatography/mass spectroscopy (GC/MS) analysis. While obtaining absolute quantitative data on the individual compounds was not possible, the equivalent treatment of all extracts ensured reliable comparison. Appropriate blanks were run on all procedures. Only the citrate buffer extraction in which phthalates were detected contained levels of extraneous contaminants above background.

The data for total chromatographable organic content (Table 3.2) reveal that the column extraction procedure is superior in extracting organics. Additionally, an estimate of the total elutable concentration is given for each sample. This estimate is based on average integrator response for aliphatic hydrocarbons and is not to

Table 3.2. Total chromatographable organics in solid waste extracts
(Liquid-to-solid ratio, 20:1)[a]

Waste sample No.	Extraction procedure (EP)					Estimated total in EP (ppb)
	EPA-EP	H_2O	Na-resin	Citrate buffer	Column	
1	100	307	872	262	2173	328
2	100	79	136	10	674	224
3	100	150	32	197	732	31
4	100	113	84	45	632	340
5	100	360	7	14	414	700
6	100	3747	263	420	4935	6
9	*b*	100	42	44	468	37[b]
10	100	151	67	90	230	754
11	100	49	40	69	891	2740

[a]Relative to concentrations observed in EP extracts.
[b]Total in distilled water EP.

be taken literally. Rather, the estimate can be used to make comparisons between samples. The conclusions that can be drawn from these data are as follows:

1. In every case, the column procedure extracted more organic material than did any of the batch extractions regardless of the level of organic material in the waste, although the differences are greatest for low levels of organics.
2. Within the set of batch extracts, no one procedure appeared to be necessarily superior, although the sodium-resin displacement was generally inferior to the others. Rather, the sample type and pH seemed to be more critical parameters.

The analyses for individual compounds in the solid waste extracts using GC/MS confirmed that the column extraction procedure extracted significantly more organics, usually by factors of 5 to 50.

Leaching Characteristics of Raw and Retorted Chattanooga Shale

One of the major environmental concerns in the implementation of an Eastern oil shale recovery technology is the contamination of surface waters and ground waters by leachates of the retorted shale and associated mining residues. To appreciate some of the problems involved, samples of raw and retorted Chattanooga shale were leached with distilled water to assess the preliminary character of these solid waste leachates.

Samples of retorted Chattanooga shale were found to contain a significantly higher fraction of fines than those in raw shale. For example, nearly 30% of the weight fraction of the retorted shale was composed of particles <1 mm diam as compared with approximately 5% in the raw shale samples. The dominant size fraction (2–1 mm diam) of both the raw and retorted shale (constituting 40–45% of the initial sample) was used in column-leaching studies.

The most significant characteristics of the solid waste leachates were the low pH and the high concentrations of sulfate and toxic trace metals in the leachates from the raw shale. The leachates from the raw shale were quite acidic (pH ranged from 2.46 to 2.96) and contained excessive sulfate concentrations (7620 to 563 mg SO_4^{2-}/L), while the leachates from the retorted shale were mildly acidic (pH ranged from 4.27 to 6.91) and contained less than 250 mg SO_4^{2-}/L. The initial sulfur concentrations in the raw and retorted shale samples were 6.7 and 3.1%, respectively, indicating that a significant proportion of the sulfur in the shale is removed during the retorting process. Leachates from the raw shale had concentrations of Fe, Al, Co, Cu, Ni, Zn, and As that constituted potential environmental concern.

Support Studies in Solid Waste Research

At the request of the U.S. Department of Energy's (DOE's) Office of Health and Environmental Research (OHER), a document entitled "Status of Health and Environmental Research Relative to Solid Wastes from Coal Conversion" was prepared by ESD. This summary document was formulated in cooperation with staff members of Battelle Pacific Northwest Laboratory, Los Alamos National Laboratory, and Lovelace Inhalation Toxicology Research Institute. The purpose of this document was to evaluate the status of and to make recommendations about the future needs of health and environmental research relative to solid wastes from coal conversion processes. The objectives were to evaluate the health and environmental implications resulting from solid wastes generated on implementation of a commercial coal synfuel technology and to identify research that will elucidate long-term effects of solid waste disposal on human health and environment.

Overall conclusions resulting from the review of past research and ongoing research on coal conversion solid wastes were that (1) research is fragmented among a variety of research projects and (2) research was near-term oriented and confined to assessing the wastes' regulatory status under RCRA and their immediate toxicity-mutagenicity characterization. Health and environmental research relative to coal conversion solid wastes has not been directly addressed by any specific federal or state research programs. Solid waste research has been conducted as part of larger programs addressing general health and environmental research related to synthetic fuels development or environmental assessment programs directly involved with DOE's Fossil Energy Program on coal conversion demonstration projects. Emphasis in solid waste health-related research centered on short-term mutagenic testing of the organic and aqueous solid waste extracts. Environmental research was directed at the physicochemical characterization of the waste and evaluation of the short-term aquatic toxicity and phytotoxicity of the aqueous solid waste extracts. The characterization research emphasized elemental analysis of the waste and inorganic analysis of the aqueous extracts. With respect to gasifier ashes and slags, considerable effort was expended in evaluating their regulatory classification under RCRA. Available data indicate that gasifier ashes and slags will be classified as "nonhazardous" waste under RCRA and will be disposed of by back-to-pit or landfill waste management practices. However, no attempt was made to evaluate the long-term effects on human health and environment as a consequence of such disposal practices.

The overall recommendations included a research program to resolve the potential health risks and long-term environmental concerns associated with coal conversion solid wastes. The research program should initiate two major research tasks immediately, one health related and the other dealing with the environmental fate of contaminants from coal conversion solid wastes. The health-related research should determine the general toxicological effects of inhaled, sorbed, and ingested solid waste materials. Emphases should be placed on organic-laden wastes such as tars, biosludges, and oily wastes because these waste-related materials were shown to demonstrate mutagenic and carcinogenic characteristics. The environmental research should evaluate the fate and effect of contaminants emanating from landfills containing coal conversion wastes. This program should develop the capabilities to predict rates of transport and fate of contaminants. It should evaluate the dissolution and sorption mechanisms of contaminants on soils and substrata relative to landfill configuration and management, with the overall objective of determining the long-term health and environmental consequences of back-to-pit/landfill disposal practices.

To implement these objectives, the ESD was assigned the lead role by DOE's Ecological Research Division of the OHER to develop a research plan focusing on the long-term research needs relative to the disposal of solid wastes from energy-producing technologies. This plan addresses the strategy, priorities, and scheduling of environmental research pertaining to disposal of energy-related solid wastes over the next five years.

Supporting Research Activities

The staff members of the Earth Sciences Section are also involved in supporting research activities in other ORNL divisions. The report on surface water flow monitoring and data base management activities support the efforts of the Operations Division and the Industrial Safety and Applied Health Physics Division; the effort on uncertainties in dose and health assessments of geologic disposal is in support of the Health and Safety Research Division.

Surface Water Flow Monitoring and Data Base Management

With the installation and reactivation of several flow-monitoring sites for surface water in the White Oak Creek basin, we decided to field check the design rating curves at eight of the permanent monitoring sites. In addition, rating equations were established in terms of a simple, mechanical point-gauge measurement, and instantaneous discharge was compared with the output of automated monitoring equipment. The results showed that all design ratings were in agreement with independent measurements of discharge. However, most automated monitoring sites showed significant and consistent bias toward overestimation of low flows. Bio-clogging of bubbler tubes is the most likely problem. Future efforts will aim at using the simple checking procedure and routine maintenance to improve the quality of recorded data.

Until recently, no attempt had been made to compile monitoring data into computerized data sets. Huff (1981) documented a simplified format and system for producing such digital data sets, and work continued on development of an interactive data base management system to allow rapid access to past results and an automated report generator capability. Collaboration with R. L. Haese (Computer Sciences Division, UCC-ND) and D. P. Carnes (Industrial Safety and Applied Health Physics Division) resulted in the establishment of a hierarchy of data files covering all aspects of ORNL monitoring. This system and associated data will become increasingly valuable. Although the system is in an early stage, efforts are currently under way to develop automatic report-generating capabilities for routine requirements.

Uncertainties in Assessment from Geologic Disposal of High-Level Wastes

This project was initiated to identify the sources and magnitudes of uncertainties associated with current assessment models for estimating long-term collective dose and health effects from the release of long-lived radionuclides to the environment. Such information could play a crucial role in the comparative analysis of alternatives in radioactive waste management. The major effort in this program is being conducted in the Health and Safety Research Division. In response to this effort, we are attempting to characterize the uncertainties associated with the geochemical aspects of radionuclide migration in ground water. Efforts were directed toward an extensive search of literature to review (1) previous uncertainty assessments, (2) general geochemical data important to the understanding of radionuclide mobility, and (3) sorption studies of radionuclides in various oxidation states and complexes on various geologic media.

A synthesis of the available information indicates that the major geochemical uncertainties in present assessments of radionuclide migration in ground water occur in the area of K_d (distribution coefficient) application and in predicting future geochemical traits of a given ground-water system. Studies have shown that a discrete value in the form of an assigned K_d cannot adequately describe the interaction of a particular radionuclide with a complex geologic environment. Moreover, little information is available that relates laboratory-derived K_d values to values in in situ geologic environments. Difficulties in utilizing K_d data also exist as a result of inconsistency among laboratory analytical techniques.

Present efforts in this study involve the preparation of a written report summarizing the geochemical uncertainties related to radionuclide migration in ground water. As an adjunct to the previously mentioned tasks, work is also being done on applying (and possibly validating) the computer program GEOCHEM (which calculates chemical equilibria speciations for specific elements and nuclides in soil solutions) to ground-water radionuclide migration from shallow land burial sites at ORNL.

Outreach Activities

Several staff members are involved in activities for which the major interest or focus is outside ORNL. These activities, such as the studies of liner evaluation of uranium mill tailings and trace metals in the sediments of New York Bight (NYB), are in direct support of DOE activities. Activity in the area of contaminant distribution in the Hudson-Raritan estuary brought added funded support by the National Oceanic and Atmospheric Administration (NOAA). Although mathematical model development played a minor role thus far, the developed models are becoming of interest to several regulatory agencies. The multimedia modeling activities are reported in a separate section, and in this section are the information transfer aspects of modeling.

Liner Evaluations for Uranium Mill Tailings

The objective of the work is to evaluate the role that liners may play in the disposal of uranium mill tailings. Past disposal practice was to place tailings in large aboveground storage piles that are subjected to natural weathering conditions and rainfall. This disposal practice allowed radon gas to leak into the atmosphere and resulted in ground-water and surface-water contamination caused by uncontrolled leachates. Two tasks were proposed that may provide solutions to these problems. The first is an evaluation of current management practices leading to suggested modifications in disposal practices that could minimize further environmental degradation. The second is the potential application of liners to control the release of gaseous effluents to the atmosphere and to attenuate trace elements leached from the mill tailings. Interaction of liner materials and leachate over long time periods will be evaluated to determine potential changes in leachate permeability attenuation as well as liner stability.

Samples of mill tailings from three disposal sites were obtained and their radiochemical and elemental characteristics determined. Chemical analyses of the samples are presented in Table 3.3. In addition, the samples were analyzed for ^{226}Ra and found to contain 795 ± 57, 304 ± 18, and 974 ± 6 pCi/g for the Durango, Shiprock, and Salt Lake City samples, respectively. A standardized method for determining saturated hydraulic conductivity was also established for samples packed in columns to predetermined bulk densities similar to those achieved in actual disposal. The hydraulic conductivities ranged from 3.8×10^{-4} (Salt Lake City) to 1.9×10^{-3} cm/s (Durango) and were directly related to their textures, particularly in the case of percent clay. Stabilization of tailings by reducing these high hydraulic conductivities is desirable to reduce the potential for leaching of radium and other contaminants.

Table 3.3. Chemical composition of uranium mill tailings samples[a]

Element	Durango (No. 8)	Shiprock (No. 3)	Salt Lake (No. 3B)
Al, %	2.13	1.02	2.61
Ca, %	0.71	0.55	1.11
Fe, %	0.88	0.15	1.33
Mg, %	<0.01	<0.01	0.17
K, %	0.73	0.66	1.38
Na, %	0.85	0.15	0.39
Ti, %	0.34	0.06	0.15
V, %	0.22	0.06	0.15
Si, %	40.2	41.3	36.6
S, %	0.22	0.58	1.32
C, %	0.02	<0.01	0.22
As, ppm	42.5	12.8	107.7
Ba, ppm	1600	645	511
Cd, ppm	0.2	2.0	1.6
Cr, ppm	19.4	23.5	63.7
Cu, ppm	10	7.5	290
Mn, ppm	95.3	18.7	158.3
Hg, ppb	25	148	230
Ni, ppm	7.6	23	30
Se, ppm	8.2	79.1	27.5
Ag, ppm	0.3	0.6	0.9
Mo, ppm	351	23.8	422
Zn, ppm	67	78	143
U, ppm	245	28.6	246
Th, ppm	2.7	1.1	4.0

[a]Samples provided by Pacific Northwest Laboratory.

A large reduction in hydraulic conductivity can be achieved using water-impermeable liners. However, utilization of liners requires that the tailings pile be excavated, the liner be constructed, and then the tailings pile be replaced. Such liners could be made from plastic sheeting, concrete asphalt, or bentonite-soil or bentonite-tailings mixtures. These liner techniques can certainly prove to be very effective; our own work demonstrated that tailings-bentonite mixes can readily achieve hydraulic conductivities down to 10^{-8} cm/s. However, a major disadvantage of this approach, as a remedial action for existing tailings piles, is that it requires excavation and movement of what amounts to an enormous tonnage of tailings.

An alternative to the movement of tailings piles to install liners would be in situ lining. Such in situ lining could be achieved by injection of wells placed in the pile. The high indigenous hydraulic conductivities of the tailings make such injection grouting quite feasible. However, grout formulations need to be developed and proven compatible with various types of tailings. Several organic grouts were tested with the three samples of mill tailings. Formulations, including acrylamide-bisacrylamide, resorcinol-formaldehyde, and urea-formaldehyde, flowed readily into columns of tailings polymerized in situ and reduced hydraulic conductivities to less than 10^{-7} cm/s. A silicate-based grout using ethyl acetate as a gelling catalyst reduced hydraulic conductivities to only 10^{-5} cm/s and, thus, was not as effective as the organic-based grouts. Attempts to inject 5% bentonite slurries failed, thus eliminating the use of bentonite slurry for in situ lining. Consequently, chemical grouting appears to offer a potential technique to line in situ mill tailings piles.

Fate of Trace Metals in Sediments of the New York Bight

This study was undertaken to assemble in one report all the available measurements of trace metal concentrations in the sediments of the NYB to understand the fate of those trace metals there. This area is a major repository for the waste products from the New York City conurbation. Interest was focused on those trace metals that are major contaminants (namely, Zn, Cu, Pb, Cr, and Ni) and especially those elements, Cd and Hg, considered to be the greatest direct toxic threat to humans via the marine food supply. The raw data assembled included more than 8000 determinations of 16 elements from 1000 stations in the NYB. Where available, additional relevant data such as grain size, total organic carbon (TOC), and loss on ignition (LOI) were also assembled.

Previous studies showed that the major sources of trace metals to the NYB are the barged loads of highly polluted dredge spoils derived from the New York Harbor and adjacent areas. A lesser source quantitatively, though possibly important, is the sewage sludge that is also dumped in the NYB apex. Other sources of trace metals are wastewaters, runoff, shelf transport, and atmospheric input. Whatever the source, many of the trace metals are rapidly sequestered on particles.

An examination of the interrelevant correlations in nitric-acid-leached sediment from the NYB apex, which includes the dump sites, shows a very high (often >0.9) correlation between all the trace metals examined -- Zn, Cr, Cu, Pb, Ni, Fe, Hg, and Cd. These elements also correlate as well with measures of organic matter, TOC, COD, and Kjeldahl nitrogen; with LOI; and with the silt plus clay content of the sediment. In this region, the sediment contains basically two components, a sand that is low in organic matter and in leachable trace metal content, and a fraction silt or clay (fine in size) that is high in organic matter and in leachable trace metals. By contrast, the sediments on the edge of the shelf are relatively unpolluted.

The trace metal concentrations in the NYB apex likely are increased by gross pollution. Within the NYB apex are areas with especially high concentrations of acid-leachable trace metals, for example, the dredge spoil dumpsite in the NYB apex. Secondary areas of high trace metal concentrations are found in the Christiaensen Basin and, to a lesser extent, in the Hudson Shelf Valley. The Christiaensen Basin is immediately adjacent to the dredge spoil and sewage sludge dump site. Fine-grained, polluted sediment might be transferred from these two sites to the basin either by slumping or suspension and redeposition. No trace metal excess anomaly exists in the area where the sewage sludge is dumped. Part of this effect may result from inaccurate dumping by the barges, but more likely it reflects the fact that most of the sewage sludge does not get to the sediment when it is dumped because of its very low density. Consequently, it is ultimately deposited elsewhere within the NYB.

The concentration of trace metals in the silt and clay fraction of the sediment was calculated, and maps of this fraction were plotted. These data showed significant trace metal pollution throughout the area, even in areas that are mainly covered with sand. The highest concentrations of trace metals in this fraction were found

at the dredge spoil dump site, to the west and northwest of that site, adjacent to the sewage spoil dump site, and in the Christiaensen Basin. Attempts were made to ascertain if this excess is caused by pollution from decomposing sewage sludge or resuspended dredge spoil particles. The excess could also be significantly influenced by airborne particulate matter.

Sediment and Contaminant Distribution in the Hudson-Raritan Estuary

One of the tools available for elucidating the fate of fine particles and their associated pollutants in estuarine and coastal marine environments is the distribution of radionuclides or synthetic organic compounds that have a known source and history of input. In this project we used anthropogenic radionuclides (^{137}Cs, ^{134}Cs, ^{60}Co, and ^{239,240}Pu) and synthetic organic chemicals (PCB's, DDT, DDE, and Chlordane) that are already present in the system as clocks and tracers to study sedimentary processes and the fate of contaminants in the Hudson-Raritan estuary.

Sediment cores were collected throughout the Hudson-Raritan estuary and analyzed for anthropogenic radionuclides and PCBs. The data were listed in Olsen (1979) and Bopp (1979) and indicate that (1) a large variation occurs in patterns and rates of sediment deposition in the system; (2) the primary zone of fine-particle and contaminant accumulation is in the inner harbor of New York City, where sediments are accumulating at rates one to two orders of magnitude greater than in upstream areas of the Hudson River or in Raritan Bay; and (3) the sediments in the inner harbor are tagged with reactor-nuclides and PCBs, indicating that river-borne particles from the Hudson are the primary source responsible for the rapid shoaling.

By extrapolating observed particle accumulation rates (as determined from vertical radionuclide distributions) over different portions of the system, we estimated that approximately $1.5 \pm 0.5 \times 10^9$ kg of fine-grained sediment annually accumulates in the inner harbor of New York City. This estimate is consistent with the amount of fine-grained material that must be dredged annually from the harbor to maintain present harbor depths. Once the sediment accumulation patterns and budget are established, measured, and assembled, contaminant concentration data can be used to estimate the total burden of specific contaminants in and the annual flux of contaminants to the sediments in the Hudson-Raritan system. For example, preliminary results indicate that (1) 10 to 30% of the ^{137}Cs, ^{134}Cs, and ^{60}Co and 80 to 100% of the ^{239,240}Pu, which were introduced into the Hudson from global fallout and reactor releases, accumulated in the estuary sediments; (2) one-half to two-thirds of this activity was dredged from the inner harbor and dumped at the dredge spoil site in the NYB; and (3) ~76,000 kg of PCBs are currently associated with the sediments in the tidal Hudson and ~1860 kg are annually dumped on the shelf as a result of dredge spoil disposal.

Eight large-quantity suspended matter samples were also collected from tributaries to the Hudson-Raritan estuary and in adjacent coastal waters by continuous-flow centrifugation. These samples are currently being analyzed for radionuclides, PCBs, and insecticides in an attempt to identify particulate geochemical signatures that can be used to infer and quantify sediment and contaminant sources.

Mathematical Modeling Training Seminar

Two 3-d training seminars on the implementation of FEMWATER (Yeh and Ward 1980) and FEMWASTE (Yeh and Ward 1981) were held at the Nuclear Regulatory Commission (NRC) offices in July and August, respectively. The purpose of the seminars was to provide technical assistance to NRC staff in adopting and applying FEMWATER and FEMWASTE to low-level waste management licensing assessment.

The topics covered at the first session included (1) derivations of FEMWATER governing equations and initial and boundary conditions, (2) basis of finite element methods, (3) finite-element implementation of FEMWATER, (4) FEMWATER program structure and its highlight, (5) uniqueness and limitations of

FEMWATER, (6) finite-element grid layout and mesh generation, (7) adaptation of FEMWATER to site-specific problems and input data requirement, (8) a one-dimensional example-code verification, (9) a two-dimensional homogeneous example-code validation, (10) a two-dimensional inhomogeneous example-code demonstration, (11) homework on a trench burial problem by NRC staff, (12) pitfalls of finite element and ways to cope with numerical instability, and (13) ways to modify subroutines SPROP by NRC staff to cope with site-specific soil properties.

The second training session dealt with the following subjects: (1) derivation of governing equations and initial and boundary conditions, (2) finite element-upstream weighting function, (3) FEMWASTE program structure, (4) computational options in FEMWASTE, (5) setup of flow variables from FEMWATER, (6) adoption of FEMWASTE to site-specific problems and data input requirement, (7) a one-dimensional example-code verification, (8) a two-dimensional problem-code validation, and (9) homework on a trench burial problem by NRC staff.

The reaction of the course participants to the material presented was very enthusiastic. Much discussion ensued, and questions were raised in the homework class. All participants completed the assignments in a timely manner. One participant even tried to apply the program to one of his problems in an attempt to compare the results with those obtained by finite difference methods. As a result of these seminars, we decided that studying technology transfer in the format of a training seminar is worth pursuing further.

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4. TERRESTRIAL ECOLOGY

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Introduction

The Terrestrial Ecology Section is involved in basic and applied environmental research to support energy technology development and to gain a better understanding of the structure and function of terrestrial ecosystems. The section is organized around three basic areas of research (ecosystem studies, physiological studies, and environmental analyses) and two major projects (global carbon cycling and ecological effects of acid precipitation). Staff members are assigned to other research divisions at the Oak Ridge National Laboratory (ORNL) and make use of other division staff in researching terrestrial activities. Within the section, our basic research program is designed to ensure continued development of expertise in disciplinary areas of terrestrial ecology. The section is currently interacting with a number of outside institutions, including the Tennessee Valley Authority (TVA), The University of Tennessee, other national laboratories, and the National Park Service. Research in the section is supported by the U.S. Department of Energy (DOE) (40%), the National

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Science Foundation (NSF) (29%), the Electric Power Research Institute (EPRI) (21%), and the Environmental Protection Agency (EPA) (11%). In the following paragraphs, we summarize recent activities in physiological ecology, forest dynamics, acid rain, and global carbon cycling.

Physiological ecology has been focusing on interfaces between the terrestrial or atmospheric environment and plant physiology and the integration of these processes into whole plant behavior. Currently, a major area of emphasis is in quantifying the influence of atmospheric pollutants from a wide variety of energy-related technologies on plant physiology, growth, and development. Among the pollutants being examined are SO_2, O_3, acid rain, and CO_2 from coal combustion processes; a variety of sulfur-containing and organic gases to be released from newly emerging coal conversion technologies; and hydrogen fluoride from uranium enrichment activities. Processes such as photosynthesis, respiration, transpiration, flux of pollutant gases into leaf interiors, and alteration of carbon allocation patterns are measured as short-term indices with longer-term potential to cause alterations in plant productivity. In providing a mechanistic basis for understanding factors influencing the rates of uptake and degree of toxicity of these pollutants, these studies are contributing to our ability to evaluate the potential impacts of these pollutants on both agricultural and natural terrestrial ecosystems.

Studying succession in a wide array of ecosystems is the primary emphasis related to our forest dynamics research. Through acquisition of tree-detail information and stand-level data of various forest types, we have built forest-stand simulation models of tropical, deciduous, coniferous, and floodplain forests. Research in forest succession utilizing stand simulators has created a necessity of understanding fundamental principles of forest dynamics and, in addition, has provided a tool for use in the applied work of ecosystem behavior. A primary objective for this work is to build a foundation for future work in long-term landscape forest ecology.

Acid rain studies are directed toward the evaluation of current and potential ecological impacts associated with the landscape deposition of acid precursors and acidic precipitation. Individual research efforts within the project are involved in the exploration of the deposition processes, transfer rates, and effects of acidic precipitation in the terrestrial landscape. During the past year, activities related to acid rain have increased significantly with the initiation of three new projects under the sponsorship of EPRI. Through the combination of these new projects and existing projects on Walker Branch Watershed (WBW), the deposition process will be studied from the atmosphere-forest canopy interface through forest soils to evaluate factors controlling inputs to surface waters. The potential interactions between dry deposition of gaseous pollutants and wet acidic deposition will be studied in the field with agricultural crops such as winter wheat and soybeans as part of a four-laboratory assessment of acid deposition effects on agricultural productivity.

The primary objective of our global carbon cycle studies is to improve our understanding of the carbon cycle's response to perturbations such as fossil fuel combustion, climate change, forest clearing, and other disturbances to terrestrial ecosystems. Basic research results that are applied to assessment of the effects of future fossil fuel use on atmospheric CO_2 concentration are incorporated into mathematical models of the carbon cycle. Carbon cycle research activities include (1) inventory of carbon storage in terrestrial ecosystems, (2) development of mathematical models of carbon turnover in the oceans and in terrestrial ecosystems at the global scale, (3) development of models to analyze the detailed responses of terrestrial ecosystems to climate change, and (4) testing, comparison, and application of carbon cycle models.

Physiological Ecology

Effects of Pollutant Stress on Carbon Allocation

A major limitation in our present ability to identify levels of air quality that should be attained to protect terrestrial vegetation is a clear association of cause and effect. Specifically, identification of combinations of pollutant concentration and time that cause permanent alteration of growth and yield potential is needed. For

field-grown plants, yield loss may occur as a cumulative effect of low-level stresses, a response to one or more episodes, or a combination of these events. Growth measurements at the end of the growing season do not routinely identify the specific events that have caused measured yield reductions. Identification of the biologically significant features of exposure dose is clearly needed if we hope to effectively minimize the effects of pollutants through air quality regulations. This research seeks to identify incipient changes in growth at the stages at which they occur so that thresholds for yield reduction can be more effectively characterized and quantified.

A wide variety of studies have been conducted to date in which plants previously stressed by gaseous pollutants and acid rain have been examined radiochemically to determine if patterns of retention and translocation of ^{14}C products of photosynthesis were altered. In laboratory studies, bush beans *(Phaseolus vulgaris* L.*)* of both the pollutant-sensitive variety 290 and resistant variety 274, resistant (Davis) and sensitive (Bragg) soybeans *(Glycine max)*, and loblolly pine *(Pinus taedia)* have been used to examine concentration thresholds for response of photosynthesis and carbon allocation. Plants are grown in the greenhouse and moved to continuously stirred chambers where exposures to SO_2 (concentration ranged from 0.20 to 0.75 ppm in various studies) or ozone (0.10 to 0.40 ppm) have been conducted over varying time periods. Subsequent exposure to $^{14}CO_2$ was followed by periodic subsampling of tissues to determine patterns of movement and utilization. Experiments thus far have demonstrated that translocation of ^{14}C photosynthate from stressed leaves may be reduced by exposures to SO_2, ozone (Fig. 4.1), or acid rain. Through our use of similar techniques, we showed

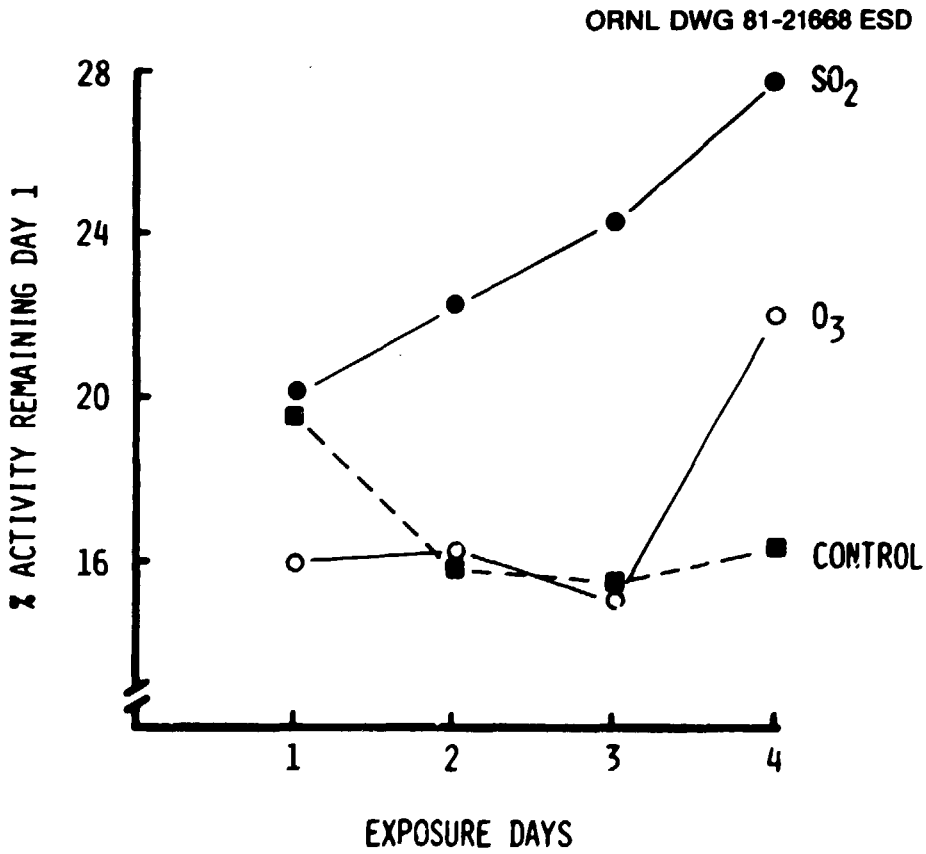

Fig. 4.1. Effects of SO_2 (0.75 ppm) and O_3 (0.30 ppm) exposures (2 h d^{-1}) on foliar retention of ^{14}C photosynthate by *P. vulgaris* (CV 290).

that foliage of pollution-sensitive white pines under field conditions retained more photosynthetically fixed ^{14}C. Coupled with reduced photosynthesis and biomass and increased respiration of foliage, reduced transport of photosynthate from foliage led to reductions in the availability of carbohydrates for growth that closely paralleled measured reductions in annual stem diameter increase for these sensitive trees. Future research in this area will be directed toward determining the quantitative relationship between altered allocation and altered growth of pollution-stressed plants.

Regulation of Pollutant Uptake by Vegetation

Gaseous pollutants pose a threat to vegetation in terrestrial ecosystems only if the pollutants are readily absorbed by foliage. This phenomenon is based on the primary site of action of the pollutants – the metabolic processes of cells of the leaf interior. Thus, the physical and biological processes governing pollutant uptake into the leaf interior are key factors in determining whether a particular pollutant or combination of pollutants will affect vegetation. The most common technique for estimating pollutant uptake is to assume that uptake is inversely proportional to leaf resistance to diffusion. This approach assumes an internal pollutant concentration of zero, a pathway for the pollutant that is analagous to that for water vapor, and a principal regulation of uptake by the opening and closing of leaf stomates. We investigated these assumptions.

The processes controlling the uptake of ozone and sulfur dioxide, the two major phytotoxic pollutants in the United States, were investigated using a combination of laboratory studies and modeling approaches. The absorption of ozone and sulfur dioxide was experimentally measured and compared with that predicated, assuming each gas experienced a resistance analogous to that of water vapor. The investigation provided accurate information on the role of stomates and the boundary layer in controlling uptake. If uptake were controlled solely by these processes, then the experimental measurements of pollutant uptake should have approximated those derived from the presumed relation between uptake and leaf resistance.

The results demonstrated that the pathways for ozone and sulfur dioxide differ markedly from water vapor and from each other. Ozone experienced more resistance to uptake than was expected based upon its analogy to water vapor. In *Glycine max*, this additional or residual resistance ranged from 15 to 50% of the total leaf resistance to ozone uptake and increased with pollutant concentration, exposure time, and leaf age. In *Phaseolus vulgaris*, this resistance to ozone uptake was more pronounced at low vs high humidity. Thus, estimates of ozone uptake derived from analogy to water vapor overestimate pollutant uptake. Consequently, it is proposed that this residual resistance results from the deeper and more metabolically complex pathway for ozone relative to water vapor.

The results from the sulfur dioxide study also demonstrated that factors in addition to stomatal resistance influence pollutant uptake into the leaf interior. However, whereas nonstomatal factors impeded ozone uptake, they significantly enhanced the uptake of sulfur dioxide. In both *P. vulgaris* and *Geranium carolinianum*, estimates of sulfur dioxide uptake based upon resistance to water vapor underestimated uptake by at least 50%. These residual factors did not vary among plant species or sulfur dioxide concentrations; however, their influence was more pronounced at high vs low atmospheric humidity. The physiological basis of these residual factors is thought to be threefold: (1) a diffusive path length for sulfur dioxide that is shorter than that for water vapor, (2) a heightened concentration differential between the atmosphere and leaf cell resulting from the rapid hydration and ionization of the gas in solution, and (3) variable resistance resulting from the countercurrent flow of water vapor molecules.

A significant role for nonstomatal factors in governing the diffusion of pollutants into the leaf interior indicates that estimates of pollutant uptake based upon stomatal resistance alone are subject to significant error. Because a pollutant's chemical properties dictate, in part, the magnitude and direction of the error, generaliza-

tions regarding the importance of nonstomatal factors among pollutants are not possible. Initial studies demonstrate that environmental conditions such as atmospheric humidity affect the role of nonstomatal factors in a predictable fashion. This relationship is valuable in establishing a scientific basis for assessing how different regional environments influence the response of vegetation to gaseous air pollutants.

Response of Bush Beans to Hydrogen Fluoride Gas

Hydrogen fluoride gas (HF), an effluent from uranium hexafluoride (UF_6) production and enrichment facilities, is the most reactive gas among major air pollutants producing plant damage at ppb levels. To assess vegetation effects of low-level emissions, two continuously stirred tank reactors were modified for safety purposes to accommodate fluoride fumigations at ppb concentrations. Bush beans were exposed to 1.6 micrograms of HF per cubic meter (Tennessee air quality standard for a 7-d average) for 6 d during a 14-h photoperiod. Net photosynthesis and leaf area were measured at 0, 1, and 4 d during exposure, and plants were scored for visible injury. Following the first day of fumigation, photosynthetic CO_2 fixation was enhanced 7%, whereas after 3 d, exposure fixation was reduced significantly from 8.4 mg dm^{-2} h^{-1} among controls to 6.4 mg dm^{-2} h^{-1} among exposed plants (Fig. 4.2). Leaf area was not significantly different from controls, and no visible

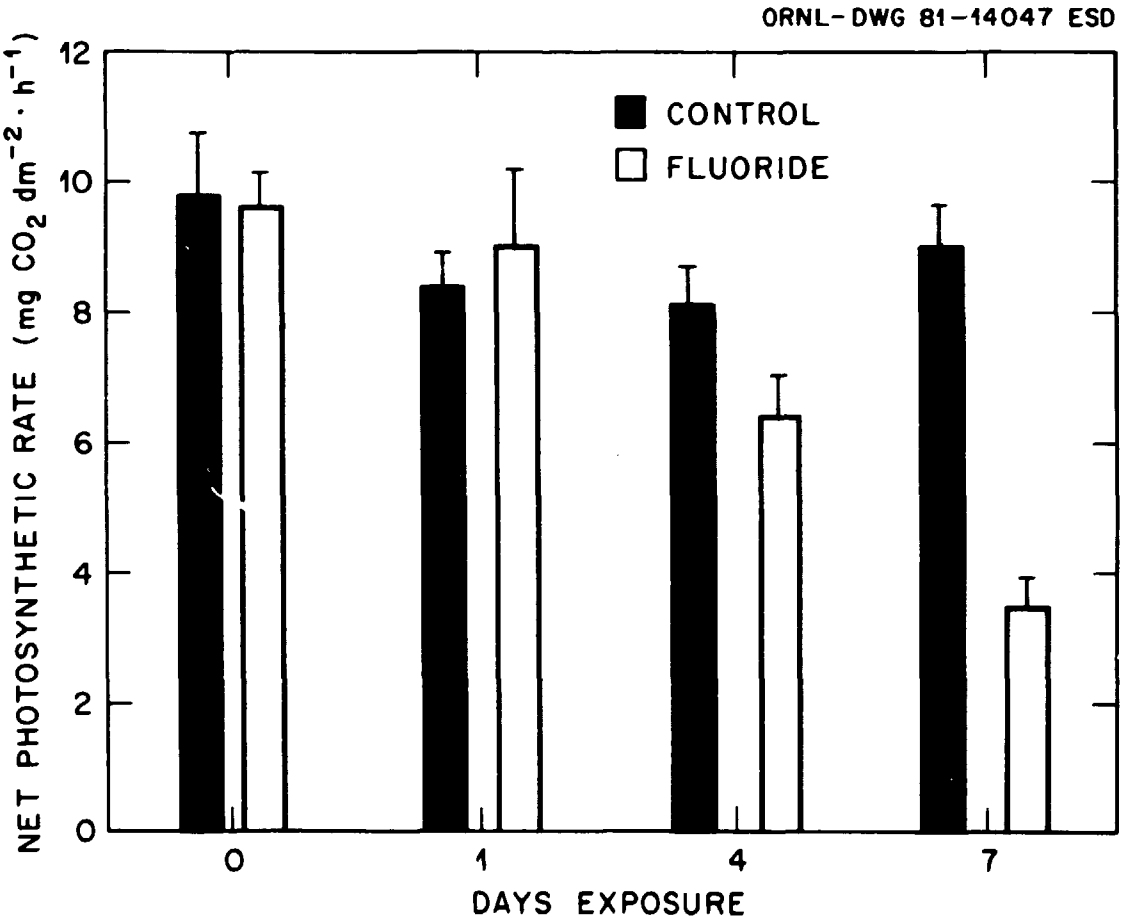

Fig. 4.2. Response of bush beans to HF fumigation during chronic exposure (6 d) to a low-level concentration (1.6 μg m^{-3}), followed by an exposure (day 7) to an acute high-level atmosphere (40 μg m^{-3}).

injury (necrosis) was evident although axillary trifoliates were epinastic. The inhibition of CO_2 fixation at a 3-d exposure is significant in that it occurred from exposure to an atmosphere containing concentrations of HF equivalent to the state 7-d standard. On the seventh day of the study, the atmosphere was increased to 40 micrograms of HF per cubic meter to permit sufficient fluoride uptake and accumulation in foliage, with a resultant reduction of 62% in net photosynthetic rate and with necrotic lesions covering 50% of trifoliate leaves. Following the acute exposure, all plants were harvested, partitioned according to leaf rank (primary, trifoliate, or axillary trifoliate), weighed, and analyzed potentiometrically for fluoride content. Plant biomass and foliage weights of fluoride-treated plants did not differ from controls, whereas the fluoride concentrations in the foliage of exposed plants were several orders of magnitude greater than those of the controls. Expanding axillary trifoliates contained a maximum fluoride concentration of 2097.7 ± 446.7 μg g. Concentrations between leaf ranks did not differ (Table 4.1) from each other, but all leaf ranks exceeded stem concentration by a factor of 5 to

Table 4.1. Allocation of fluoride following 7-d exposure (μg F g ± SE, n = 10)

	Control	Fumigated
Primary leaves	12.8 ± 0.8	1727.6 ± 169.7
Trifoliate leaves	5.3 ± 0.5	1648.2 ± 141.9
Axillary trifoliate leaves	1.4 ± 0.2	2097.7 ± 446.7
Stems	1.6 ± 0.3	351.6 ± 19.1

6. Results of this preliminary chamber study illustrate that (1) deleterious effects (physiological) are possible during short-term exposures at seemingly safe atmospheric concentrations, (2) fluoride accumulates rapidly in photosynthetically active leaves, and (3) fluoride is not transported against the transpiration stream to other plant parts (e.g., stems and roots). Future studies will focus on the response of plants to a fluoride atmosphere typical of the environs near UF_6 facilities ($<5\ \mu g\ m^{-3}$), response to airborne fluoride during postulated accidental releases ($>5\ \mu g\ m^{-3}$), and both short- and long-term effects (physiological effects without growth impacts vs growth impacts).

Whole-Plant Behavior

The quantification of the complex interactions of the plant physiological processes controlling water, carbon, and nutrient uptake and utilization by whole plants has been aided by computer simulation modeling. The supply of environmental resources required for growth in relation to the plant demand for water, carbon, and nutrients has been described mathematically with five component models. These codes are linked together and describe the source, sink, storage, and transport dynamics of important materials in the soil-plant-atmosphere system. Modeling has been a valuable tool in whole-plant physiology by providing (1) insight into the hourly dynamics of physiological processes in the diurnal cycle and (2) hypotheses about plant response to natural and pollutant stress.

The analysis of diurnal physiology has been summarized to show that plants change from two relative states (dawn and dusk condition) and exhibit differences in the water, carbon, and nutrient storage (buffer) tendencies during day and night conditions (Fig. 4.3). These summary concepts have been used in conceptual experiments on whole-plant response to air pollutants and elevated atmospheric CO_2 (Luxmoore 1986). In the latter case, the analysis resulted in the hypothesis that at elevated CO_2 levels whole plants could obtain greater nutrient supplies from the soil environment through stimulated mycorrhizal, nitrogen fixation, and root exudation

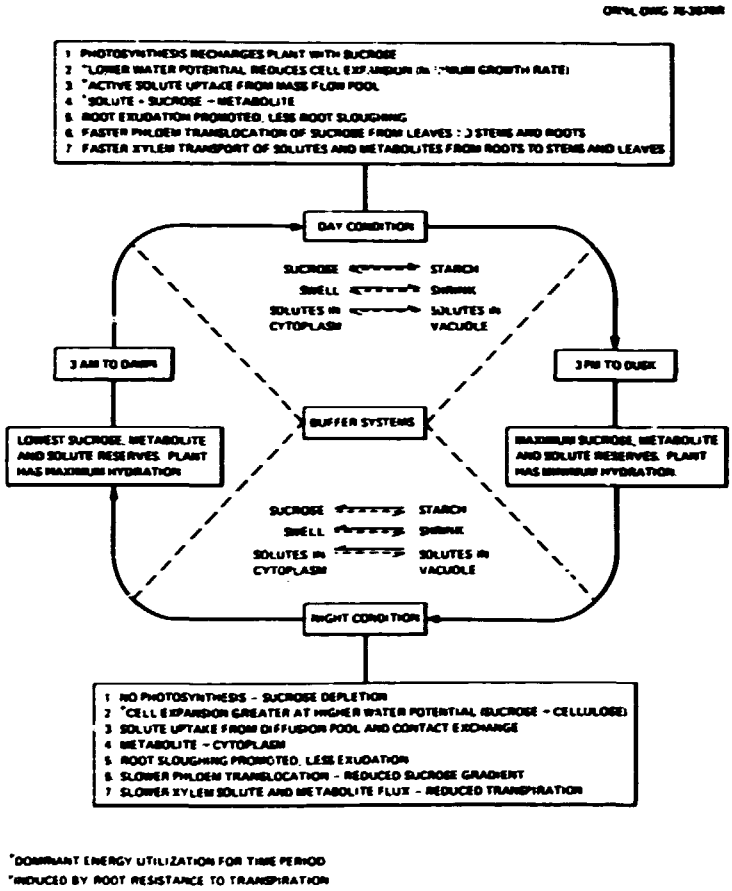

Fig. 4.3. Diurnal pattern of carbon, water, and solute dynamics showing *relative tendencies* and *relative states* in vegetation.

activity (Luxmoore 1981). This hypothesis is being tested in a new research project, and confirmation will assist in reassessment of terrestrial ecosystem responses to elevated CO_2.

Forest Dynamics

The difficulties in studying tree population dynamics thwart an increasing need for more understanding of how forest ecosystems might respond to natural and anthropogenic environmental disturbances. We need to know (1) how certain forests will respond to altered atmospheric pollutant levels and to major or minor climate change, (2) how responses of forests will affect the global budgets of atmospheric gases (particularly CO_2), (3) what will be the consequences of new and untried forest management schemes, and (4) how forests can be managed to ensure the survival of rare and endangered species. To solve these problems, we are studying the long-term successional characteristics of several types of forest ecosystems. A concerted effort for the past several years has included the collection of extant climatic, forest, and autoecological tree data from many ecosystems and subsequently building stochastic gap models for simulating the dynamics of the respective ecosystem types.

A recurrent theme in many of the tests of the gap models has been an emergence of results that could not easily be inferred from a simple tabulation of the attributes of the dominant species that make up the ecosystem. These results indicate that a consideration of ecosystem effects must be included when attempting to extrapolate

from the species the responses of trees to the dynamics of forests. It is particularly important, in our opinion, that such results should be obtained from models based on species-level attributes of tree populations as an underlying paradigm. By comparing behavior of gap models of several different forest systems with each other, we are beginning to formulate general predictions of the expected responses of forest ecosystems to disturbance. This approach amounts to using a model as if it were a single data point in a study on the long-term dynamics of a forest.

This work has led to some interesting philosophy regarding the comparison of old and new ideas related to the fundamental theories of forest succession. Classical succession theory suggested that the regularity of ecosystems, especially in the new American wilderness, resulted in ordered communities that developed under constant prevailing climates after geological processes created new substrates. Secondary succession was seen as a response of ecological systems following an unnatural disturbance, particularly such as has been influenced by man in the recent past. With help from our modeling efforts, we see a more modern theory that attempts to bring our understanding of succession into agreement with our increased awareness of change at multiple scales of time and space. The observations that led us to classical successional theories are still valid, and the new theory logically must include valid insights previously developed. However, lost from the modern theory is the comforting but misleading generality of the old.

We have learned that to adequately study forest dynamics, variables must include organisms and environments, types and regimes of disturbance, and dominant processes and the spatial and temporal scales of their dynamics. Successional theory constructed from observations of one ecosystem invariably proves to be a special case when the comparison of one system with another system is attempted. Some common features do exist, however. Repeatable successional patterns can be defined for many common combinations of ecosystems and disturbance. Successional mechanisms (e.g., competition, facilitation, tolerance, inhibition, and secular change) appear to be valid but of widely varying importance.

Acid Rain Project Activities

Factors Influencing Acidity and Concentrations of Sulfate and Trace Metals in Precipitation

Precipitation is an important component of atmospheric deposition because of its episodic nature and its transfer of material to the receptor partly in solution, thus enhancing the possibility of biological interaction. In part, as a result of the interest in acid rain, a need exists to understand the behavior and effects of various constituents in precipitation. The relationship between concentrations in rain and the quantity of rainfall has been discussed for several major constituents; however, the relationships between trace constituent concentrations in rain and precipitation characteristics require further study. Factors contributing to the temporal and spatial variability of concentrations in precipitation include precipitation-event characteristics such as intensity, rainfall amount and duration, antecedent conditions, air quality, and meteorologic parameters.

We present here a summary of a recent paper that describes the factors influencing the concentrations and distribution of Mn, Zn, Cd, Pb, sulfate, and hydrogen ions in rain collected at WBW, a 98-ha deciduous forest catchment in a rural area of eastern Tennessee (Lindberg, in press). The watershed is within 22 km of three coal-fired power plants (total capacity = 2000 MW) and 350 km of 22 power plants (total capacity = $\sim 2 \times 10^4$ MW).

Regional meteorological factors play an important role in controlling rain chemistry at this site in the Tennessee River Valley. Precipitation at this site is dominated by H^+ and SO_4^{2-} ions and includes Cd, Mn, Pb, and Zn at concentrations typical for rural areas. For most constituents, significantly higher rain concentrations occur during the warmer months, a pattern that is reflected for SO_4^{2-} at several sites in the Northeast. The similarity in these patterns suggests the importance of synoptic meteorologic conditions in influencing rain chemistry.

Concentrations in rain generally decrease as rainfall amount, intensity, and duration increase, although rainfall amount appears to exert the most uniform and significant influence based on correlation analyses. Plots of rainfall amount vs concentration, which illustrate the dilution curve as a negative exponential, were used with a precipitation-scavenging model to estimate the contribution of in- and below-cloud processes to wet deposition. For the large-particle-associated elements, cadmium and manganese, below-cloud scavenging contributes significantly to wet deposition (30–40% of the total), while for the small-particle-associated constituents, lead, and SO_4^{2-} in-cloud processes dominate (90% of total).

Plots of rainfall amount vs wet deposition of each constituent were used to test a published hypothesis that such curves could be defined roughly as half-power relationships. With the exception of that for H^+, the regression coefficients are not significantly different from 0.6, a value recommended in the literature as an average power law exponent. The relationship between H^+ deposition and rainfall amount (exponent 0.8) requires further study.

Precipitation-scavenging ratios determined for selected events are comparable with those in the literature. Increases in the order Pb < Zn < SO_4^{2-} < Mn < Cd exhibit little influence of rainfall amount but exhibit a general increase with increasing mass median diameter (MMD) of the particles with which each element is associated (MMD: Pb < Zn < Cd < Mn). This finding suggests the importance of impaction scavenging because collision efficiency for particles by raindrops increases as particle size increases above 0.5 μm.

Based on data from eight events of comparable rainfall amount, there are no statistically significant ($P > 0.05$) differences in rain concentrations between events during which local power plant plume trajectories crossed the sampling point and events during which no plumes were present.

Effects of Acid Rain on Forest Nutrient Status

Studies coordinated at ORNL and funded by EPRI are currently under way to assess the effects of acid precipitation on the nutrient status of five diverse forest ecosystems — two on the WBW in Tennessee, one on Camp Branch Watershed in Tennessee (with the cooperation of J. M. Kelly of TVA), and two at the Thompson Research Center in Washington (with the cooperation of Dale Cole at the University of Washington). The major objectives of this effort are to (1) determine the relative importance of atmospheric acid input vs internal, natural acid generation on nutrient cation leaching from the forest soils and (2) determine the fate of incoming SO_4^{2-} and its effects on sulfur cycling and nutrient leaching.

Initial results from WBW indicate that sulfate dominates the anionic component of soil solutions from the WBW during June 1980–May 1981. This finding implies that atmospheric H_2SO_4 inputs dominate leaching processes in the ecosystem and that natural H_2CO_3 production is of secondary importance. In one (Fullerton soil) of the two sites on the WBW, however, sulfate is adsorbed to the B horizon of the soil (approximately 40 cm deep), thus reducing the leaching caused by atmospheric H_2SO_4 inputs by about one-half. In contrast, the Tarklin soil adsorbed no sulfate, and the cation-leaching rate was undiminished throughout the profile. The different sulfate adsorption characteristics of these two soils appear to result from differing amounts of Fe and Al hydroxides.

Soil solutions from the Thompson site indicate that sulfate and bicarbonate are dominant and of about equal importance in the Douglas fir site. In the red alder site, nitrate is clearly the dominant anion, implying that nitrification (which results in the production of HNO_3) is the dominant force in soil leaching at that site. This finding is not entirely surprising because red alder is a nitrogen-fixing species. However, it is notable that soil solution pH is quite acidic in the red alder A horizon compared with the same level in the Douglas-fir site (which is on the same soil and adjacent to the alder site), thus implying that the natural nitrification processes have produced considerable acidity in the red alder soil.

Because the Camp Branch site did not have the advantage of early instrumentation (under a University of Washington-ORNL NSF grant on basic soil-leaching processes), insufficient data exist to provide average concentrations.

It must be emphasized that 1980 was an exceedingly droughty year, with only 85 cm of precipitation (normal precipitation at the WBW is 150 cm), and further data collection is essential before any conclusions can be drawn. This need for continued study is especially important in the case of carbonic acid formation in soil because a virtually inexhaustable supply of CO_2 is available for combination with incoming H_2O to form carbonic acid. Thus, increasing water fluxes in normal years should result in greater carbonic acid leaching than was the case during 1980–1981.

Effects of Acid Rain on Vegetation

Experiments are being performed in a continuing effort to identify any effects that rain acidity may have on agricultural and natural vegetation. The major portion of our research effort is directed toward elucidation of the following questions: At what levels of rain acidity are plants affected? Do acids in rain interact with other air pollutants to cause plant damage?

To answer the previous questions, we have exposed plants of several species to simulated rain with levels of acidity that approximate (1) unpolluted rain (pH = 5.6), (2) moderately polluted rain with levels of acidity equal to average annual values for the eastern United States (pH 4.0–4.5), (3) heavily polluted rain with levels of acidity approaching worst-case situations for single events in the northeastern United States (pH 3.0–3.5), and (4) severely polluted rain with levels of acidity equal to the highest levels recorded in the eastern United States (pH 2.3–2.6). Exposures are conducted twice weekly (30–45 min/exposure, 1.1-cm total deposition) throughout the life cycle of the plant.

We have determined the threshold acidity for several response parameters for several species of plants. The threshold for visible necrosis to the foliage of broad-leaved plants (beans, tomatoes, and radishes) is between pH 3.3 and 4.0. This finding indicates that the acidity of individual rain events over much of the eastern United States is approaching the threshold for visible damage for plants as sensitive as those we have tested. However, the threshold rain pH for growth and yield depression of radishes, beans, and tomatoes is ≤ 3.3, indicating that these plants can sustain low levels of foliar damage ($\leq 10\%$ of the total leaf area) without exhibiting significant growth reduction. Reduction of the chlorophyll concentration in the leaves of radish plants was generally proportional to the amount of necrosis present. In an experiment that used tomatoes as the test plant, growth in treatments that received simulated rain was depressed when pH levels were ≤ 3.3. Plants receiving the same amount of rain simulant as a soil drench (no foliar exposure) were not significantly affected by the pH of the solution—except at pH 2.3, where a stimulation of growth occurred. Therefore, the negative growth and yield response of tomato plants to acid rain exposures in this experiment were direct foliar effects rather than secondary effects via soil exposure. The effects of acid rain on photosynthate allocation and SO_2 uptake were studied in an experiment with bush beans (*P. vulgaris* CV Blue Lake 274). Plants were exposed to acid rain (six events, 6.3-cm total deposition), were subsequently exposed to SO_2, and then were tagged with $^{14}CO_2$. Photosynthate allocation to roots was enhanced 50% at both pH 4.0 and 3.3, with a downward trend occurring at pH 3.0. Both the ratio of nodule:root allocation and retention of photosynthate by foliage were enhanced at pH treatments of 3.3 and 4.0. Bean plants treated with rain simulants at pH 3.3 and 3.0 tended to recover from SO_2-induced depression of photosynthesis at a faster rate than those exposed to rain at pH 4.0 or 5.6. While these experiments are being repeated, the preliminary results suggest significant effects of acidic rain on photosynthesis and photosynthate allocation. Loblolly pine seedlings were not visibly damaged by any of the acid rain treatments that were imposed (pH 5.6–3.0) after 24 exposures over 12 weeks.

Lichens, which were useful bioindicators of gaseous pollutants (especially SO_2), were tested for sensitivity to rain acidity. Three species found in the eastern United States [*Umbilicaria mammulata* (Ach.) Tuck., *Pseudoparmelia carpetara* (L.) Hale, and *Usnea* sp.] were exposed twice weekly for six weeks to our rain simulants. Photosynthesis was increased after test plants were exposed to rain (with pH $\geq$4.3 for *Usnea* and pH 5.6 for *Pseudoparmelia*) when compared with controls (lichens soaked in distilled water while the test plants were exposed to the simulated rain). Because the lichens were collected from a location where rain acidity averages pH 4.1 annually, the stimulations of photosynthesis observed in the experiment may demonstrate recovery of the lichens from the effects of ambient rain. This experiment is currently being repeated for confirmation. Simulated rain at pH 2.3 caused marginal necrosis of *Umbilicaria* thalli after two exposures.

Currently, we have not demonstrated significant effects of acidic rain at pH levels comparable with average annual pH levels in ambient rain. However, the threshold pH for several plant growth parameters occurs within the range of pH levels that are occasionally measured in ambient rain in the eastern United States.

Global Carbon Cycle Studies

Carbon Storage in Terrestrial Ecosystems

An updating of earlier inventories of terrestrial carbon storage has been completed (Olson et al. 1978). This inventory, which arrives at a lower value than many earlier studies for carbon in vegetation of 558 Pg (1 Pg = 10^{15} g), represents an improved treatment of farms and woodlots in the world's temperate forest regions that have been so heavily altered by man's activities. Furthermore, careful analysis is given to the range of carbon densities in tropical forest systems where only the most favorable sites actually allow the very high carbon storages often attributed to the entire region. In addition to this estimate of current carbon storage, the data of Rodin et al. (1975) has been reorganized to provide an estimate of preagricultural conditions.

Most recently, estimates of vegetation distribution have been computerized using the data organization system originally developed by Hummel and Reck (1979). A vegetation classification is assigned to each cell on the earth's land surface at 0.5° lat by 0.5° long. The resulting map forms a much improved basis for constructing models of the terrestrial component of the carbon cycle, thus allowing treatment of each type of ecosystem and its geographical distribution. The terrestrial carbon inventory resulting from this digitized map of vegetation distribution has been submitted for publication to *Nature* (Olson 1981).

In addition to this ongoing effort to estimate global terrestrial carbon storage, the historical changes in carbon at the regional level have been analyzed in detail for areas where data are available and where our group has first-hand experience: southeastern United States (Delcourt and Harris 1980), Georgia Piedmont (Sharpe and Johnson 1981), and Malaysia (Chan 1981).

The largest actively exchanging pool in the terrestrial component of the carbon cycle is in the soil. In collaboration with Paul Zinke of the University of California, Berkeley, about 3500 profiles for soil carbon have been assembled in a computer-readable form. These profiles were sorted initially according to major ecosystem types and climate conditions to provide preliminary estimates of average soil carbon density for each ecosystem type (Post et al. 1981). When mean soil carbon densities for each climatic life zone are arranged simultaneously along climatic gradients of temperature and precipitation, strong climatic trends are evident. The lowest mean soil carbon densities (less than 2 kg/m^2) occur in hot and dry climates where organic material input to soil is low. The highest mean soil carbon densities (greater than 30 kg/m^2) occur in cold, wet climates where oxidation of organic material in soils is inhibited by waterlogging and low temperatures. The mean soil carbon density under natural vegetation for the entire globe is 10 kg/m^2 (this amount is also the mean density in life zones where rainfall matches potential evapotranspiration). As rainfall outstrips potential evapotranspiration, soil carbon density increases regardless of the absolute amounts of rainfall and heat. The reverse trend occurs as potential evapotranspiration increasingly exceeds rainfall.

Climate changes caused by CO_2 enrichment of the atmosphere are not expected to be uniform, thus resulting in responses from the soil carbon reservoir that will vary from place to place. Our understanding the relationship between soil carbon density and climate as well as the global distribution of climate will allow prediction of the direction and magnitude of carbon exchange between the soil reservoir and the atmosphere. It appears that climatic warming, particularly of polar regions, will result in large losses of carbon to the atmosphere from the carbon-rich soils of tundra regions.

Conventional harvest and intensive harvest (residue removal) methods are being studied for their effects on soil carbon losses resulting from CO_2 efflux, leaching, and erosion at seven research sites in the eastern United States and one research site in the Northwest. All sites have been harvested, and data are being collected from treated and adjacent control plots. In an oak-hickory forest in Tennessee, carbon losses caused by leaching did not exceed inputs by precipitation, and erosional losses were zero for all treatments during the first year following harvest. The CO_2 efflux from the uncut (control) plot during the summer following harvest exceeded that from the clear-cut plot with residue removed (intensive) and the clear-cut plot without residue removed (conventional) by a factor of 1.3 and 1.2, respectively. These differences were the result of tree root respiration in the control plot and differences in surface residue in treated plots, not the result of losses from the mineral soil carbon pool. In fact, only 7% of the control plot forest floor CO_2 efflux resulted from mineral soil carbon respiration vs 13 and 11% for intensive and conventional harvesting, respectively.

The concern is the long-term (turnover time in hundreds of years) carbon in the mineral soil. One year of data collection does not permit the prediction of a long-term effect of different harvest regimes on this recalcitrant soil carbon. However, assuming that the mineral soil CO_2 efflux rates at the Tennessee site continue for 20 years (an extreme assumption because both biotic and abiotic factors effecting CO_2 efflux will change as the cut forests regenerate), $\approx$18% of the present soil carbon pool in the control plot will return to the atmosphere as CO_2 during the 20-year period vs 23 and 24% for intensive and conventional harvesting, respectively (i.e., the mineral soil carbon in the treated plots is respiring faster than in the control plots).

Carbon Cycle Models

Carbon cycle models are calibrated against an assumed initial steady state that is perturbed by CO_2 releases from fossil fuel combustion and forest clearing. Carbon cycle models are tested against all available data that reflect the dynamics of the total cycle (e.g., atmospheric CO_2 observations, dilution of ^{14}C inferred from tree rings, relative ^{13}C abundance in tree rings, and measurements of changes in the specific activity of ^{14}C in the atmosphere resulting from testing of nuclear weapons.

Utilizing data provided by our inventory work, a five-compartment model for the terrestrial component of the carbon cycle was developed and tested with a two-compartment model for the oceans. The general approach to developing this model and a discussion of its utility are given in Emanuel et al. (1981). The major improvement made by this model is a breakdown of the terrestrial carbon pool among compartments that are analogous to the functional groups used by ecologists to organize field data. By including this level of functional detail, greater resolution in representing the range of response times in the terrestrial system is possible. The model is structured to allow consistent analysis of the primary issues concerning the role of terrestrial ecosystems in the global carbon cycle with particular attention to releases of carbon by forest clearing and associated shifts in carbon storage capacity between "trees" and "ground vegetation."

The time series of ^{13}C:^{12}C ratios in tree rings potentially can serve as a surrogate for direct observations of CO_2 concentration. The ^{13}C:^{12}C time series show a decreasing trend in the relative abundance of ^{13}C that generally cannot be entirely accounted for by the release of carbon from fossil fuel that is depleted in ^{13}C relative to the atmosphere. Release of carbon by forest-clearing activities is conjectured to have been an additional source

of ^{13}C-depleted CO_2. A dynamic model of the carbon cycle is required to reconstruct the magnitude of forest-clearing release and resulting atmospheric CO_2 concentrations implied by any particular $^{13}C:^{12}C$ time series. We have used our global carbon cycle model to examine the implications of the $^{13}C:^{12}C$ data collected by Freyer (1979).

By adjusting the releases of carbon by forest clearing, a close fit of model response to the $^{13}C:^{12}C$ tree-ring time series is derived. The resulting forest-clearing release function peaks in 1935 with a net transfer of carbon to the atmosphere of 4.5 Pg.

The ocean is one of the major carbon reservoirs. It covers three-quarters of the earth's surface area. The amount of carbon taken up by the ocean makes up a major portion of the global carbon budget. Unfortunately, because the amount of increase of total CO_2 concentration caused by the uptake of fossil fuel carbon is too small to be measurable with enough precision at the present time, the estimates of the amount of uptake by the ocean must rely on ocean modeling.

Based on GEOSECS data, an estimated 35×10^{14} moles of fossil fuel CO_2 have been taken up by the ocean as of the end of 1973. Compared with the accumulative production of fossil fuel carbon from 1860 to 1973 (i.e., a total of 107×10^{14} moles), the amount in the ocean accounts for 33% of the total. If regional models are used, the estimate becomes 44×10^{14} moles (~41%). In this calculation, the upwelling in the equatorial region, downwelling in the temperate region, and deep water formation in the polar regions are included in the model. Because of insufficient ocean data, the latter estimate carries a higher uncertainty.

Assuming a constant airborne fraction of 55% since the introduction of fossil fuel CO_2 into the atmosphere, the amount remaining in the air as of the end of 1973 is 59×10^{14} moles. The other fraction is, thus, 48×10^{14} moles. The model estimates of oceanic fraction ranges from 29×10^{14} to 44×10^{14} moles. It appears that a third carbon reservoir is required to balance the carbon budget. The terrestrial biosphere is a good candidate for balancing the budget, but it also has been considered an important source of CO_2 input into the atmosphere.

Response of Terrestrial Carbon Cycling to Climate Change

The essence of our approach to the bioclimatology of atmospheric CO_2 concentrations involves coupling forest-stand simulation models (e.g., Botkin et al. 1972 and Shugart and West 1977) with paleoecological data. We achieved early success with verification of the forest-stand simulator for multimillenial periods. After the solution of initial difficulties, we were encouraged by the close match between the vegetation simulated by the model and the vegetation actually recorded by pollen. The resulting paper (Solomon et al. 1980) details the verification in which growth of 65 species was simulated during 16,000 years. Perhaps more importantly, the simulations documented characteristics of the vegetation that were unavailable from pollen evidence, including the dynamics of insect-pollinated tree species (e.g., basswood and yellow poplar), the variance in species and community biomass, and the structural characteristics of the communities (e.g., stem diam frequencies and densities of species) that must have existed to produce the resulting fossil-pollen spectra.

Based upon the verification study, we undertook a second series of simulations to examine the roles of species immigration and climatic change in forest succession (Solomon et al. 1981). A significant result of these simulations was the identification and separation of forest changes caused by species migrating from those forests as a result of climate shifts. Both changes influence vegetation recorded by Holocene pollen chronologies, but only the rapid climatic changes, which are induced by atmospheric CO_2, are likely to control vegetation that cannot respond by migrating.

Another important characteristic of the simulations involved the temperature change associated with the rapid shift from coniferous spruce- and pine-dominated forest to deciduous oak-dominated forest. The pattern closely resembles such changes at Anderson Pond, Tennessee; Silver Lake, Ohio; Hack Pond, Virginia; Rocky-

hock Bay, North Carolina; and White Pond, South Carolina. Previously attributed to climatic warming of 10° C, the vegetation change was simulated under a temperature increase of about 1° C. This threshold behavior of forest succession contrasted with behavior under subsequent gradual warming of 5 to 9° C, a variance that had little effect upon community structure. The basic paleoecological data used in simulations specify the nature of vegetation response to climate change under an interglacial climatic regime. Exploration for new sites indicates that Holocene lacustrine sedimentary deposits exist in the southeastern United States. Cahaba Pond, St. Clair County, Alabama, one such site, has a surface area of 0.2 ha and a sloping, forested watershed of 5 ha. The basal organic section of the 6.5 m core dates 11,960 ± 70 radiocarbon years before the present. Cahaba Pond, thus, has one of the thickest Holocene sediment accumulations of any lacustrine site examined in the mid-South.

Prehistoric climate records were examined for use as simulation model driving variables. Preliminary dendroclimatic reconstructions and verifications were carried out in two selected areas. Eastern Tennessee was selected because of its location near the center of the southeastern United States and near our facility, because available tree-ring chronologies there extended back before 1700 AD, and because earlier work indicated strong responses to moisture stress by the two important species (*Quercus alba* and *Pinus echinata*) for which chronologies were available. The *Quercus alba* chronologies from Iowa were also investigated (Duvick and Blasing 1981) because we had extended those chronologies to over 300 years and because climatic reconstructions from the central United States are necessary to bridge the gap of climatic reconstructions from the east to the west.

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PART II. ENVIRONMENTAL SCIENCES DIVISION PROGRAMS

5. ADVANCED FOSSIL ENERGY PROGRAM

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Introduction

The United States continues to strive for energy independence, and coal and oil shale are expected to provide future liquid fuel and petrochemical feedstocks. Technological emphasis centers on construction of a few large-scale demonstration or commercial facilities and longer-term research to develop more efficient second generation processes.

Our research program maintains the primary goal of producing data that will facilitate development and siting of environmentally amenable advanced fossil technologies. Emphasis continues to shift toward longer-term "generic" studies designed to (1) determine exposure pathways for contaminants (including the form,

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source, and potential concentrations of potentially hazardous materials), (2) identify potential ecological effects (including developing data bases for different levels of biological organization), and (3) develop environmental assessments. Use of materials from a range of processes (such as H-Coal and SRC) enables bracketing the magnitude of effects that might occur from products and effluents of the types of technologies being developed.

Increasing emphasis toward predictive modeling of transport and effects and integration of data gathering to parameterize the models took place during FY 1981. Two new initiatives also began in 1981. One initiative, a project to conduct environmental research related to eastern oil shale, preliminarily identified land rehabilitation and solid residual disposal as potential environmental constraints to exploitation of this energy source. The other initiative is an environmental risk assessment of synfuels technologies. The latter project is particularly exciting because it integrates quantification of probability of risk to socially accepted ecological parameters with predictive modeling. More detailed descriptions of this effort are contained within this section and in the Environmental Impacts Program section.

Atmospheric and Terrestrial Effects of Coal Conversion Technologies

To address the potential impacts of coal conversion on terrestrial systems and provide data that will be useful to the developing technology from the standpoint of the need for emission controls, research is under way to identify which emission component or components are most toxic to vegetation and to develop a data base from which effects can be predicted. These objectives are addressed along several fronts and include:

1. comparative studies of the toxicity of gaseous effluents,
2. determination of pathways and fate of PAH in plants,
3. evaluation of the influence of environmental variables on uptake and toxicity of gases, and
4. regional analysis of air quality changes and environmental effects of multitechnology siting options.

Collectively, these results are applicable to the environmental assessment of coal conversion technologies both from the standpoint of recommending the level and specificity of emission control and evaluating the relative environmental risks associated with regional siting options.

Comparative Uptake and Toxicity of Sulfur-Containing Gases

Coal-conversion facilities will release to the atmosphere a number of reduced and oxidized sulfur-containing gases. The principal compounds are carbonyl sulfide (COS), carbon dissulfide (CS_2), methyl mercaptan (CH_3SH), hydrogen sulfide (H_2S), and sulfur dioxide (SO_2). Although much is known regarding the fate and effects of SO_2 in the terrestrial environment, comparable data for the reduced sulfur gases are not available. The response of vegetation to these atmospheric emissions will be dictated by the rate of pollutant uptake in the subsequent toxicity of the gas or its derivatives to sensitive physiological processes that underlie plant growth and development. When combined with projected ground-level concentrations, measurements of pollutant uptake and indicators of physiological stress can identify emissions most likely to pose a threat to vegetation. With this rationale, five sulfur-containing gases were examined for biological reactivity using the Air Pollution Effects Research Facility. Primary interest centered on comparisons of relative uptake potential and principal factors controlling foliar uptake. The uptake by vegetation of each gas by *Glycine max* and *Phaseolus vulgaris* L. was measured at an ambient concentration of 0.12 ppm, which is equal to or less than projected ground-level concentrations for most of these compounds. As an indicator of toxicity, the response of phytosynthesis in each species was monitored for a range of pollutant concentrations (0–1.5 ppm).

At an equivalent ambient concentration, the uptake rate of the sulfur gases into the leaf interior varied twelvefold in *P. vulgaris* from 0.3 to 0.36 $\mu g\ cm^{-2}\ h^{-1}$ (Fig. 5.1). For both plant species, the hierarchy of reactivity among gases was identical:

$$SO_2 > H_2S > COS > CH_3SH > CS_2 \ .$$

ORNL-DWG 81-5913 ESD

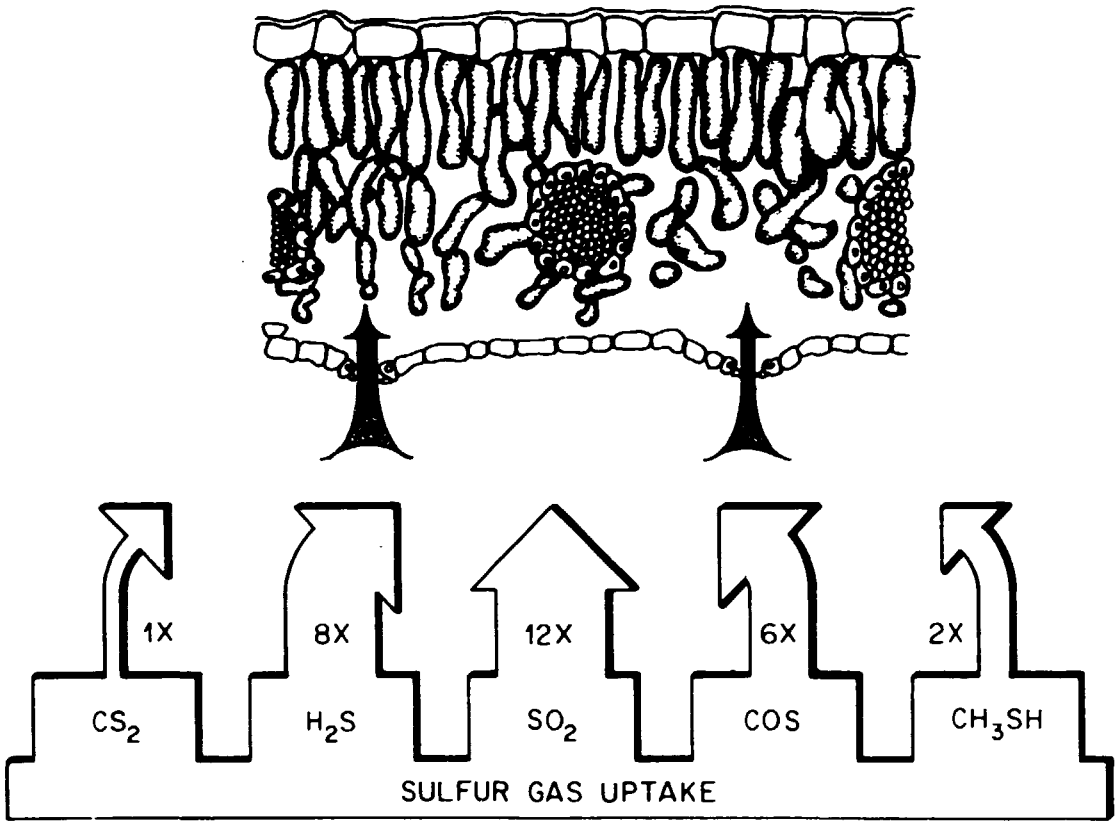

Fig. 5.1. A comparison of leaf uptake of five sulfur-containing gases emitted from coal conversion facilities. Gas uptake is expressed relative to that for CS_2, which was the lowest.

Using multiple linear regression techniques, 84% of the twelvefold variation in uptake among gases was attributable to two chemical properties of the gases: solubility in water and molecular diameter. The regression equation was

$$\text{uptake} = 37.9 + 7.5\,(\text{LN solubility}) - 13.5\,(\text{diam})^{1/2}$$

The response of photosynthesis to the sulfur gases revealed a correlation between the uptake rate of a gas and the effect of the uptake rate on photosynthesis. Neither CS_2 nor CH_3SH influenced photosynthesis, while SO_2 and H_2S had pronounced negative effects. The COS was intermediate in its influence on photosynthesis. Thus, the hierarchy of toxicity among gases is identical to the hierarchy for uptake. This relationship suggests that the ability to predict uptake of a gas based upon its chemical properties may serve as a valuable tool to screen gases for their potential toxicity to vegetation.

Uptake and Fate of the Polycyclic Aromatic Hydrocarbon (PAH), Anthracene, in Vegetation

Even in remote areas of the world, PAHs are present in soil and vegetation. Research has shown that the presence of the PAHs results partially from the ability of some plants and some soil bacteria to synthesize their

own PAH. However, the amount of PAH in the environment is increasing to above "background" levels because of anthropogenic sources. Because some of the PAHs are carcinogenic, concern exists that they might be concentrated in plant tissues and, thus, enter food chains leading directly to man. Research to date at the Oak Ridge National Laboratory (ORNL) has centered on uptake of a typical PAH (anthracene) by soybean *(Glycine max)*. The research addressed the following three basic questions: Will plants assimilate anthracene through their roots and/or leaves and translocate it to other plant parts? If so, what is the effect of anthracene concentration on uptake rates? Can anthracene be catabolized by soybean plants?

Through short-term (3–4 d) solution culture and soil culture experiments, it was demonstrated that soybeans can assimilate ^{14}C-anthracene through their leaves or roots and translocate it to other plant parts. Uptake rates were linearly related to anthracene concentrations in solution culture within the range of concentrations tested (3–120 ng/mL). Catabolism of anthracene to CO_2 by soybean plants occurred at a very slow rate. However, thin layer chromatography (TLC) analysis of plant extracts indicates that metabolites of anthracene were formed within hours after uptake.

Future research will address the following five questions: To what extent will plants concentrate PAH during their full life cycle (in total and in specific tissues)? What are the limits of PAH uptake rates by plants? Will plants assimilate PAH from soil contaminated with flyash which contains PAH? How do molecular structure and size of PAH affect uptake rates by plants? How does distance from a source affect PAH concentrations in natural vegetation, crop species, and soil?

Environmental Modification of Pollutant Effects on Vegetation

In laboratory studies to assess the influence of relative humidity on foliar uptake of SO_2 and O_3 by *Phaseolus vulgaris* (Bush Blue Lake beans, variety 274), foliar uptake was enhanced two- to threefold for SO_2 and three- to fourfold for O_3 as exposure to humidity was increased from 35 to 75% (Fig. 5.2) (McLaughlin and Taylor 1981). Differences in internal flux of these pollutants were attributed primarily to differences in internal resistance to movement of the gases from air to sites of reaction in the leaf interior. These results reflect the importance of pollutant solubility in water on uptake potential and the probable influence of changes in water status of the substomatal chamber to atmospheric humidity. The strong dependency of pollutant uptake on atmospheric humidity further indicates that very different levels of control of atmospheric emissions may be required for coal-conversion facilities sited in the arid western United States compared with those facilities located in the much more humid eastern states.

Additional research on the influence of low levels of SO_2, O_3, and NO_2 singly and in combination on growth of agricultural and forest species is being conducted through respective subcontracts with North Carolina State University at Raleigh and Virginia Polytechnic Institute and State University at Blacksburg. This work will provide data on the extent to which plant growth may already be influenced by regional background pollutants in the areas where siting is being considered.

Preliminary Analysis of Air Quality Changes in Western Kentucky

The multiple siting of coal combustion and liquefaction facilities in a 60-km radius within Western Kentucky could alter regional air quality patterns. As a first step in a regional environmental analysis, both present ambient and projected changes in air quality levels have been determined. Current patterns of agricultural and forest vegetation have also been examined.

The U.S. Environmental Protection Agency (EPA) monitoring stations provided regional background levels for SO_2 and ozone in the western Kentucky region. To calculate projected emissions from the coal combustion and liquefaction plants, an air diffusion model utilized input data from process-engineering studies for

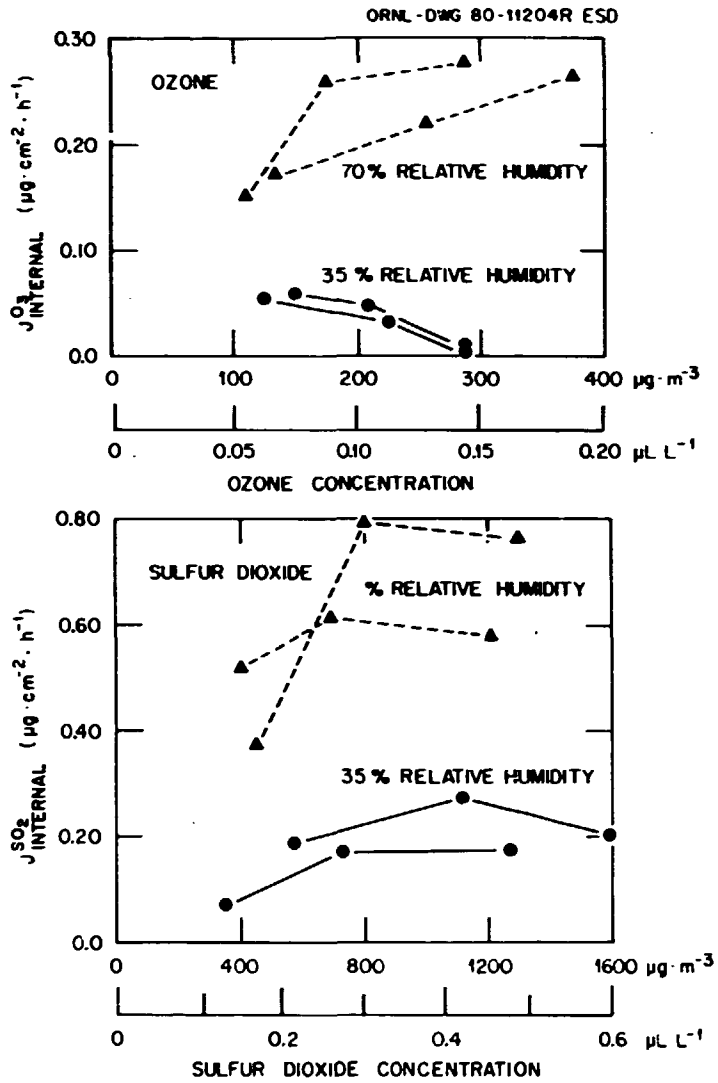

Fig. 5.2. Foliar uptake of O_3 and SO_2 as influenced by relative humidity and pollutant concentration. Results of two exposures (10 plants each) at each humidity × pollutant combination are shown.

the SRC-I synthetic fuel plant and the Rockport coal combustion facility. Emissions within a 50- to 100-km radius of the facility were calculated by the model and overlain on ambient air-quality levels to determine changes associated with the mix of coal technologies in this region.

Large, economically important areas of soybeans occur within the air shed defined by the eight proposed coal utilization facilities. Background levels of SO_2 and ozone already appear to occur at chronic and, during certain periods, acute levels at which effects on sensitive species have been demonstrated, with added facilities resulting in increased atmospheric loading. As better data on possible emissions from the planned facility become available, we shall be able to quantify individual contributions and provide input for decisions on future facility sitings. These results support the importance of regional environmental analyses to incorporate and quantify principal components associated with landscape environmental problems.

Solid Wastes from Coal Conversion

The prevailing management strategy for disposal of solid wastes from coal-conversion technologies is disposal in landfills. Solid waste research is being conducted to characterize and predict the long-term behavior of coal-conversion wastes following disposal under a range of environmental conditions. Past and continuing work involves leaching studies on a variety of gasification ashes and slags, the major solid waste generated in coal conversion processes. Research has recently been initiated defining the extent of degradation and corresponding degradation rates of oily and wastewater sludges under simulated disposal conditions. The similarities and differences between the weathering rates of gasifier ashes and ashes produced in conventional coal combustion processes are also being determined; the purpose of the determination is to translate information already known about coal combustion ashes into information relative to coal-conversion ashes. Work evaluating the influence and magnitude of sulfur oxidation in gasifier ashes and the potential of toxic trace elements in these ashes to be transported to man via biotic and abiotic food chains is being conducted.

The research objectives are pursued by conducting a variety of experiments under laboratory and greenhouse conditions. Initial analyses of leachables in the solid wastes are determined using short-term (<24 h) batch-type extractions. The weathering characteristics of solid wastes are studied using intermittent and continuous-flow column elution studies. The influence of biological oxidation mechanisms on the oxidation of reduced forms of sulfur are studied in the presence and absence of organisms known to rapidly oxidize sulfur. Other factors such as essential nutrients, oxygen supply, and the effect of toxic elements are also considered. The ability of certain soils and geologic substrata to attenuate hydrologic transport of known coal conversion pollutants is being evaluated to (1) develop predictable transport models and (2) identify needed environmental control practices. The approach is to identify potential health and environmental problems related to coal-conversion solid waste disposal and to suggest how these problems might be avoided or mitigated.

The objectives of the present and future research are to answer questions relative to the major health and environmental issues associated with the disposal of coal-conversion solid wastes: What are the impacts on surface-water and groundwater quality, the effects on land use (coincident effects on aquatic and terrestrial ecosystems), and, ultimately, the risks to human and environmental health? The objectives are as follows:

1. evaluate the long-term chemical and biological characteristics of the solid wastes and their leachates,
2. predict solid waste leachate composition and effects on water quality,
3. measure acute and chronic toxicities on aquatic and terrestrial environments,
4. evaluate effects of land rehabilitation practices, and
5. clarify and quantify the mechanisms (biotic and abiotic) responsible for transport of pollutants in the environment.

Leachability of Solid Wastes from Coal Gasification and Coal Combustion

The slag generated as a consequence of many coal gasification processes has been hypothesized to be similar to slag and bottom ash generated in conventional furnaces and, thus, to be equally resistant to dissolution in landfill environments. To test this hypothesis, three solid wastes from the gasification and direct combustion of Pittsburgh seam coal have been subjected to continuous-flow-column leaching using distilled water and dilute hydrochloric acid. Gasification slag was obtained from the Combustion Engineering gasifier (120-Mg/d process development unit) in Windsor, Connecticut. Conventional combustion slag (cyclone furnace) and bottom ash (pulverized coal furnace) came from electricity-generating plants in New Hampshire and Pennsylvania, respectively. Table 5.1 summarizes selected characteristics of the solid wastes and column dimensions.

Except for nickel in the gasification slag, all three wastes showed low (<1%) distilled water leachabilities of Al, Ca, Fe, Mn, Ni, Cr, Cd, and Ba. The gasification slag exhibited the highest distilled water leachability of

Table 5.1. Summary of column and waste characteristics[a]

	Gasification slag	Combustion slag	Combustion bottom ash
Sample weight, g	350	310	300
Sample volume, cc	200	200	235
Specific gravity	2.82	2.79	2.41
Void volume, cc	75	90	110
Surface area, m^2/g	0.56	0.012	1.25
Extraction duration, d	17	17	24–28
Al, %	14.9	12.6	11.9
Ca, %	1.32	5.52	2.38
Fe, %	14.4	12.2	14.9
Mn, μg/g	273	205	176
Ni, μg/g	228	98	122
Cr, μg/g	4750	126	87
Ba, μg/g	1470	1253	551
Cd, μg/g	0.18	0.64	0.1
Pb, μg/g	4.9	8.1	8.0

[a]Wastes were extracted in duplicate using distilled water or 0.05 *N* HCl applied continuously to the top of each column at 200 mL/d.

all elements except Cr, thus reflecting the more acidic reaction of the gasification slag. Under dilute acid leaching, the gasification slag and combustion slag exhibited remarkably similar leachabilities of all elements except nickel and cadmium. The latter elements were from three to four times more leachable from the gasification slag than from the combustion slag. Similar values of leachability (~2%) for most of the elements in the two slags were consistent with the dissolution of a homogeneous solid phase (i.e., a silicate glass). In contrast, the values of dilute acid leachability for elements in the combustion bottom ash varied widely (0.85–10.8%), thus suggesting that bottom ash is a heterogeneous mixture of solids with varying resistances to dissolution.

Some of the differences in leachability among the wastes were suspected to result from the inclusion of an easily soluble component, one that perhaps was derived from the quench water. Because quench water is recycled at the gasifier, the water contains high dissolved solids. Even small quantities of this water retained with the gasification slag could elevate the values of element leachability. To eliminate this possibility, leaching rates *(k)* were calculated for the final column effluents as:

$$k = \frac{a_n}{A_o} \cdot \frac{1}{t_n} \quad ,$$

where a_n is the quantity of an element leached in period n, A_o is the quantity of the element initially present in the solid sample, and t_n is the duration in days of the nth leaching period.

Overall, these results suggest that under similar leaching conditions, gasification slag is not greatly different from combustion slag in its resistance to dissolution. If total leachability or the rates of leaching are normalized to specific surface areas of each waste (Table 5.1), the lower surface area of the combustion slag (0.01 m^2/g) relative to the gasification slag (0.56 m^2/g) actually leads to higher apparent total leachability and rates of leaching for the combustion slag compared with the gasification slag. The chief inference from this research is that slag from coal gasification plants can be disposed of in the same manner as slag from coal combustion plants.

Microbial Oxidation of Sulfur in Coal-Conversion Solid Wastes

Many coal gasification ashes and slags contain from 0.3 to 4.0% inorganic, reduced sulfur. Chemical or microbial oxidation of this sulfur to sulfuric acid during landfill disposal of the wastes could lead to adverse

environmental effects similar to those encountered with acid- (coal) mine drainage wastes. Previous experimental results have shown that chemical sulfur oxidation was possible in four out of five gasifier ashes tested. Significant microbial sulfur oxidation occurred in three of these ashes. Because sulfur-oxidizing bacteria could not be detected ($<3\times 10^3$/g) at the start of this experiment, the apparent lack of microbial sulfur oxidation in two of the ashes may have been a result of an inadequate inoculum rather than an availability of the reduced sulfur. Therefore, a protocol for inoculation of wastes with an active, mixed culture of sulfur-oxidizing microbes was developed and tested to standardize the methods for determining the potential for microbially mediated oxidation of reduced sulfur contained in gasifier ashes and other coal conversion solid wastes. A sample of runoff from the ORNL coal pile was used as a source for the mixed-culture inoculum because a previous study had indicated the presence of sulfur-oxidizing bacteria in these acid (pH ~2.0) producing wastes. The number of sulfur oxidizers in the coal pile runoff was increased by the addition of mineral nutrients and using thiosulfate as a source of energy for the microbes. Preliminary tests of this inoculum have shown that its addition to a gasifier ash can also significantly stimulate the oxidation rate of reduced sulfur and concomitant release of iron. Further tests with other gasifier wastes are in progress.

Disposal of Coal-Conversion Wastewater Sludges

Oily wastewater sludges are expected to contain high concentrations of toxic organic and inorganic substances and will likely be disposed of by either land-filling or land treatment. The purpose of this research is to investigate the long-term environmental impacts of the disposal of coal-conversion wastewater sludge. Particular emphasis is being placed on the degradation of organic compounds and leachability of the waste.

Sludge samples from three operating pilot-plant wastewater treatment systems (H-Coal, SRC-I, and SRC-II) and one conventional oil refinery have been collected and are being physically and chemically characterized. To simulate land treatment disposal techniques, a 20-g sample of each sludge was mixed with 100 g of agricultural soil and placed in laboratory columns. These columns were designed to allow for periodic leaching of the soil-sludge mixture as well as the quantitative collecting of carbon dioxide that evolved. Factors of interest in the experimental design included the differences in the rate of organic matter degradation occurring between the four sludge samples as well as the effects of adding a small quantity of municipal wastewater sludge to the soil-sludge mixture prior to disposal.

To date, the sludge samples have been incubating in the columns for 100 d and have been subjected to one simulated rainfall event. Carbon dioxide production has been greatest from the SRC-II centrifuge sludge (9.6 mg of CO_2 per 1 g of waste), followed by the oil refinery sludge (4.8 mg of CO_2 per 1 g of waste), the H-Coal American Petroleum Industry (API) sludge (2.8 mg of CO_2 per 1 g of waste), and the SRC-I sludge (0.96 mg of CO_2 per 1 g of waste). Carbon dioxide production from the soil control treatment (0.11 mg of CO_2 per 1 g of soil) ranged from 9 to 90 times lower than wastewater soil-sludge mixtures. The addition of municipal wastewater sludge was shown to increase the carbon dioxide production from both the H-Coal and SRC-II sludges by a factor of 2.8 and 2.0, respectively, but the sludge made insignificant differences in carbon dioxide production in the case of the SRC-II and oil refinery samples. Studies are continuing in the areas of organic compound identification, carbon balance through the columns, and organic matter degradation to determine if land treatment is a viable disposal alternative for these oily wastewater sludges.

Bioaccumulation of Toxic Trace Elements from Coal-Conversion Solid Wastes

One of the major environmental and health concerns in the disposal of coal-conversion solid wastes is the transport of toxic contaminants present in these wastes to man via biological food chains. Transport and possible bioaccumulation in terrestrial food chains may result as a consequence of revegetation of disposal sites.

To investigate the possibility of plant uptake of toxic trace elements from gasifier ash, a greenhouse experiment was conducted in which ryegrass was grown in mixtures of soil and gasifier ash. Three gasifier ashes were used at three levels (10, 50, and 90% by weight) in two soils, a highly weathered shale residual that is a candidate for use in land reclamation and an agricultural soil. The influence of lime and fertilizer amendments was also evaluated. Six cuttings or harvests of the ryegrass have been taken over an interval of six months. The objectives of the experiment were to evaluate the phytotoxicity of the coal-conversion solid wastes applied directly to soils and to determine the extent of plant uptake of toxic trace elements from gasifier ashes.

Yields of ryegrass after intensive cropping (fourth and later harvests) were appreciably lower at high waste/soil ratios than were yields from the control pots (soil only). However, where fertilizer and lime were applied, there appeared to be no difference in plant yields. This lack of difference in plant yields also appeared to be the case in the unlimed soil and the soil that had no fertilizer treatments up to about the second harvest. A statistical analysis of the data is presently being conducted.

Concentrations of some selected toxic trace elements in the second harvest of ryegrass are presented in Table 5.2. These data show that biological transport of toxic trace elements may occur to a significant extent if land applications of some of the coal-conversion wastes are practiced. For example, this particular waste applied to an unlimed Conasauga shale will significantly enhance the biological transfer of known toxic trace elements (B, Be, Co, Ni, Zn, and Cd) in grass to man's food chains.

Table 5.2. Evidence of bioaccumulation of toxic trace elements in ryegrass grown on a mixture of coal gasification ash and Conasauga shale[a]

	Concentration in plants (μg/g dry wt)		Approximate enrichment factor
	Control	Mixture[b]	
B	29.9 ± 6.3	97.8 ± 22.8	3[c]
Be	0.06 ± 0.01	0.63 ± 0.50	10
Co	1.05 ± 0.04	36.6 ± 8.4	35
Cr	0.31 ± 0.08	0.34 ± 0.07	1
Cu	9.71 ± 1.04	17.8 ± 10.9	2
Fe	53.2 ± 11.1	188 ± 32	4
Mn	243 ± 11	386 ± 44	2
Mo	BD[d]	0.36 ± 0.14	NA[e]
Ni	5.59 ± 0.41	515 ± 97	90
Pb	BD	1.09 ± 0.70	NA
Zn	63.9 ± 4.9	1095 ± 118	17
Cd	0.78 ± 0.11	18.6 ± 2.3	24

[a]Second harvest, average of three replicates.

[b]Mixture of coal gasification waste, 90% waste and 10% weathered Conasauga shale.

[c]The approximate enrichment of the element in the ryegrass grown on the mixture of waste and shale relative to ryegrass grown on shale only.

[d]BD = below detection.

[e]NA = not applicable.

Coal Liquefaction Product Spills

Accidental releases of liquid products from coal conversion are among the major potential environmental hazards of synthetic fuel production. It is estimated that a commercial liquefaction industry (8×10^6 L/d) would result in spillage of from 1.6×10^5 to 2.4×10^6 L of product annually into aquatic ecosystems alone (Leggett

et al., in press). Failure to consider the possible impacts of product spills has already contributed to delays in the completion of environmental impact statements for some coal conversion facilities. The need for investigation of the hazards of product spills has been underscored by accidental releases from coal liquefaction pilot plants within the past two years.

Research is under way to define the problems associated with spills of coal liquefaction products on land or water and to explore strategies for dealing with these problems. The objectives are to

1. determine pathways and measure rates of transport, transformation, and partitioning of synthetic oils spilled in aquatic and terrestrial environments as environments are influenced by physical/chemical characteristics of the oils and conditions during the spill;
2. determine the effects of acute and chronic exposure to synthetic oils, oil fractions, and residues on aquatic and terrestrial organisms and ecosystems; and
3. evaluate strategies for reducing the environmental hazards of coal liquid spills.

Mass Transfer Model for the Dissolution of Organics from Synthetic Fuel Films

The "two-film" model used to describe volatilization of organics from liquids was modified to describe dissolution of solutes from floating oil films into water. The following expression for the mass flux of solute across the oil-water interface was obtained:

$$F = \frac{k_o k_w}{k_w + k_o P}(C_o - PC_w) ,$$

where F is instantaneous mass flux, $\mu g\ cm^{-2}\ h^{-1}$; k_o and k_w are oil and water phase mass transfer coefficients, respectively, $cm\ h^{-1}$; P is the oil-water partition coefficient; and C_o and C_w are concentrations of solute in oil and water, respectively, $\mu g\ cm^{-3}$.

Laboratory investigations of the variation in dissolution rate with P by using binary oil-solute mixtures demonstrated that the previous equation adequately described the dissolution of chemicals from oil films. Further studies with various synthetic liquid fuels indicated that the model worked well for such complex mixtures.

Studies on the effects of oil, solute, and environmental properties indicated that oil viscosity, solute partition coefficient, and degree of aqueous phase mixing were major determinants of dissolution mass flux. Partition coefficients *(P)* for phenolic compounds decreased with increasing degree of hydrogenation of the synthetic fuels and increased with increasing alkylation of the phenolic compounds. The oil-phase mass transfer coefficient (and thus the rate of dissolution of low P compounds) decreased markedly with increasing oil viscosity. The aqueous-phase mass transfer coefficient (k_w) was shown to be correlated with the aqueous reaeration coefficient, thus providing a means for estimating values of k_w in field conditions from the reaeration coefficient, which can be calculated from a knowledge of river depth and velocity.

The dissolution mass transfer model incorporates variations in oil, solute, and environmental properties into an estimate of interfacial solute flux and has been applied as a subroutine in an overall oil-spill transport model.

Transport Model for Synthetic Oil Spills in Rivers

We have developed a one-dimensional mathematical model to predict the spatial and temporal distribution of contaminants that would dissolve from spilled coal liquid into underlying river water. The model consists of three submodels that describe (1) slick spreading, (2) dissolution, and (3) hydrodynamic dispersion, respectively. In the simulation, a point discharge of a given volume of synthetic oil (density less than one) is permitted to

spread across the surface of the river water in accordance with forces of gravity, inertia, viscosity, and surface tension, and to move downstream because of river flow. Rates of contaminant dissolution from the oil film are defined as a function of the contaminant oil-water partition coefficient, water turbulence, oil viscosity, and instantaneous oil film thickness by equations that have been developed and validated in laboratory studies. Once in the water column, contaminants disperse because of hydrodynamic turbulence.

Initial sensitivity tests indicate that the oil film thickness substantially affects the contaminant dissolution rates and, thus, waterborne concentrations of compounds, particularly those with high P values. For a hypothetical 3000-L coal liquid spill into a river 200 m wide and 4 m deep, maximum predicted concentrations of phenol ($P = 2.8$) 1.5 and 9 km downstream from the spill are 20 and 4 ppb, respectively, regardless of assumptions of slick thickness. For tetramethylphenol ($P = 320$), however, the maximum predicted concentration 1.5 km downstream ranged from 2 to 18 ppb, depending on the assumption of slick spreading used.

An Efficient Algal Bioassay Based on Short-Term Photosynthetic Response

A procedure was developed for measuring effects of toxicants on algal photosynthesis ($H^{14}CO_3$ uptake) in 4-h experiments and applied in studies of a variety of aromatic compounds and the water-soluble fractions (WSFs) of coal-derived oils. The toxicity of the WSFs varied among the seven algal species tested, and responses of some species were pH dependent. With *Selenastrum capricornutum* as the test organism, bioassay results were unaffected by variations in pH from 7.0 to 9.0, light intensity from 40 to 200 $\mu E\ m^{-2}\ s^{-1}$, culture density up to 0.5 mg chlorophyll-*a* L^{-1}, and agitation up to 100 rpm. The photosynthesis bioassay is simpler and faster (4 h vs 4–14 d), uses smaller culture volumes, and requires less space than standard static culture-growth tests. One person can conveniently test four materials per day, and the entire procedure, including preparation, exposure, and analysis, takes less than 2 d. The short incubation time reduces bottle effects such as pH changes, accumulation of metabolic products, nutrient depletion, and bacterial growth. Processes that remove or alter test materials are also minimized. Data indicate that algal photosynthesis is inhibited at toxicant concentrations similar to those that cause acute effects in aquatic animals.

Role of Particulate Organic Matter in Decreasing Bioaccumulation by *Daphnia magna*

For organic compounds in aqueous systems, a positive correlation exists between the hydrophobic tendencies of the organic (water solubility^{-1}, octanol/water partition coefficient) and both its potential for bioconcentration in aquatic organisms and its potential for sorption to particulate organic matter (POM) in the water (partition coefficient). Sorption to suspended POM would decrease the amount of xenobiotic organics in solution but would permit entry of a potentially toxic organic into the food chain as filter feeders ingest the POM laden with sorbed chemical. What is the net effect of POM on the bioaccumulation potential of an organic compound? Which process contributes more to bioaccumulation potential—direct uptake of the organic from solution or uptake from ingestion of POM with sorbed organics?

The bioaccumulation of ^{14}C-benzo[a]pyrene (BaP), a carcinogenic PAH found in coal-derived fuels, by *Daphnia magna* was examined in two sets of experiments: uptake by *Daphnia* in a filtered BaP solution and uptake by *Daphnia* in an equilibrated suspension of BaP and yeast cells, a model POM. Results were analyzed by the following multicompartmental analysis:

$$dD/dt = (K_u \times W) - (K_d \times D) + (k_f \times Y) \ ,$$

where D = micrograms of BaP per gram of *Daphnia;* W and Y = micrograms of BaP in dissolved and sorbed form, respectively, per milliliter of suspension; K_u = uptake rate of dissolved BaP; K_f = uptake rate of BaP sorbed to ingested yeast; and K_d = depuration rate. Rate coefficients were fitted by nonlinear iterative least-squares

procedure in the statistical analysis system (SAS) using a two-step fit; K_u was first determined in the absence of yeast, then K_u was fixed and K_f fitted when yeast was present.

The presence of yeast cells dramatically decreased the rate of uptake and total bioaccumulation of BaP by *Daphnia*. The nonlinear fit gave the following estimates for rate coefficients (± asympotic standard error): K_u = 1060(±44) h^{-1}, K_f = 118(±20) h^{-1}, and K_d = 0.1(±0.007) h^{-1} when no yeasts were present, and K_d = 0.22(±0.02) h^{-1} when yeasts were present. Thus, the rate of uptake of BaP from water is an order of magnitude greater than is uptake from ingestion of particles with sorbed BaP.

Sorption of BaP to suspended POM results in removal of BaP from solution and, therefore, decreases its bioavailability to *Daphnia*. Preliminary experiments indicate that sorption of BaP to colloidal or dissolved organic matter such as humic acids also reduces bioaccumulation. This finding suggests that predictions about bioaccumulation of hydrophobic organics need to take into account the removal of those organics by sorption to naturally occurring organic matter in the water.

Fate and Effects of a Coal Liquefaction Product in Aquatic Microcosms and Ponds

The fate and effects of contaminants in natural ecosystems are often influenced by complex interactions among organisms and between organisms and their environment. Such interactions are normally excluded from laboratory bioassays and process measurements, but they can be studied in laboratory model ecosystems or microcosms. Eight aquatic microcosms were assembled in August 1980 for a study on the fate and effects of an unrefined coal liquefaction product. The microcosms consisted of 200-L aquariums containing sediment, water, and a complete biotic community (excluding fish) from a shallow pond. By January 1981, the microcosms were dominated by pondweeds and snails, and physical/chemical conditions were relatively constant. In late March, the microcosms were treated with 2, 10, or 50 mL of a crude coal liquid. Concentrations of oil in the water and effects on populations and ecological processes were monitored for three months.

Concentrations of phenols and anilines in samples of water taken 24 h after oil addition corresponded closely with values predicted from dissolution studies. Phenols ranged from 0.2 to 9.1 mg L^{-1} and anilines from 0.007 to 0.7 mg L^{-1}. (The WSFs containing 4.3 mg L^{-1} phenols and 0.6 mg L^{-1} anilines were acutely toxic to *Daphnia magna*, a sensitive bioassay organism.) The 50-mL treatments destroyed virtually all plants and animals and created anaerobic conditions for nearly two months; a gradual recovery began shortly before the experiment was ended. The 2-mL treatments, which corresponded to 1 to 4% of the 48-h LC50 for *D. magna*, caused the following changes in the model ecosystems: elimination of most zooplankton, reduction of overall productivity, decreases in pH and dissolved oxygen, and increases in the abundance of feeders on detritus. Effects of 10-mL treatments were intermediate between the two treatments just described.

A parallel experiment involving a series of 14-m^3 outdoor ponds took place during the summer of 1981. The objectives of the experiment were to refine and extend the microcosm results and to assess the ability of microcosms to provide information relevant to larger ecosystems. The ponds were treated with the same oil and the same dosages per water volume as were used in the microcosms. Dissolved oil concentrations and rates of disappearance of phenolic compounds were similar in the ponds to those in the microcosms. Preliminary analysis of monitoring data from the ponds indicates qualitative and quantitative agreement with microcosm results. In both types of experimental ecosystems, significant changes in ecosystem metabolism and in abundances of some invertebrate taxa were observed at the lowest oil dose, thus implying that pond ecosystems are at least as sensitive to the coal liquid as are the standard bioassay organisms.

Fate and Effects Modeling of Aromatic Hydrocarbons in Ponds

A model was constructed to simulate transport and toxic effects of aromatic hydrocarbons in experimental ponds. Model processes include dissolution of synthetic crude oil applied to the pond surface, photolytic degra-

dation and volatilization of dissolved aromatics, sorption to suspended and settled particulate matter, direct uptake of dissolved aromatics by pond biota, and indirect accumulation of aromatics through the pond food web. Lethal and sublethal toxic effects on pond biota were expressed in relation to concentration of dissolved aromatics, LC50 data for representative pond organisms, and data that describe changes in rates of physiological processes that comprise growth equations for biological components in the model.

Values of parameters that determined rates of hydrocarbon dissolution, photolysis, volatilization, sorption, and bioaccumulation were derived from basic chemical characteristics of aromatic hydrocarbons, including molecular weight, octanol:water partition coefficient, melting point, and light absorption spectra.

Model output included time-varying concentrations of aromatic hydrocarbons in water, sediments, suspended particulate matter, macrophytes, zooplankton, benthic invertebrates, and fish. Mortality resulting from the toxic effects of aromatics on pond biota is predicted along with production/respiration and respiration/biomass ratios of the pond ecosystem.

Monte Carlo methods were used to determine model responses to error associated with parameter estimates. The results of Monte Carlo simulations provided information for modification of the model and identified critical parameters for robust predictions concerning transport, accumulation, and toxic effects of aromatic hydrocarbons in ponds.

Insect Embryotoxicity and Teratogenicity of Chemically Fractionated Petroleum, Shale Oil, and a Coal Liquid

Petroleum has long been known to contain chemicals with insecticidal activity, and the increase in production of fossil fuels from oil shale and coal raises the question of whether these fossil fuels from oil shale and coal also contain chemicals toxic to insects. Comparison of the toxicities of coal, shale, and petroleum oils using eggs of the cricket *Acheta domesticus* indicated that coal liquids caused the highest mortality. In addition, treatment with some coal liquids produced crickets with extra compound eyes, antennae, and heads.

Three fuels (a crude shale oil, a petroleum crude oil, and a coal-derived oil) were fractionated by liquid-liquid extraction and column chromatography into saturates, mono- and diaromatics, polyaromatics, ether-soluble acids, insoluble acids, ether-soluble bases, insoluble bases, and remaining residue. Each fraction was assayed for insect embryotoxicity and teratogenicity.

The ether-soluble bases were the most toxic component of the fuels. This fraction constituted 7.2, 5.1, and 0.2% by weight, respectively, of the shale oil, the coal liquid, and the petroleum crude. When isolated from the shale oil and the coal liquid, this fraction caused duplication of insect body structures. Both the mono- and diaromatic fraction and the polyaromatic fraction from the coal liquid were highly toxic; but these fractions from the shale oil were only moderately toxic, while those derived from the petroleum crude were of low toxicity. The aromatic fractions differed quantitatively as well as qualitatively among the fuels. Mono-, di- and polyaromatics constituted 70% by weight of the coal liquid, 41% of the shale oil, and 23% of the petroleum crude.

Subfractionation of the ether-soluble bases from the coal liquid by column chromatography with subsequent bioassay produced only one teratogenic subfraction, which contributed less than 0.5% by weight to the whole fuel. Primary aromatic amines are the major constituent of the teratogenic subfraction based on analysis by capillary column GC combined with mass spectrometry.

University of Minnesota-Duluth (UMD) Coal Gasifier Studies

The purpose of these studies was to document actual and potential environmental effects of a small coal gasifier installed at the UMD campus to provide a low-Btu gas substitute for a heating plant burning oil and natural gas. The studies focused on monitoring of ambient air quality and testing of solid wastes (gasifier bottom ash and cyclone separator char).

Ambient air quality monitoring performed under subcontract by Dr. Sagar Krupa of the University of Minnesota-St. Paul began in February 1979 and continued through the end of the 1980–1981 UMD campus heating season. Conversion of the campus steam plant to partial use of gasifier products appears to have resulted in an increase in SO_2 and particulate emissions and a decrease in NO_x emissions relative to the previous fuel mix. Samples of particulates are being analyzed for constituents (trace elements and organics) to determine if they might be attributed to the gasifier.

University of Minnesota-Duluth Data Management Project

It was anticipated during the development of the program plan that data would be voluminous and that attempts to analyze and compare samples and integrate the assessment through time would require computerized procedures for the data management and analysis methods. The UMD data management project was formulated to address and develop the procedures required to organize, computerize, analyze, and integrate the variety of data that would be collected during the three-year program. Figure 5.3 shows the organization and flow of data and the number of samples for the UMD project.

The UMD data management project developed the capabilities in five areas: the organization of the sampling programs; systematic structuring of the conversion of all data to computers at ORNL; characterization of

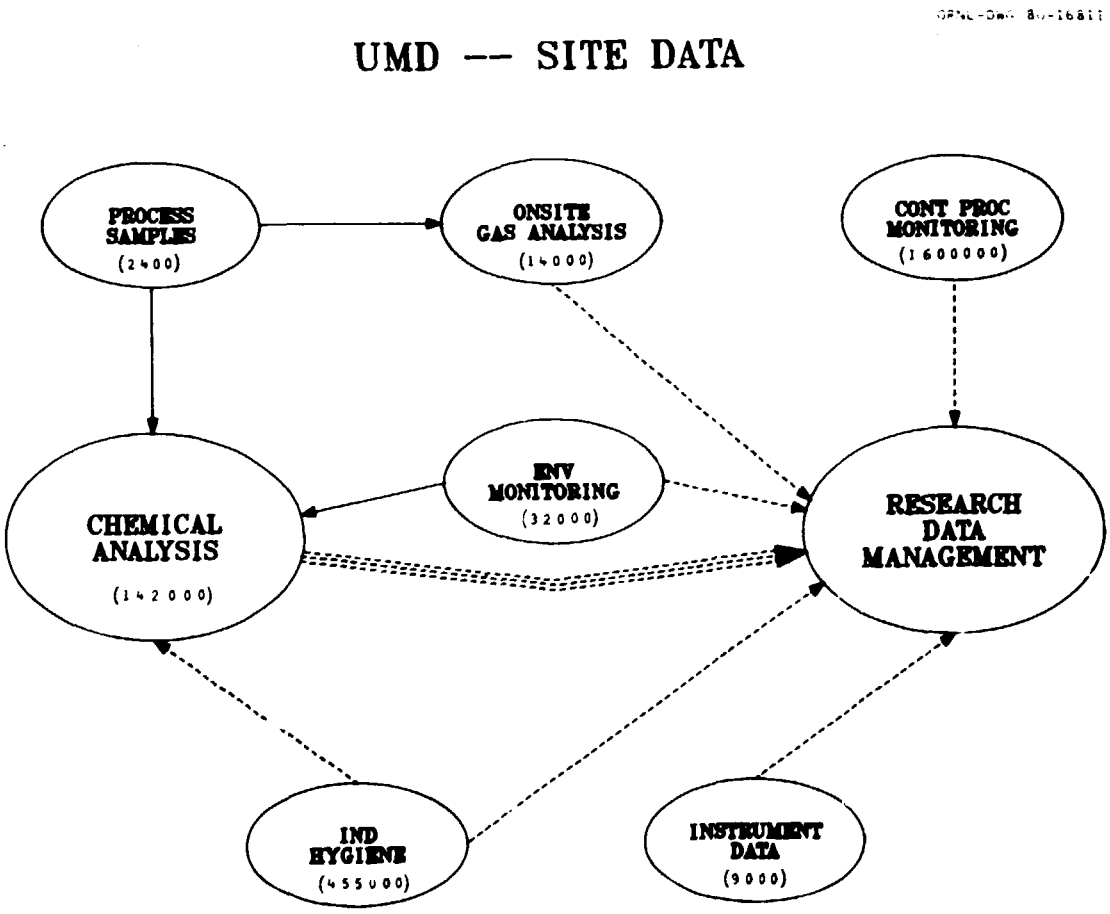

Fig. 5.3. The UMD environmental assessment data collections. Dashed lines represent data. Solid lines represent samples. Numbers in parentheses represent number of records in the data collection.

what data were gathered, missing sampling periods, errors in data, and the spatial and temporal identifiers that would be required to integrate the data gathered for the assessment; the data reduction and analyses for summarizing components; and the summarization and data reports containing results for researchers, managers, and contract officials.

Over 55 statistical and tabular programs were developed for the data reduction and analysis required during the UMD data management project. These statistical analyses and summary programs were used to detect statistical differences among components within the gasifier, product streams, and waste emissions. Analyses of the ash leachates among sampling periods were performed, and calculation of stack emissions and particulate and air quality loadings at the downwind locations where monitoring was occurring were calculated. Analysis of the frequency distribution of wind direction to determine the adequacy of location for the air-quality and meteorological monitoring stations surrounding the gasifier and evaluations of the process monitoring of temperatures, pressures, and flows were performed to evaluate the potential health and environmental effects of the gasifier. These analyses and summaries represent a sampling of those capabilities that were developed to support the required analyses for the assessment of the gasifier. Numerous other correlations, graphical presentations, and summaries were prepared for the purposes of aiding the researchers in the UMD assessment develop their particular evaluations of the gasification process. The establishment of the data management effort provided a secondary resource of numerous data files that were integrated into the total health and environmental effects assessment performed by ORNL personnel.

H-Coal Pilot-Plant Studies

Development and commercialization of the H-Coal liquefaction technology will entail a number of potential environmental impac .sulting from storage or discharge of waste materials or accidental spillage of product oils. Previous studies with H-Coal Process samples from the development unit indicated that WSFs of raw H-Coal products were considerably more toxic than those of natural petroleum products. Data from ecological testing of representative materials from the 190-Mg/d H-Coal pilot plant located at Catlettsburg, Kentucky, will permit a realistic evaluation of environmental effects of the H-Coal process. Moreover, this information can be used to point out areas where development of control equipment is needed to ensure environmentally sound operation of commercial-scale plants.

Sample points and ecological tests were selected for the purpose of providing a data base for evaluation of the H-Coal technology rather than of the H-Coal pilot plant per se. Consequently, the program includes no environmental area monitoring (e.g., ambient air-quality or water-quality studies of the Catlettsburg site); rather it concentrates on the study of product oils, treated effluents, and solid wastes that would be relevant to commercial H-Coal facilities.

Samples of product oils, aqueous effluents (treated process wastewater), and solid wastes (vacuum bottoms, oily sludges, and biosludges) resulting from liquefaction of different coals are collected at the pilot plant. These samples are chemically characterized and examined for their acute toxicity to algae, *Daphnia*, midge larvae, and minnows, important components of the aquatic food chain. Some of the materials are tested for their chronic effects on *Daphnia* and terrestrial insect reproduction and developmental abnormalities of fish embryos and larvae. Toxicities of natural crude oil are also being tested for comparison with the synthetic products. Biosludges from H-Coal are studied under simulated landfill conditions, and particular concern is given to the attenuation of organic matter in the leachates. The decomposition of H-Coal oily sludges following land treatment will be examined and compared with oily sludges of petroleum refineries and other coal liquefaction technologies.

These tests will (1) yield a data base that can be used to guide the development of this key synfuels technology in an environmentally sound manner, (2) provide recommendations for the treatment and disposal of waste

materials, and (3) be a primary source of information for the H-Coal technology evaluation that will be prepared at the completion of the study. The evaluation will draw on and integrate research from both the H-Coal pilot plant project and from related studies in the program that utilize H-Coal materials for basic scientific research. Results of specific studies are contained within the first three group reports of this section.

H-Coal Data Management Project

Similar to the UMD assessment project a coal liquefaction process assessment (H-Coal) was implemented in 1980 to evaluate potential environmental and health effects of this process. The 3-year H-Coal project has focused this past year on process monitoring and sampling at 39 points, with examination of the products and effluents for possible occupational exposures and environmental impacts. The H-Coal data management project has considered the sampling design and the organization and tracking of material samples taken from the H-Coal process. The development of the computerized tools for tracking samples under the UMD project has been reconfigured for the H-Coal project. There are currently 500 samples either available for characterization or already in the process of being evaluated by investigators in the H-Coal assessment. As the results from these characterizations become available, statistical and graphical techniques developed for the UMD project will be modified for the needed analyses in the H-Coal effort. The level of effort for the data management project is not nearly as great as that for the UMD project because of major differences in the H-Coal assessment vs the UMD assessment; for example, the H-Coal assessment does not contain the atmospheric and air quality components included in the UMD assessment. In addition, the data being automatically monitored within the H-Coal working environment that relate to industrial hygiene and process control are being collected and managed by the non-ORNL investigators working at the H-Coal site. We anticipate that during the next year the H-Coal project will involve not only the evaluation of the samples from the H-Coal process but also the incorporation of certain specific sampling periods and concomitant process measurements and appropriate parameters into the health and environmental assessment of the H-Coal process.

Environmental Risk Assessment

We are currently assessing the environmental risks associated with effluents and products from indirect and direct coal liquefaction and production of oil from shale. Because environmental risk assessment must consider the emission rates, transport, fate, and effects of effluents, it integrates all aspects of synfuels environmental research. The assessments consider effects on socially valued end points such as the production of game and commercial fish, crops, and forests. Because the emphasis of risk assessment is on estimating the probability of effects rather than simply predicting their occurrence, innovative techniques must be applied. The five methods that we currently are using were selected so as to utilize a broad range of data types, expertise, and knowledge of ecological dynamics. More detailed description of this effort is contained in the Environmental Impacts Program section of this report.

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6. TOXIC SUBSTANCES PROGRAM

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Introduction

The Toxic Substances Program consists of two major areas of research. One conducted for the U.S. Department of Energy (DOE) involves radioecology and environmental chemistry. The subjects of importance include the actinide elements, particularly the transuranium group Pu, Np, Am, and Cm. The research emphasis is on establishing the ecological distributions of the actinides using historically contaminated sites and on environmental chemistry. Other research for DOE includes terrestrial behavior of ^{99}Tc near operating uranium enrichment plants, ^{95}Nb and ^{95}Tc behavior in freshwater ecosystems, and radionuclide cycling in coastal environments. Staff expertise in environmental chemistry of the artificial radioelements plutonium, neptunium, and technetium has also assisted DOE waste management efforts in evaluating long-term migration questions in repositories.

Research and test development in the area of ecotoxicology is underway for the U.S. Environmental Protection Agency (EPA) Office of Toxic Substances. The issue of multispecies test protocols for hazard assessments on new chemicals was recently addressed in the form of workshops and a review document. Several test protocols recommended for development are now under experimental evaluation. The Organization for Economic Cooperation and Development (OECD) single-species test protocols are also being evaluated before incorporation into EPA's chemical assessment scheme. A multimedia modeling project is expanding the Oak Ridge National Laboratory (ORNL) Unified Transport Model to include toxic substances (organics). This model (UTM-TOX) will assist EPA in evaluating chemical dispersion and potentials as part of a chemical assessment.

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Radioecology and Environmental Chemistry

Differential Uptake of Actinides by Fish

Concentrations of actinides (Pu, Am, Cm, and U isotopes) were determined in the carcasses and digestive tracts of goldfish from pond 3513 that had been exposed for one year in 1978–1979 and compared with samples analyzed in previous years. The results indicate that ^{241}Am, ^{244}Cm, and ^{238}Pu concentrations were not significantly different in fish exposed to the 1978 accidental spike than fish exposed for the same length of time before the spike despite manyfold increases in solution concentrations of all three isotopes. Concentrations of ^{239}Pu increased by approximately 50% in fish exposed during 1978–1979, while ^{238}Pu concentrations did not increase at all. The increase in ^{239}Pu concentration is attributable either to a shift in feeding locale in the pond or to increased mixing of the sediments by fish (bioturbation) (Auerbach and Reichle 1981). Concentration ratios (CRs) for ^{239}Pu relative to those for ^{238}Pu that were calculated using the contents of the digestive tracts as a reference source remained constant in all data sets compared. It is significant that fish exposed during the period of the accidental spike actually exhibited higher ^{239}Pu:^{238}Pu ratios than the previous samples because the spike shifted the ^{239}Pu:^{238}Pu ratio in water (both solution and suspended particulates) to significantly lower values. Because the spike was predominantly comprised of oxidized Pu, these results indicate that either oxidized Pu is significantly less available than reduced Pu in complexed form or that particulate matter in the diet is the principal biologically available source to biota. In contrast, ^{233,234}U and ^{238}U concentrations in fish carcasses appear to track the corresponding solution concentrations [CRs averaging 5.0 (dry wt basis)], apparently independent of date and relative isolation from sediments.

Actinide Solution-Sediment Exchange

Differences between ^{244}Cm:^{241}Am activity ratios in solution and those in particulates (seston and sediment) reported previously (Auerbach and Reichle 1981) have virtually disappeared in pond 3513. As expected, the ^{244}Cm:^{241}Am activity ratio had fallen to an average value of 1.6 to 1.9 during the summer of 1981, which is within 50% of the predicted equilibrium value based on measurements of concentrations in surficial sediments. We had earlier concluded that bioturbation would resolve an apparent physical occlusion of ^{241}Am relative to ^{244}Cm in sediments; the hypothesized result was the lowered ^{244}Cm:^{241}Am ratio observed.

This conclusion appeared to be supported by a lowering of the ^{244}Cm:^{241}Am activity ratio in water above surficial sediments that had been thoroughly mixed and isolated inside plexiglas™ enclosures constructed in situ in pond 3513 (Auerbach and Reichle 1981). However, this change required a period of several months to complete. In another enclosure, in which anaerobic conditions were produced by addition of sucrose, the change occured within a few days, and strikingly divergent behavior between ^{244}Cm and ^{241}Am was observed. During the period of anaerobiosis, the solution concentrations of ^{241}Am, ^{239}Pu, and ^{238}Pu all increased by over an order of magnitude (^{241}Am and ^{239}Pu strongly correlated; $r = 0.99$, $P \leqslant 0.0001$, and $n = 13$), while the concentration of ^{244}Cm changed by less than a factor of two. The former three isotopes were all strongly correlated with dissolved iron ($r = 0.83$ to 0.91; $P \leqslant 0.001$) and with othophosphate and pH but not with calcium ($r \leqslant 0.21$ and $P \geqslant 0.50$) nor with manganese ($r \leqslant 0.50$ and $P \geqslant 0.10$). Although dissolution of a significant amount of sedimentary carbonate resulted as indicated by an order of magnitude increase in soluble calcium, the occurrence did not produce an increase in transuranic concentrations. In fact, when calcium and manganese had reached maximum values during the observation period, transuranic concentrations had returned to ambient or minimal levels.

This experiment indicated that ^{241}Am was both chemically and physically occluded relative to ^{244}Cm in sediments. In this case, differing chemical and temporal factors (^{241}Am being formed in situ under the chemical conditions of a ^{241}Pu parent nuclide buried in sediments and ^{244}Cm entering the system in a soluble waste stream at a much later date, thus localizing in the upper sediment layer) produced these differences in behavior. This

phenomenon, often hypothesized but seldom, if ever, demonstrated, may be more widespread than formerly believed. If such phenomena are not correctly interpreted, significant deviations in predictions of transuranic biological availability will result. Perhaps a more significant result of the experiment is the strong inference that hydrous iron oxides, perhaps associated with organoclay matrices, are the dominant sorption site for transuranics, but especially plutonium, in this aquatic system. This observation has even more significant implications for our understanding of the biogeochemical behavior of transuranics in natural aquatic systems.

Evaluation of Potential Specific Natural Chelators of Actinides in Aquatic Systems

Previous work on Pu(III,IV) and Am,Cm(III) at ORNL pond 3513 (Auerbach et al. 1979) and on Pu(IV) by investigators at Argonne National Laboratory (Nelson et al. 1981) has identified natural organic complexes of presently unknown origin as important factors affecting solubility of these reduced actinide states. Further, evidence from pond 3513 studies indicates that a specific fraction of dissolved organic carbon (DOC) is responsible for binding reduced actinides. This conclusion is based on the results of previous gel-filtration chromatography and the absence of significant correlations between concentrations of DOC and reduced actinides. We attempted to determine whether an association existed between concentrations of trihydroxamate siderochromes and Am,Cm(III) in the dissolved phase in ORNL pond 3513. It has been demonstrated that microbially produced trihydroxamate chelators, which are important in iron transport and metabolism, are ubiquitous and also have a high affinity for lanthanides (and actinides by inference).

Water samples collected in February and March 1981 were assayed for trihydroxamate activity using the auxotroph *Arthrobacter flavescens* JG-9 following concentration in a Buchi Rotovapor-R apparatus. Although the *Arthrobacter* JG-9 assay confirmed the presence of trihydroxamate siderochromes in these water samples, the concentrations were only 2.0×10^{-12} to 2.5×10^{-12} *M* (Desferal equivalents, Ciba Pharmaceutical Co.). These concentrations are four to five orders of magnitude lower than those found in some soils (Powell et al. 1980) and in near-shore marine systems (Estep et al. 1975) and are four orders of magnitude lower than concentrations of dissolved iron in the same ORNL pond 3513 water samples. In addition, the concentrations of Am(III) and Cm(III) declined during the period of the study by factors of 2 and 4, respectively, while the trihydroxamate activity actually increased slightly.

Because trihydroxamate chelators have stability constants of $\sim 10^{30}$ for iron and are estimated to be an order of magnitude higher than those for actinide complexes, with reduced actinide concentrations in pond 3513 water typically 10^{-14} to 10^{-15} *M*, the patterns observed even with a limited number of samples indicate that other types of dissolved organic species (e.g., catecholamines and more general humic and fulvic acid complexes) rather than trihydroxamate siderochromes are responsible for binding reduced actinides in pond 3513.

Plutonium Oxidation Kinetics

A continuing question exists as to the rates at which Pu(IV) species oxidize under natural conditions. In the laboratory, oxidation of Pu(IV) can be observed when small volumes of unhydrolyzed Pu(IV) species [i.e., Pu(IV) in strong acid solution as a citric acid complex (in acid) or in 45% Na_2CO_3] are added to large volumes of neutral-to-alkaline solutions. Oxidation is not observed (for several months) when a neutralized Pu solution is similarly added.

The most significant finding in the above experiments is that the final distribution of oxidized/reduced species are never the same even though the final solution composition is. Isotopic dilution studies using different valence ratios also indicated that equilibrium is not obtained between plutonium species for periods of at least two months.

A final study showed that ^{244}Cm(III) decaying to ^{240}Pu will produce Pu in both Pu(IV) and Pu(V + VI) forms that are about equal. This phenomenon occurred in an alkaline solution. This mechanism should be remembered

when ^{238}Pu (daughter of ^{242}Cm) is found in wastes containing Cm and when this ^{238}Pu "behaves" differently from $^{239,240}Pu$.

These results all argue that rapid oxidation can occur when Pu(III,IV) is undergoing hydrolysis but that when Pu(IV) is hydrolyzed (i.e., $Pu(OH)_4^0$), the rate at which oxidation occurs is extremely slow. This effect on oxidation rate is well recognized for many metals—that is, partial hydrolysis promotes the transfer of electrons (Fe, V, Co, and U). What is not yet available in the literature is the effect of complete hydrolysis.

Plant-Soil Dynamics of Technetium under Field and Laboratory Conditions

Three separate studies on technetium were conducted to understand better this element's behavior in soils and plants. In previous years, we reported that soil-to-plant transfer factors for ^{99}Tc near operating gaseous diffusion facilities were much less than transfers measured using potted soil contaminated with pertechnetate (TcO_4^-) in the laboratory. After collecting soil at two facilities, the soluble pertechnetate fraction was extracted by shaking the moist soil with a solution of 0.01-*M* calcium chloride. Successive extractions with weak (0.5%) and strong (5%) bleach were used to oxidize reduced technetium in soil to pertechnetate. For soil from the Oak Ridge gaseous diffusion facility, less than 15% of the ^{99}Tc was extracted with the calcium chloride solution, while 86 to 99% was extracted by bleach. For soil from the Paducah gaseous diffusion facility, less than 5% of the ^{99}Tc was extracted with calcium chloride, and more than 95% was extracted by bleach. The low extractability of ^{99}Tc from soil by weak salt solutions and its subsequent higher extractability with a strong oxidant indicate that technetium in soil near gaseous diffusion plants is not predominantly the highly soluble pertechnetate form. This lower soil solubility is a probable cause for lower soil-to-plant transfer factors for ^{99}Tc in the vicinity of gaseous diffusion plants.

A greenhouse experiment was begun to determine the effect of soil disruption (sieving), soil type, pot size, and vegetation type on the uptake of technetium by plants. About 2 μCi of ^{95m}Tc (pertechnetate) were applied to the surface of the soil in the pots. Concentrations in plants, soil, and the 0.01-*M* calcium chloride extractable technetium from soil were measured each month. In undisturbed soil (i.e., large 25-cm diam cores excavated from the field and placed into pots) and in sieved soil, most of the ^{95m}Tc remained in the top 4 cm of soil throughout the experiment despite the watering of the soil every few days. For all pots, at the end of the experiment, the amount of technetium leached from soil by percolation was less than 5% of the initial spike. The extractability of technetium from soil with 0.01-*M* calcium chloride solution ranged from 16 to 32% immediately after application of the isotope to soil and was 4 to 15% after six months. Thus, technetium does not appear to be very mobile in the Captina silt loam soil used for this experiment.

In previous years, we reported on the decreasing availability of ^{95m}Tc to plants following the contamination of 1-m^2 field plots. Last year, we applied about 100 μCi of pertechnetate to each of three field plots to determine changes in the extractability of technetium from Captina silt loam soil and changes in the associated availability of technetium to plants over a six-month period. Samples of soil and plants were collected monthly after a single application of pertechnetate in the field. Following application of the pertechnetate, concentrations in soils and plants (*Festuca* and *Lespedeza*) decreased with time. Plant/soil concentration ratios that were about 40:1 one month after contamination fell to less than 1:1 in six months. Over the period of this experiment, technetium was found in highest concentrations in surface soils (0 to 4 cm deep), and the calcium chloride (0.01 *M*) extractable technetium in this surface soil fraction decreased from about 30% to about 5%. These results further support our previous conclusion that following application of technetium as pertechnetate to ORNL soil, the uptake of this nuclide by plants decreases over time. The final extractability of technetium from soil with 0.01-*M* calcium chloride solutions was similar for the gaseous diffusion plants' soils and the ORNL soils in the greenhouse and the field.

Coastal Sedimentation and Radionuclide Cycling

In earlier work (Cutshall et al. 1981), we found that profiles of man-made radionuclides in sediment cores from the James River estuary confirmed the rapid burial of the pesticide Kepone. The greatest deposition of Kepone appeared to have occurred in zones of very high sedimentation rates, 10 to 20 cm/year (Fig. 6.1). Because sediment is the major Kepone reservoir, rapid burial was presumed to reduce the exposure of organisms to further contamination. We have resampled the James River estuary 30 months after the first sampling. These new cores will be analyzed to determine if the sedimentation rates estimated earlier were accurate and if high sedimentation has continued.

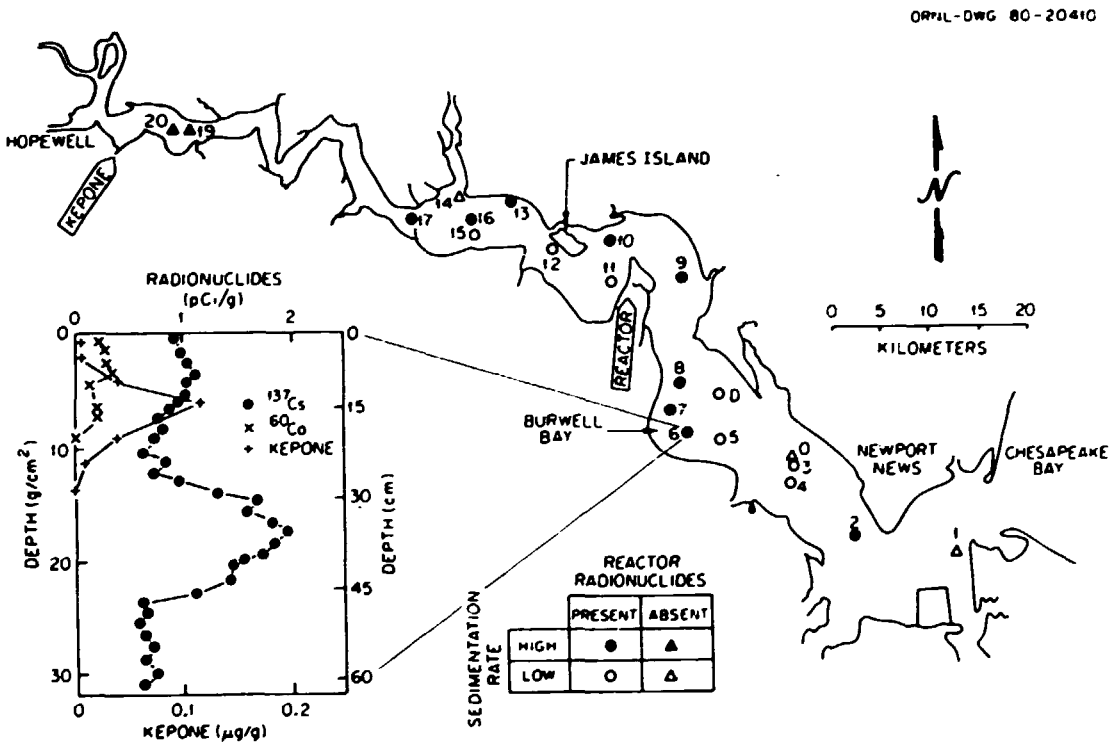

Fig. 6.1. Locations of 1978 sampling sites in the James River estuary. Station symbols indicate the rates of sedimentation and presence or absence of reactor radionuclides. Sedimentation rates >1 cm/year are labeled "high," and lower rates are labeled "low." The inset shows the profiles for ^{137}Cs, ^{60}Co, and Kepone at station 6. Maxima in ^{137}Cs are believed to represent a reactor release in 1975 and the maximum deposition of fallout from atmospheric testing in 1963. The Kepone maximum corresponds to the year of greatest production, 1974.

Only the uppermost layers of sediment from the most recent samples have been analyzed thus far. In these, we have measured the 53-d cosmic-ray-produced nuclide ^{7}Be using the procedure described by Larsen and Cutshall (1981). We have also measured ^{7}Be in suspended matter and water samples taken at the same time. Concentrations of ^{7}Be in water samples were about the same for all parts of the estuary and were all<0.1 pCi/L. Suspended matter concentrations were 1 to 2 pCi/g, with the lowest values found on particles collected from the turbidity maximum zone. Surface (0–1 cm) sediments contain ^{7}Be, which range from not detectable to about 1 pCi/g. The highest contents of ^{7}Be in bottom sediments were found below the turbidity maximum. In this zone, the suspended matter and 0–1 cm layer contained about equal levels of ^{7}Be. A core from this area contained detectable ^{7}Be as deep as 8 cm and a total inventory of 3.3 pCi/cm^2, nearly twice the expected inventory

based on perfect collection of the average atmospheric deposition. It appears that sediment particles in the zone of maximum turbidity are effectively scavenging ^{7}Be and other particle-reactive substances such as Kepone from the water column. Deposition at such sites forms a significant component of the budget for such substances during their transport through coastal ecosystems.

Freshwater Studies on ^{95}Nb and ^{95m}Tc: Studies in an Experimental Pond

Data from two studies conducted with ^{95}Nb in a small experimental pond are being analyzed to determine the distribution and concentration of Nb in a freshwater ecosystem. In one study, ^{95}Nb was released to a pond at a constant rate for a period of 30 d. The second study was a short-term release of 6 d. Because it may be impractical to carry on studies of this type long enough to obtain steady-state conditions to determine equilibrium bioaccumulation factors, modeling methods have been developed that can use data collected over relatively short periods of time to calculate expected steady-state body burdens. Uptake and elimination data of ^{95}Nb by aquatic biota in the short-term experiment were used to construct a mathematical model to calculate bioaccumulation factors at steady-state conditions. Based on the mathematical model, the calculated bioaccumulation factors for ^{95}Nb are 3.6 for bluegill *(Lepomis macrochirus)*, 162.8 for crayfish *(Orconectes* sp.*)*, 122.0 for clams *(Corbicula minlensis)*, and 239.1 for snails *(Helisoma trivolvis)*. When compared to the measured bioaccumulation factors for bluegill (12) and snails (688) after approximately 30 d of chronic exposure to ^{95}Nb in the long-term experiment, the model values underestimated the measured values by a factor of approximately 3. For conservative purposes, when calculating radiation dose to man, a model that overestimates bioaccumulation is preferable; however, when one considers the variability generally observed in measured bioaccumulation factors, the calculated and measured values obtained here are relatively close.

An acute release of ^{95}Tc was made to a small experimental freshwater pond. After the release, all components of the pond were sampled for 37-d and analyzed for ^{95m}Tc. Bioaccumulation factors for fish and snails from the pond were reported previously (Auerbach et al. 1981). After termination of the experiment, the pond was destructively sampled to determine the biomass of the macrophytes and periphyton. The biomass of the fish and macroinvertebrate populations was estimated from the number of individuals released into the pond and the range of weights taken during routine sampling. The distribution of ^{95m}Tc in the various components of the pond for each sampling period is shown in Fig. 6.2. The amount of water in the pond fluctuated with the inflow of water and rainfall and subsequent seepage from the pond. Analyses of filtered and unfiltered water samples showed that ^{95m}Tc did not sorb significantly to particles suspended in the water but remained in solution. Sediment accumulated ^{95m}Tc slowly. Periphyton accumulated ^{95m}Tc rapidly, reaching the highest concentration 4 h after the release of ^{95m}Tc, and remained at a relatively high concentration throughout the experiment. Fish and invertebrates accumulated ^{95m}Tc gradually. The estimated biomass of the components in decreasing order were periphyton, macrophytes, invertebrates, fish, and algae. About 1% of the ^{95m}Tc released into the pond was accumulated by the biota, while most of the ^{95m}Tc remained in the water.

Uranium in Drinking Water and Potential Uranium Removal Methods

The National Interim Primary Drinking Water Regulations for Radionuclides does not include the maximum contaminant level for uranium, but it has been proposed to be added to the regulation. As a survey study, uranium concentrations in raw water and treated water samples from 20 municipal water treatment plants representing 8 states were determined. The results showed that uranium ranged from 0.1 to 15.9 μg/L and that present treatment practices are not effective in removing uranium from raw waters.

Our batch experiments revealed that lime ($Ca(OH)_2$) treatment alone reduced uranium concentration of pond 3513 water (pond 3513 is a hard water pond located at ORNL and contains uranium concentrations of

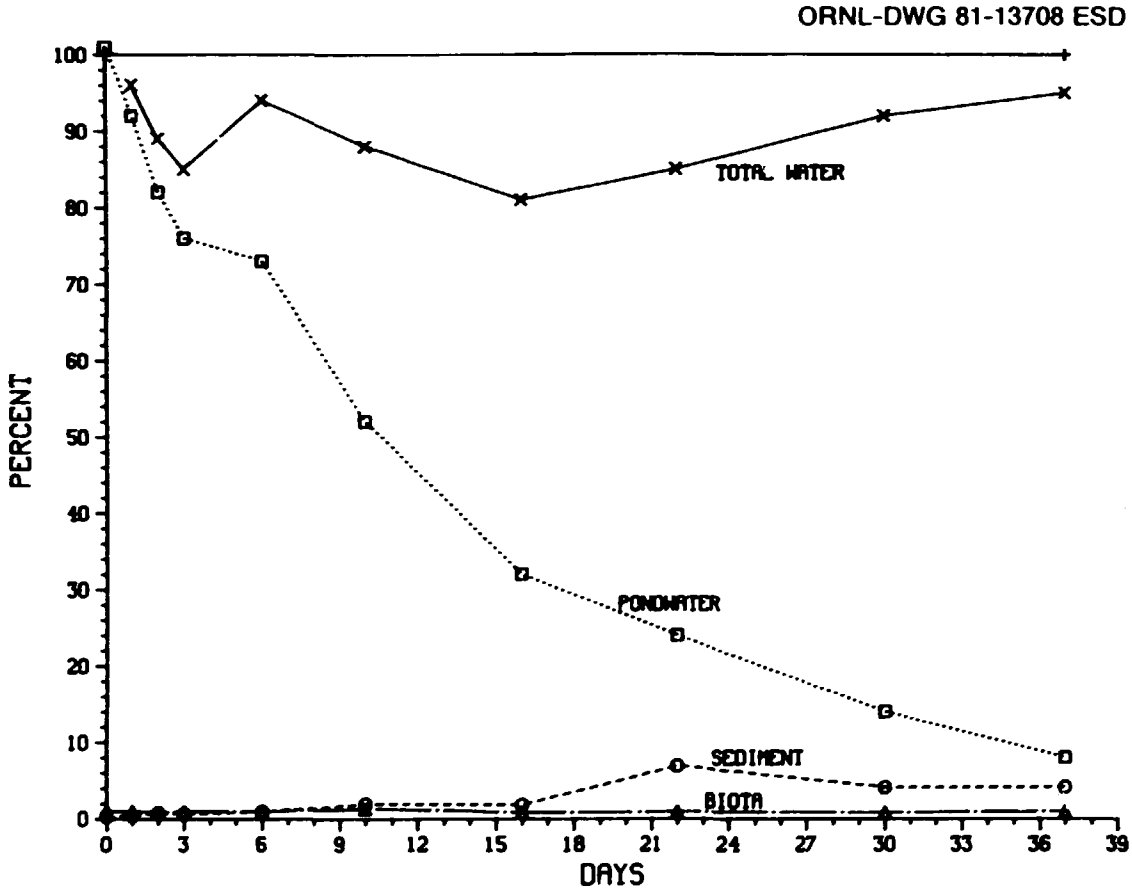

Fig. 6.2. The distribution of ^{95m}Tc is shown for the components of a freshwater pond ecosystem after an acute release of the isotope. The percentage in each component of the pond represents the total amount of ^{95m}Tc in that component at a particular sampling time, which was then divided by the amount of ^{95m}Tc released after correction for physical decay. The percentages of ^{95m}Tc in the total water represent the sum of the ^{95m}Tc in the pondwater and in the water lost by drainage or seepage.

about 80 μg/L) by 90% at pH 10.6 to 11.4. The removal efficiency was improved up to 99% by the addition of $MgCO_3$ to the lime treatment. Coagulants [$Al_2(SO_4)_3$, $Fe_2(SO_4)_3$] removed 85% or more uranium at pH 6 and 10, but the removal efficiency was less than 50% at pH 8. At pH values above 9.5, carbonates in the presence of calcium would be depleted by precipitation, and the uranyl hydroxide complex could be the dominant uranium species. The uranyl hydroxide complex would then be easily coprecipitated with indigenous and/or added metal hydroxides. Other studies besides those mentioned above were also made. Activated charcoal and titanium oxide removed more than 90% of uranium at pH <7.5. Strong-base anion exchange resin was the most effective absorbent in terms of efficiency and loading capacity at a wide range of pH (>5), and the resin could be regenerated by NaCl-$NaHCO_3$ elution. Cation exchangers were not affected, as would be expected, except at low pHs.

Current water treatment practices can be used for uranium removal from drinking waters generally requiring lowering or raising the natural pH from the seven to eight regions where the U-carbonate complex is most stable. The anion exchange technology for large volumes of water treatment is available, but it will require large capital investment. Small anion exchange columns should be considered, however, to remove uranium from private well waters containing uranium at higher than desirable levels. These results are to be incorporated into pilot-scale evaluations soon to be initiated by EPA's Municipal Environmental Research Laboratory, Cincinnati.

Technetium in Sulfide and Iron-bearing Geologic Media

It is believed that transport of $^{99}TcO_4^-$ away from a breached high-level radioactive waste repository would be controlled by physical and chemical environments of the surrounding geologic media. Chemical reduction of Tc(VII) to less soluble Tc(IV) was evaluated in relation to oxidation of Fe(II) to Fe(III) under anoxic conditions (Auerbach and Reichle 1980). Because sulfide and ferrous iron can have a significant geochemical influence in anoxic geological environments, work on chemical reactions between technetium and sulfide-ferrous iron and other heavy metals was initiated.

Varying amounts of sulfide and/or ferrous iron were added to a salt brine solution containing TcO_4^-. The loss of TcO_4^- from the solution increased with the increase in initial sulfide and ferrous iron concentrations, and the loss was larger when both sulfide and ferrous iron were added to the solution. A blackish precipitate obtained from the TcO_4^- and sulfide equilibration was a poorly crystallized technetium sulfide that was insoluble in both acid and alkali solutions. The precipitate, most likely Tc_2S, had several x-ray diffraction peaks, but the diffraction pattern did not match known technetium and sulfur compounds. In the presence of ferrous iron, TcO_4^- appears to be reduced and incorporated into an amorphous ferrous iron sulfide structure and then retained in the structure during transformation of the sulfide precipitate to a hydroxide form. Other heavy metals (Co, Ni, and Cu) could remove TcO_4^- by coprecipitation as a sulfide, but redox reactions did not seem to be involved in the removal process. Minerals containing ferrous iron also removed TcO_4^-, and addition of sulfide to the solution increased in removal efficiency.

The experiments indicated that the TcO_4^- ion, a potentially mobile species from radioactive wastes, would be immobilized by formation of less soluble technetium sulfide and technetium-iron sulfide/hydroxide if ferrous iron and/or sulfide are available at the breached repository site.

Ecological Toxicology

Evaluation of Ecotoxicological Test Systems

The need for predictive tools in environmental hazard assessment has become increasingly important since the passage of the Toxic Substances Control Act (TSCA) in 1976. Such tools are especially meager for assessing the effects of toxic chemicals on complex interactive systems. For this reason, we were asked to help the EPA to identify and evaluate available multispecies laboratory test methods for their potential utility in the environmental hazard assessment processes under TSCA.

The methods for measuring the effects of chemicals on aquatic and terrestrial population interactions and ecosystem properties were evaluated according to the following criteria. (1) cost per test, (2) documentation, (3) generality, (4) rapidity, (5) realism, (6) rejection standards, (7) replicability, (8) reproducibility, (9) sensitivity, (10) social relevance, (11) standardization, (12) statistical basis, (13) training-expertise requirements, and (14) validity. Criteria were also developed for evaluating and selecting models for environmental hazard assessment.

No multispecies tests or mathematical models are ready for use as predictive tools. Although multispecies tests are necessary for successful environmental hazard assessment, their development has been hampered by limited understanding of community and ecosystem responses to perturbations. Nevertheless, several multispecies laboratory methods and categories of mathematical models could be made available with relatively little research and development. Recommended laboratory methods include tests for effects of chemicals on (1) algal competition, (2) predation by fish, (3) mixed flask cultures, (4) periphyton communities, (5) pond microcosms, (6) soil microbial communities, (7) legume-rhizobia symbiosis, and (8) mycorrhizae-plant symbiosis. Mathematical methods recommended for further development are (1) ecosystem simulation models, (2) generalized multipopulation models; (3) loop analysis and time averaging; (4) input-output analysis; and (5) population genetics models.

EPA Multispecies Bioassay Development for Toxicity Testing with Algae

Work began during FY 81 to determine the feasibility of using two species of algae in cocultures for bioassays. The objective of the research is to examine how algal competition under defined conditions alters toxicity response. Impetus for the work came from the desirability of producing bioassays that are more representative of natural environmental responses than are single species tests. Greater "real world" likeness is considered more germane than enhancement of sensitivity. The research is being funded by the Office of Toxic Substances in support of information needs for implementation of the TSCA.

Pairs of algal species (bacterized but clonal) have been cocultured in defined media under standard EPA bioassay growth conditions (e.g., 24°C, 4000 lm) in 250-mL flasks. Copper (as $CuSO_4$) in concentrations of 0.1–1.5 mg/L has been used as the model toxicant. Growth of individual species grown separately are compared to the growth of each grown competitively. The variables of Cu(II) concentration and inoculum density are used to determine test responsiveness.

Research to date has concentrated on finding a compatible species pair (or set of species pairs) that (1) displays distinct competitive behavior, (2) is not difficult to grow or enumerate, and (3) may individually represent distinct and different niches in nature. The behavior of the candidate pairs with different toxicant concentrations is being simultaneously determined. No candidate pairs have satisfied all the selection criteria; pairs tested have included various greens, bluegreens, and diatoms. To formulate a viable species pair, it appears that criterion 3 (above) will need to be relaxed. Despite this relaxation, some of the data indicate that toxicity can be readily detected in cocultures and that a bioassay employing such a scheme may be feasible for use in the early stages of a chemical hazard assessment program. If feasibility seems probable, extensive testing with various toxicants and environmental conditions will be necessary to certify the test and standardize it for use under TSCA.

Evaluation of OECD Protocols for Testing of Toxic Chemicals on Aquatic Biota

In 1978, OECD met in Stockholm, Sweden, to discuss the control of toxic chemicals, with special emphasis on chemicals affecting the environment. As a result of this meeting, which was attended by representatives from 16 countries and 6 international organizations, guidelines for testing of chemicals were developed. Because the EPA is required as part of TSCA to make decisions on the safety of any chemical before it is marketed in the United States, the EPA must base its decisions on various types of information regarding human, terrestrial, and aquatic environments. The law requires the potential manufacturer to provide such information. In the area of aquatic toxicity, one of the useful types of information that may be required is bioassay data. Recognizing the desirability of improved national control of toxic chemicals and the need to harmonize national efforts to avoid unnecessary barriers to international trade, the EPA has undertaken the task of evaluating the protocol of the OECD guidelines for testing chemicals on aquatic organisms to determine whether these tests can also be used to provide some of the information required under TSCA. The Environmental Sciences Division is aiding EPA in this task. The following OECD guidelines for testing of chemicals on aquatic organisms are currently being evaluated: (1) Alga Growth Inhibition Test, (2) Daphnia Acute Immobilization and 14-d Reproduction Test, (3) Fish Acute Toxicity Test, and (4) Bioaccumulation Flow-through Fish Test.

Modeling Activities for EPA

The ORNL Unified Transport Model for Toxicants: UTM-TOX

Development of ORNL's unified, multimedia (air, land, and water) model (UTM-TOX) for estimating movement and environmental concentrations of toxic materials proceeded on four fronts this year. Building on

the previous UTM model for trace metals, (1) physicochemical processes peculiar to organic chemicals were specified and incorporated in the model; (2) additional submodels for water and chemical transport in terrestrial and aquatic systems were developed, refined, and documented; (3) existing and new submodels were more thoroughly coupled within a framework of multimedia exchanges in a typical watershed; and (4) environmental data were organized for use by the UTM-TOX model.

The major physicochemical processes to be accounted for in the representation of transport and fate in the UTM-TOX by system are (1) aquatic — adsorption-desorption, volatilization, photolysis, hydrolysis, and biodegradation; (2) terrestrial — adsorption-desorption, volatilization of surface and subsurface chemical, and degradation, and (3) atmospheric — vapor-phase particulate and vapor-phase water partitioning, oxidation by OH radicals and ozone, and direct photolysis. A detailed examination of the literature led to a major report (M. G. Browman et al., in review) that presented the basis for alternative formulations of the various physicochemical processes, assessed the current representations in the UTM-TOX, suggested ways to upgrade the UTM-TOX, and identified research needs.

The terrestrial and aquatic chemical processes were implemented primarily in two parts of the model: the portion of the model that deals with runoff from a unit area of landscape (LAND) and the portion that deals with runoff in stream channels (CHANL). The subroutines that treat volatilization from canopy, litter, and soil are implemented in the LAND module along with a subroutine to handle degradation of the chemical in the soil. A routine called CHMIST is coupled directly to LAND and invokes the volatilization and degradation routines at appropriate times during the annual cycle. In a similar fashion, modular subroutines are available to the channel routines that deal with the aquatic system. The greater compartmentalization of this part of the hydrologic transport model forces the coupling of the chemistry routines in two subroutines. Although both of these routines handle the routing of flow in the channel, one treats steady-state flow, and the other treats transient conditions. Each of these includes the same set of process subroutines for biodegradation, hydrolysis, volatilization, and photolysis in the stream channel. The appropriate time interval is used for each process according to which routines call the process subroutine. Equations for the major atmospheric physicochemical processes have been designated (Browman et al., in review) but are not yet incorporated in UTM-TOX.

A new, detailed soil chemistry model for simulation of chemical adsorption, volatilization, and degradation in land (CAVDIL) was conceptualized and designed for coupling with the AGTEHM hydrologic model. The CAVDIL code was based on the subroutines of the SCEHM model of Begovich and Jackson (1975). The original K_d adsorption function in SCEHM was replaced with the Freundlich isotherm, which allows for nonlinear adsorption of chemicals with an increase in chemical concentration.

The CAVDIL chemical transport equations were coupled with the AGTEHM calculations of water movement in soil macropores. The basic approach assumes (1) a chemical moving with macropore water occurs as slug flow, and the chemical is completely mixed in the macropore water; (2) a chemical moving from macropore to mesopore is instantaneously mixed with the mesopore chemical; (3) a chemical moving from mesopore to macropore is added to the macropore water and instantaneously mixed; and (4) chemicals in dead-end macropores are considered to be part of the mesopore chemical because movement of these chemicals can take place only through the mesopores. Mass balance equations have been included in CAVDIL so that complete accounting of chemical concentration and fluxes can be made. Testing is continuing with the chemical mass balance. The combined AGTEHM-CAVDIL codes will provide new capability in the modeling of chemical transport through porous media with channels and fractures.

A model of water and heat transport in unsaturated soils using the integrated compartment method (ICM) was developed with the flexibility of applications to one, two, or three dimensional problems. The code was verified against results from an analytical model for three test cases. The accuracy and consistency of the ICM algorithm are shown by the very close agreement between the two simulation methods. Soil temperature is a

most important variable in volatilization and chemical degradation processes in soil, and the new code is a valuable component of the terrestrial suite of models.

Development and implementation of CHNTRN for chemical and sediment transport in a stream/river network were completed. The mechanisms included are advection, dispersion, sediment-chemical interactions, and transformation by physical, chemical, and biological degradation. A total of five partial equations govern the distributions of sediment concentration, bed sediment, dissolved chemical concentration, particulate chemical concentration, and bed chemicals. Each equation takes into consideration four types of boundary conditions: the Dirichlet, Neumann, and Cauchy boundaries and the junctions. The ICM, which utilizes the concept of connectivity in finite element methods and simple flux laws in finite difference approximations, is used to discretely examine the entire system of branched and joined streams and rivers in any watershed. Implementation of the boundary conditions is relatively easy using the ICM algorithm. The model was tested for two simple cases: one for chemical transport in a single river and the other in five rivers of the watershed. Preliminary applications indicate that the model yielded plausible results; however, verification and validation of CHNTRN are continuing.

Coupling was established among UTM-TOX submodels in order to use the available environmental data more efficiently and to increase interactions among media. For example, the precipitation records available in the hydrologic model now provide data for calculation of the washout rates in the atmospheric transport model. Similarly, wind speed data that are used to calculate potential evapotranspiration now also provide data necessary to the calculation of volatilization in the aquatic system. The juxtaposition of submodels allows one to consider the material that is volatilized from either the land surface or a stream as secondary sources for atmospheric contamination. Uncoupled submodels [e.g., the Atmospheric Transport Models (ATMs)] are also available for special uses.

Data management efforts have involved selection of specific alternative watershed data sets and attempts to select environmentally representative regions of the United States for use in chemical risk assessments using UTM-TOX. Initial development of the UTM-TOX used chemical and environmental data from ORNL's Walker Branch Watershed (WBW) that have been gathered over a period of several years. These data furnished environmental input and calibration and validation data depending in part on the period of record. A study of extensive data from a second watershed at East Lansing, Michigan was initiated so that a different geographic section of the country could be simulated. Also, climatic parameters that influence chemical transport were aggregated using cluster analysis to provide a tentative regionalization of the eastern United States. Twenty-one regions were characterized based on average (1) county-level data on annual precipitation, (2) annual evapotranspiration, (3) April precipitation, (4) July and October potential evapotranspiration, (5) annual solar radiation, (6) average afternoon and evening mixing heights, (7) absolute humidity, and (8) average January maximum and minimum temperatures.

In addition to traditional model development and report preparation, the project team assisted EPA assessment staff in implementing and using the computer codes. Training sessions and in-house manuals helped convert the project results into useful assessment tools.

Models for Assessing the Bioaccumulation of Xenobiotics in Aquatic Organisms and Food Chains

A review was conducted to evaluate the use of mathematical models to (1) identify problem chemicals that have a significant potential for bioaccumulation and (2) predict the concentration in aquatic organisms and food chains of chemicals whose release to the environment was never intended by their use. Binary structure-activity relationships (SARs) between the octanol-water partition coefficient and the steady-state bioaccumulation factor in aquatic species appear reliable as screening models for identifying and ranking new chemicals with a significant potential for bioaccumulation in aquatic species and food chains. For chemicals that rapidly reach

steady state relative to growth of the organisms exposed, simple static models will probably be adequate for predicting equilibrium concentrations in aquatic organisms in natural systems. For systems where environmental concentrations of the chemical vary and where rates of uptake are slow relative to growth of organisms, more complex models that include the combined influence of biological, environmental, and chemical factors on uptake and depuration kinetics will be needed to accurately predict concentrations of xenobiotics in aquatic species. At the present time, too little information on which to judge the ability of various dynamic models exists to predict the uptake of xenobiotics for situations other than those for which they have been paramaterized because very few of such models have been validated with independent data sets and because no complete error analyses of these models have been conducted.

Development of Predictive Models for Xenobiotic Accumulation in Terrestrial Food Chains

A need exists to predict the bioaccumulation potential of chemicals in food chains solely on the basis of physicochemical and biochemical properties. For organic compounds in aquatic systems, a simple set of criteria involving only stability in water and hydrophobicity has been suggested to identify materials requiring rigorous testing for potential bioaccumulation. It has been further suggested that such criteria are adequate for terrestrial systems. However, the validity of the quantitative SARs used to define those criteria has not been demonstrated.

Following an extensive review of bioconcentration and physicochemical data for xenobiotics, we evaluated the suitability of existing simple empirical models developed for aquatic organisms and the question of extending such models to terrestrial systems. We found that when earlier data sets of other investigators were significantly expanded and edited with the most recent information available, r^2 values associated with regressions fell significantly. Expansion of the analysis to include nonruminant mammals and birds produced similar conclusions. A simple sorting model based on hydrophobic tendency was able to successfully separate all bioaccumulation "hazards" except one from groups of organic compounds ($N > 100$) when the screening criterion was a specified bioconcentration factor for fish/water (in water-only exposure systems or model ecosystems) or mammal-bird diet (long-term feeding under laboratory conditions). About one-fourth of the chemicals sorted into the "hazardous" category did not exhibit significant bioaccumulation, and the one "hazardous" material that would not have been identified as such was methylmercury. This toxic chemical accumulates by covalent reaction and represents a class of materials that is not properly accounted for in existing SARs.

Our results indicate that although a measure of hydrophobicity is a highly satisfactory "first approximation" indicator for bioaccumulation potential for most organics in both terrestrial and aquatic vertebrates, this potential is frequently controlled by environmental distribution functions and specific metabolic steric interactions not adequately represented in existing SARs. Unless physicochemical or biochemical characteristics that consistently identify hazardous materials that bioaccumulate by covalent reaction (as distinguished from lipid partitioning) are developed, SARs for bioaccumulation potential of xenobiotics may be of limited utility.

The single most important test procedure for screening purposes, and one with the least risk of failing to identify a bioaccumulation "hazard," is a chronic feeding test with either birds or rodents. The time-honored rodent-testing protocols outperform any presently available predictive model for bioaccumulation by terrestrial vertebrates. We see no present justification for abandoning this procedure in favor of structure-activity models. The present inadequacy of structure-activity models is exacerbated by the error-riddled data sets for physicochemical variables that our review has also identified. It would appear that some mechanism should be found to both centralize and debug the existing data, particularly for the user who may not be an expert in the requisite analytical techniques.

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7. ENVIRONMENTAL IMPACTS PROGRAM

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Introduction

The mission of the Environmental Impacts Program (EIP) includes three major goals: contribution of ecological and environmental resource analyses to environmental impact statements and assessments prepared at the Oak Ridge National Laboratory (ORNL) for major federal actions, technical assistance to federal agencies to ensure compliance with the National Environmental Policy Act (NEPA) of 1969, and analysis of environmental issues for established and emerging technologies to guide development and to identify needed environmental research. During this reporting period, the EIP contributed to environmental impact statements and assessments for the uranium fuel cycle facilities (mines, mills, and fuel fabrication), nuclear generating stations, geothermal projects (hydrothermal, geopressure, and hot/dry rock), oil-to-coal fuel conversion projects, and synfuels demonstration facilities. Technical assistance was provided to the U.S. Department of Energy (DOE)

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regarding the U.S. Strategic Petroleum Reserve, and the EIP continued to provide the DOE NEPA Affairs Division with technical guidance for the preparation of environmental reports and for review of environmental analyses conducted by other federal agencies. Representative environmental analyses that help to guide technology development and to identify needed research included support of the DOE Division of Hydroelectric Resource Development, assessments for the DOE Office of Alcohol Fuels, and input to an ORNL effort to analyze the Chattanooga Shale resource.

Two new programmatic activities this year deserve special recognition. The EIP, in cooperation with other divisions at ORNL and the Advanced Fossil Energy Program within the Environmental Sciences Division (ESD), initiated studies regarding environmental risk assessment. The EIP staff prepared a draft environmental risk assessment for H-Coal liquefaction technology for DOE and began a challenging environmental risk assessment project for the U.S. Environmental Protection Agency (EPA) addressing direct coal liquefaction, indirect coal liquefaction, and oil from shale. A second new activity this year, which is supported by the DOE Office of Nuclear Waste Isolation (ONWI), involves a regional environmental characterization and analysis of granitic areas potentially suitable for the permanent disposal of high-level nuclear wastes.

Summarized below are seven EIP activities that reflect the diversity of projects within the program beyond our traditional role in preparation of environmental impact statements and assessments.

Environmental Risk Assessment

In mid-FY 1981, the Environmental Sciences Division began a new initiative in environmental risk assessment for EPA. Risk assessment of the effects of human actions on components of the environment other than human health is a new field for the ecological profession as well as for ESD. It differs from environmental impact assessment in that it is concerned with the probability of particular standard environmental effects called end points, while impact assessment makes nonprobabilistic statements about project-specific effects.

The end points for environmental risk assessment were selected so as to be clearly defined, quantifiable, relevant to societal concerns, and reflective of the major components of the environment. The end points are (1) reductions in production of commercial and game fish, (2) development of nuisance algal communities, (3) reductions in timber yield and quality, (4) reductions in agricultural production, and (5) reductions in wildlife populations.

Because satisfactory methods do not exist for environmental risk assessment and because a diversity of information and data types is available, five different analytical methods are being used. The first is the quotient method, which consists of dividing the expected environmental concentration of a chemical by a toxicological benchmark such as an LC50 or the lowest observed toxic concentration. This method produces an easily understood numerical indicator of relative risk. It does not indicate the expected level of response or estimate the probability of response.

The next two methods were developed by this project. The analysis of extrapolation error is based on the estimation of bias and variances associated with the assumptions necessary to extrapolate from the laboratory to the field. Extrapolations between taxonomic groups, life stages, and physiological states are sources of error. By estimating the increase in variance of the benchmark response (e.g., game-fish mortality), it is possible to estimate the probability that the benchmark will be reached at a particular chemical concentration.

Ecosystem uncertainty analysis consists of error analysis of ecosystem models that have been modified by toxic effects. The modification consists of an effects matrix containing both the expected percent change in each model parameter resulting from direct toxic effects and a corresponding estimate of the coefficient of variation on the direct effect. Through Monte Carlo simulation, the modified model provides an estimate of the probability that a predefined percent change in the biomass of any of the component species has occurred.

The last two methods (fault tree analysis and the analytical hierarchy technique) are borrowed from other fields. Fault tree analysis is an engineering technique for analyzing the possible failure sequences of a mechanical system. We are using it to trace causal pathways between contaminant releases and end points of interests because it reveals modes of pollutant action that would be missed by other methods.

The analytical hierarchy technique is a method for making decisions based on expert opinion. Because data on the environmental toxicology of chemicals are meager, expert opinion is an important assessment resource. This technique provides a formal method for eliciting and analyzing opinion.

During FY 1982, these methods will be used to assess the environmental risk of direct liquefaction of coal, indirect liquefaction of coal, and oil shale production. The results of the five methods will be compared to determine their respective critical assumptions and to suggest improvements in the methodology of risk assessment.

Assessment of Instream Flow Needs at Small-Scale Hydroelectric Sites

The DOE Small-Scale Hydroelectric Development Program was organized in 1978 to encourage the redevelopment of existing small dams (those with a capacity of 30 MW or less) for hydroelectric generation. Staff in the EIP assisted DOE by assessing the potential environmental issues related to development of this resource. Analyses conducted during the past year focused on the issue of instream flow need (Loar and Sale 1981), which refers to the amount of water required within a natural stream channel to sustain various instream uses (e.g., fish and wildlife, recreation, and aesthetics) at an acceptable level (Bayha 1978). Interest in preserving instream uses of water is increasing as greater demands are placed on water resources to meet various industrial, agricultural, and domestic needs (offstream uses). The issue of instream flow is especially critical in the West, where water supplies are limited and offstream uses are well defined by law. As a result of the recent emphasis on development of small hydropower projects, the issue has become an important concern in other regions of the country, especially in the Northeast, where hydropower resources are abundant

Effects of Hydroelectric Generation on Instream Flows

The issue of instream flow maintenance in hydropower development is essentially a problem of evaluating the effects of planned modifications in hydrologic patterns. Alterations in flow regimes below hydroelectric dams can include both spatial and temporal changes in the amount of water moving through a natural stream channel. The degree to which spatial and temporal flow patterns are altered is directly related to the design and operation of the facility. Localized spatial changes in stream flow are characteristic of many small-scale hydropower projects where water is diverted through a canal or penstock to a turbine/generator at a lower elevation before the water is returned to the stream channel. The purpose of such diversions is to increase the hydrostatic head on the generator, but the result often involves the dewatering of a significant length of the original stream channel. Temporal changes in stream flow are generally short term; that is, they occur over a span of several minutes or hours. Such changes are characteristic of small hydroelectric projects that are operated in a peaking mode. Because the demand for electricity varies over a 24-h period, water is stored during off-peak hours (usually at night) for generation during the period of greatest demand. Peaking operations often result in a dramatic increase in the frequency and rate of change of major water level fluctuations and a reduction in the duration of a given water level (stage height) in the downstream channel.

Management for instream flow needs below dams usually involves minimum release requirements that are incorporated into operation schedules. Because water needed to protect various instream uses is often unavailable for power production, establishment of an instream flow regime may significantly affect the economic feasibility of many small hydropower projects. Resolution of conflicts between hydroelectric generation and other instream uses (e.g., the maintenance of aquatic habitats) requires information on the flow regimes needed

to protect these aquatic habitats. Our assessment of the instream flow issue included (1) review and evaluation of existing methods for determining the instream flow needs of aquatic biota and (2) development of a strategy to assist developers in selecting appropriate methods for assessing instream flow needs below small hydroelectric dams.

Existing Methods for Assessing Instream Flow Needs

Assessment of the instream flow needs of aquatic biota, particularly fishes, has proven to be the most difficult and controversial aspect of the instream flow issue. Over the past two decades, numerous methods have been developed to assess the effects of flow regulation on fishery resources and to provide a basis for the determination of suitable instream flow regimes that will protect these resources. These methods differ in their use of existing hydrologic records, hydraulic simulation techniques, and habitat evaluation procedures and in their capability of providing seasonal and/or species-specific flow recommendations. We found that the existing methods could be grouped into three general categories: discharge methods, which rely only on the use of historical flow records for making recommendations; hydraulic-rating methods, which use various hydraulic parameters (e.g., maximum depth and wetted perimeter) to develop generalized habitat-discharge relationships; and habitat-rating methods, which analyze in detail the quality and quantity of habitat available to selected fish species under different flow regimes.

Assessment methods that are based on historical flow statistics are among the simplest approaches because they usually require little or no field work and a minimum amount of time and money. Discharge methods that utilize a fixed percentage of the stream flow (e.g., 10% of the mean annual flow) as the minimum flow involve several implicit assumptions. Using thresholds based on a fixed-flow statistic to determine instream flow requirements on different watersheds implies that equivalent responses to flow regimes exist among watersheds. This assumption ignores the fact that the hydraulic geometry and local aquatic populations are adapted to past hydrologic conditions. All the discharge methods assume that these conditions can be accurately represented by particular flow statistics. None of the methods can incorporate unique watershed or fishery resource characteristics that are important in establishing site-specific recommendations. The best available discharge methods are those procedures that use flow-duration data and, thus, can incorporate natural flow variability at a specific site into the minimum flow calculation. Most of the discharge methods are primarily applicable to reconnaissance-level analyses where a low level of resolution is acceptable.

In contrast to discharge methods, hydraulic-rating methods involve the collection of field data to examine the relationship between selected physical parameters and stream flow at specific sites. An important component of these intermediate-level methods is the identification of physical parameters of the stream environment that can be used as surrogates for factors that are limiting to fish and other aquatic biota. The implicit assumption is that provision of some threshold value of a selected parameter (e.g., wetted perimeter) will protect the integrity of the aquatic ecosystem in general. Data collection and analyses are usually restricted to single transects across a river in a region where the limiting factor is most responsive to changes in flow (e.g., riffle area). The most significant capabilities of the hydraulic-rating methods are (1) introduction of simplified prediction techniques to reduce field survey needs and (2) examination of site-specific aspects of streambed morphology.

While hydraulic-rating methods eliminate some of the implicit assumptions regarding thresholds of habitat alteration that are inherent in the discharge methods, the selection of critical transects and specific hydraulic parameters includes important assumptions about biological responses. For example, hydraulic-rating methods usually assume that the factors limiting aquatic biota can be represented by a single parameter and that one critical transect accurately represents the influence of that parameter throughout a heterogeneous stream reach. The best available methods in this group are those based on stage-discharge rating curves and the Manning equation, when the equation is used within the limits of extrapolation to unobserved flow conditions.

The most advanced methods of assessing instream flow needs utilize a habitat-rating approach. These methods assess the effects of flow regulation on aquatic habitats by applying habitat preference criteria to quantify the usability of the stream at different flows. The most widely used of these methods is the Incremental Methodology (IM), which was developed several years ago by the U.S. Fish and Wildlife Service. The overall approach of the IM combines (1) multiple transect field data from a representative or critical stream reach; (2) hydraulic simulation models to predict physical habitat parameters such as mean velocity, depth, and substrate; and (3) suitability functions to calculate weighting coefficients that represent the habitat preferences of various life stages of selected fish species. Measures of habitat suitability and availability are combined in an index of habitat condition that can be plotted against stream discharge for each life stage. These habitat response curves can, in turn, be utilized in various ways to derive minimum flow recommendations. Because of this flexibility and the capability for hydraulic simulation, IM is the best available habitat-rating method. None of the existing instream flow assessment methods can provide the detailed analysis of the effects of habitat alteration (i.e., the biological responses) caused by flow regulation that the IM provides. Yet, even this method does not fully address these biological responses. For example, the method examines only two of the determinants of biological responses (habitat structure and flow regime), although other factors (e.g., food resources and water quality) may limit production in many riverine systems.

Assessment of Instream Flow Needs at Small Hydroelectric Sites

Environmental impacts resulting from flow regulation can be represented within the conceptual framework of an impact chain that begins with stream flow regulation, progresses to habitat alteration, and ultimately results in some type of biological response. The three categories of assessment methods described above provide a hierarchy of approaches with progressively greater resolution of this impact chain. The hierarchy not only allows for a tiering of the amount of detail that can be incorporated into an instream flow recommendation but also involves progressively greater data needs and overall application costs. Predictions of biological responses, the last level of the impact chain, are extremely complex, expensive, and inadequately addressed by any of the existing instream flow methods. Even if the proper methods existed, such a detailed level of analysis would probably be beyond the scope of the type of environmental assessment usually required of most small-scale hydroelectric projects.

Using the various categories of instream flow methods in a hierarchical arrangement represents a strategy for addressing the instream flow issue at potential small hydroelectric sites. Selection of the most appropriate method or methods is dependent upon the level of resolution required. To assist developers in determining what level of resolution is needed, criteria were developed related to (1) design and operation of the project and (2) the nature of the downstream fishery resources. The selection of an appropriate instream-flow assessment method should focus on achieving a reasonable match between the potential impacts of the project, as determined by its design and operation, and the ecological resources in the stream or river. The use of high-resolution, habitat-rating methods at small hydroelectric projects that have little potential for altering stream flows is just as inappropriate as the use of low-resolution methods at large projects that can significantly alter existing temporal and spatial flow patterns. A single method cannot meet the assessment needs of all types of hydropower facilities. To further ensure that the most appropriate method has been identified, the assessment should be conducted in consultation with those state/federal agencies responsible for the establishment of instream flow requirements.

Development of Guidelines for DOE's NEPA Affairs Division

During FY 1981, the EIP continued to provide technical assistance to DOE's NEPA Affairs Division - recently renamed the Environmental Compliance Division within the Office of Environmental Protection, Safety,

and Emergency Preparedness. This year's activities have focused on finalizing the *Generic Guidelines for Preparing Environmental Reports for DOE Activities* and drafting six technology-specific appendices to the generic document covering the following technologies: (1) tar sand, (2) western oil shale, (3) coal gasification and liquefaction, (5) unconventional gas, (6) fuel ethanol, and (7) peat.

The generic environmental report guidelines prepared in FY 1980 have been significantly modified this year to reflect the current administration's emphasis on reduced regulatory requirements and DOE's orientation toward emerging high-risk energy technologies. The final guidelines emphasize potentially significant issues associated with most large-scale energy projects. Upon final approval, the guidelines will be published by DOE for use by project managers and other preparers of environmental reports.

The technology-specific appendices identify those environmental, health, safety, and socioeconomic (EHSS) issues that are potentially significant for specific technologies. Each appendix contains (1) a general background section to familiarize a reader with the energy resource and technology; (2) a synopsis of the generic guidance on description of the project, the process stream, and the general site; and (3) a detailed treatment of potentially significant EHSS issues associated with the technology. Summaries of two of the technology-specific appendices follow.

Environmental Issues Associated with Tar Sand Projects

Tar sand is any consolidated or unconsolidated rock (excluding coal, oil shale, or gilsonite) that contains hydrocarbon-bearing material with gas-free viscosity at reservoir temperatures. The largest deposits occur in Canada and Columbia, and significant resources are found also in Trinidad, Tobago, and Venezuela. Although the United States has an estimated resource of 4.8×10^7 to 5.2×10^7 m^3 in 22 states, only six (Alabama, California, Kentucky, New Mexico, Texas, and Utah) contain deposits that could be commercially developed. More than 93% of all U.S. tar sand resources are located in Utah.

Processes for extracting and separating bitumen from tar sand deposits fall into two general categories: those that extract the ore using conventional mining techniques and those that use in situ extraction. Although limited surface mining may be possible in some Utah deposits, in situ extraction may prove to be the most feasible approach. In situ extraction would be used for deposits that are too deep for surface mining or that lack sufficient consolidation to permit underground mining. Approaches to in situ extraction that have been proposed include chemical solvent injection, steam-hot water injection, and combustion. These approaches are being tested, but they have yet to be demonstrated at a commercial scale.

Because of the high concentration of tar sand deposits in Utah, a high potential for conflict with national parks, monuments, and recreation areas exists. Land disturbance associated with surface mining, in situ well field development, construction of plant facilities, and settling ponds for spent ore sands all represent potential intrusions on the natural setting of the region. Increased population and traffic can also affect land use in the surrounding regions.

Atmospheric emissions from tar sand developments will include (1) large quantities of particulates from mining operations, (2) possible release of hydrocarbons from exposure of fresh bitumen and from the separation process, (3) potentially large emissions of sulfur oxides from use of coke and product fuel and from upgrading of the separated bitumen, and (4) nitrogen oxides from combustion of product fuels. The close proximity of some tar sand deposits to Class I air quality regions may mean that prevention of significant deterioration (PSD) increments will not be available for project development.

Significant quantities of water are used in all phases of tar sand operations. Because high-quality tar sand is located predominantly in regions of the United States where fresh-water availability is limited, careful consideration should be given to the water resource impacts of proposed projects. In addition, development of tar sand deposits may contribute to water quality degradation through (1) increased erosion and sediment loading,

(2) leaching or overflow from tailings retention basins, (3) nonpoint surface runoff, (4) groundwater contamination, (5) point-source discharges of waste effluents, and (6) accidental spills of process and waste streams or finished syncrude products.

Potential impacts on biotic communities include direct impacts of construction and waste disposal on species populations and their habitats, effects of effluents on aquatic biota and habitat, consumptive water withdrawals altering instream habitat conditions, and effects of toxic wastes on sensitive biota. Disposal of solid wastes produced by a tar sand development including spent mineral tailings, overburden, waste treatment sludges, and ash and catalysts will require additional land disturbance. The control and collection of leachates will be necessary to avoid contamination of groundwaters and surface waters.

Other potential socioeconomic problems include boomtown effects on the small isolated communities characteristic of the tar sand region and potential occupational and safety problems associated with mining and processing of tar sand. Exposure to known mutagens and carcinogens during processing will need to be carefully controlled, and monitoring of poorly characterized waste streams will be required.

Impacts of Developing Peatlands for Energy

Recent interest in alternative energy resources has included consideration of developing the nation's peatlands. Proven technology exists for harvesting peat and burning it directly in power plants, while ongoing research indicates that peat can be used as a feedstock for production of synthetic gas and liquid fuels. Reclamation of harvested peatlands offers a number of interesting possibilities, including agriculture, silviculture, or production of biomass energy crops. Although the use of peat for energy may be feasible from a technological viewpoint, the disruption of peatlands may result in significant environmental impacts. Therefore, any proposed projects should be carefully evaluated.

The major steps in the peat fuel cycle are (1) site selection and preparation, (2) harvesting, and (3) conversion to energy. Clearing involved in peatland preparation may involve both drainage and flooding operations. Dried peat can be harvested either in large blocks of sod or in a milled form. Flooded peat can be harvested as a slurry. Several energy conversion strategies are possible including direct combustion to produce heat and electricity, gasification to produce substitute natural gas and other liquid synfuels, or biogasification to produce methane. The most significant environmental impacts are associated with the preparation and harvesting of the peat. While the impacts of conversion of peat to a marketable fuel (e.g., brickettes and synthetic natural gas) are not well understood, control and mitigation measures developed for similar technologies should be readily applicable.

Draining peatlands to prepare for harvesting can cause significant modifications to watershed hydrology. Water storage of the peatlands will be modified, and the water table will be lowered. In coastal areas, saltwater intrusion, which can contaminate important freshwater aquifers, may occur. Peat harvesting may cause significant deterioration of groundwater and surface water quality by (1) erosion, (2) release of bound nutrients and metals from peat oxidation, (3) reduction of ecosystem retention of cations, and (4) increased mobilization of elements from underlying mineral soils. Input of acidic drainage to receiving systems downstream may adversely affect sensitive biota that are ecologically and economically important.

Air quality can be affected by dust created during harvesting, particularly when the milled harvest method is used. This dust may affect visibility and cause potential occupational health problems for workers. In addition, draining of peatlands increases their susceptibility to fires that, when once started, are difficult to control.

Peatlands provide critical habitat for many specialized plants and often represent wetland habitats of regional importance. These ecosystems are also an important scientific and educational resource in that peat deposits contain a pollen record that can be used to reconstruct the vegetation and climate changes that have

occurred over the period during which the peatland developed (often as long as 10,000 years). Therefore, peatlands are irreplaceable natural resources whose energy development must be carefully evaluated.

Alcohol Fuels Environmental Project

The EIP has been the major environmental compliance support group for alcohol fuels in DOE. Over the past year, we have contributed to the Office of Alcohol Fuels's NEPA-compliance activities at generic and site-specific levels and have provided outreach to the alcohol fuels industry on regulatory compliance.

The Office of Alcohol Fuels was established as an independent office within DOE by the Energy Security Act (ESA) (P.L. 96-294). The office was mandated to promote alcohol fuels production, distribution, and use by means of financial assistance programs. The ESA established two goals for the office: a production capacity of 9500 m^3/d by December 31, 1982, and displacing 10% of gasoline consumption with alcohol by 1990. The office's mandate created a need for NEPA compliance at the programmatic level (i.e., the environmental consequences of meeting the goals) and at the site-specific level (i.e., the environmental consequences of a project receiving a financial incentive). A programmatic assessment of the 1982 goal was prepared elsewhere, and ORNL was asked to prepare the site-specific assessments. To reduce repetition in the various site-specific assessments, a generic assessment document was prepared first. The 1990 goal has since been rescinded.

The Generic Environmental Assessment Report for Conventional Fuel Alcohol Plants (Elmore et al., in press) addresses the environmental consequences of the kinds of fuel alcohol plants expected to receive support in meeting the 1982 goal. The size of such plants would range from 60×10^6 to 600×10^6 L/year; use grains or sugars as feedstocks; burn coal, natural gas, wood, or bagasse for process heat; and dehydrate by azeotropic distillation with a hydrocarbon. Except for dehydration and size, conventional fuel alcohol plants are similar to beverage alcohol distilleries. As a result, environmental controls to limit impacts are readily available. The greatest potential impacts would derive from liquid process waste streams, which have high biochemical oxygen demand (BOD) and, possibly, metals, and from atmospheric emissions arising from coal- or biomass-fired boilers. Both sources of emissions are regulated, and control technology exists to comply with those regulations.

Impacts to the socioeconomic environment were assessed to be of concern only in the case of larger plants located in rural environments. The expected influx of construction workers was judged to be capable of exceeding local housing availability, medical resources, and tax-supported services such as sewers, fire protection, and police. To date, no statutory requirements for mitigating such boomtown impacts exist. No adverse impacts were predicted for smaller plants in urban environments.

Impacts to food availability and cost, consequences of increasing row-crop production on marginal land, and the effects on air quality of burning alcohol in motor vehicles were addressed in the programmatic assessment (DOE 1981) and have fallen outside of the responsibility of ORNL.

On August 22, 1981, the Office of Alcohol Fuels awarded conditional commitments of loan guarantees to 11 companies wishing to enter the fuel alcohol market. The task of preparing environmental assessments for the ten projects of those companies that chose to enter negotiations was assigned to ORNL. All are conventional plants, as defined in our Generic Environmental Assessment Report (Table 7.1). Sizes range from 57×10^6 to 450×10^6 L/year. The feedstocks are either molasses or corn, and all dehydrate by azeotrophic distillation with a hydrocarbon. Two companies plan to purchase steam from adjacent power plants, and one plans to burn a mixture of corn stover and manure obtained from corporate farms and feedlots. Only potential impacts such as siting and burning manure not addressed in the generic assessment are being addressed for these plants. Prior assessments from the programmatic and generic documents are being incorporated, as appropriate, by reference. In this way, we are meeting the objectives of the regulations for NEPA (40 CFR Parts 1500–1508) by reducing paperwork and subsequent delay. Analyses for all ten projects will be completed during the first quarter of FY 1982.

Table 7.1. Fuel alcohol loan guarantee applications

Project	Location	Size (10^6L year)	Feedstock	Fuel
Agrifuels Refining Corporation	New Iberia, La.	130	Molasses	Bagasse
Circle Energy Corporation	Garden City, Kan.	57	Corn	Corn stover and manure
D. W. Small and Sons, Inc.	Auburn, Me.	95	Corn	Wood
Eastern Ethanol	Lane, S.C.	75	Corn	Coal
Energy Conversion Corporation	Miley, S.C.	75	Corn	Wood
Gulf Coast Resources, Inc.	Keokuk, Iowa	75	Corn	Coal
Minnesota Alcohol Producers	Mankato, Minn.	75	Corn	Purchased steam
New Energy Corporation of Indiana	South Bend, Ind.	190	Corn	Coal
Tennol, Inc.	Jasper, Tenn.	95	Corn	Coal
U.S. Ethanol Corporation	East Baton Rouge Parish, La.	450	Corn	Purchased steam

The final environmental compliance activity for FY 1981 was organizing and conducting a regulatory compliance workshop for Federal Region IV. The proceedings were published at the end of the fiscal year (Salk et al. 1981). Held in Atlanta, the workshop, Moonshine to Motorfuel, emphasized the illicit beverage alcohol production for which the region was once noted and the additional regulations that production has created for fuel alcohol. The meeting placed into perspective the full set of regulations the industry must observe. Regulations were divided into areas of economics, environment, and health and safety. In regard to economic regulations, a speaker from the Bureau of Alcohol, Tobacco, and Firearms explained the beverage tax exemption available to fuel alcohol and the regulations for obtaining the tax exemption, and a representative of a brokerage firm (E.F. Hutton) explained other tax incentives available and how they may be used in setting up financing for a fuel alcohol venture. Environmental regulations were presented by staff from the EPA Federal Region IV and from the Georgia Institute of Technology. In addition to having the regulations explained to them, the attendees were told how to comply both technically and procedurally with the regulations. The health and safety panel was comprised of an academician, an engineer, a representative from the Occupational Safety and Health Administration (OSHA), and a representative of Williams Brothers Pipeline Company, which has experience in transporting fuel alcohol. The panel alerted the attendees to the hazards of fuel alcohol, explained the pertinent regulations, and offered advice on both compliance and safe handling. Two plenary sessions focused on the then-current regulatory atmosphere for alcohol fuels and speculated on the future for alcohol fuels.

The current loan guarantee program appears to be the final governmental stimulant to the alcohol fuels industry, although it falls short of the 1982 goal contained in the ESA. Because the ESA's 1990 goal has been eliminated, no further NEPA-compliance activity for alcohol fuels is anticipated.

Regional Environmental Characterization—Office of Nuclear Waste Isolation

This task characterized the environment of the Southern Piedmont, a region that includes a number of granitic formations that have geological characteristics potentially suitable for the permanent disposal of high-level nuclear wastes. The region was screened using environmental and geologic criteria in order to identify the most favorable areas for further study. This work supported the DOE Office of Nuclear Waste Isolation in the office's overall goal of providing assurance that high-level nuclear wastes can be isolated from the biosphere in a safe and environmentally acceptable manner.

The regional characterization consisted of an analysis of the following environmental variables: (1) demography, (2) mineral resources, (3) water quantity and quality, (4) land use, (5) terrestrial and aquatic systems, and

(6) climatic patterns. Sources of information for these variables included federal agencies, state natural history offices, personal contacts, the open literature, and computerized data bases. The level of spatial resolution of each environmental data set was equivalent to the average size of the granitic areas in the region. This level of spatial detail allowed for an adequate degree of discrimination between each of the 29 granitic areas under study.

Criteria for the selection, construction, and operation of a long-term nuclear waste repository have been established by DOE and have been utilized in the granitic area selection process. The selection criteria for the variables analyzed in this study outline the potential environmental and demographic conflicts that could occur during the siting and operation of a repository. Quantitative analyses of each of the appropriate environmental and geologic variables screened the data according to the criteria to exclude areas that would be unsuitable for long-term waste storage.

Discrimination criteria to judge the acceptability of a granitic area for a repository were applied to the regional level information on the environmental and demographic variables of concern. Suitability based on demographic variables was a function of low population density and distance from urban areas. The potential or current use of mineral/energy resources within a granitic area determined the degree to which extraction processes could influence a repository. In the analysis of surface hydrology, the location of dams, reservoirs, and 100-year floodplains could present conflicts with certain potential granitic areas. Suitability based on unique natural areas (i.e., wildlife refuges, natural resource research areas, endangered species habitats, and park lands) was influenced by the potential for habitat disruption in each area. In addition, areas of high agricultural productivity were considered less suitable for repository siting than were forested areas. Climatic information located areas that may present extremes of winds, air pollution, or precipitation in the study region.

Through the utilization of the selection criteria and the associated regional environmental data, an initial selection was made of plutons considered acceptable for further area studies. The selection criteria were used in conjunction with an evaluation matrix for each of the regional environmental variables and the 29 plutons in the study area. Through projections of the spatial pattern of environmental variables on the array of granitic areas, the acceptability of each area for more intensive site studies was determined. Areas considered acceptable based on the environmental data were then compared with those areas found acceptable based on the geological criteria to rank the overall suitability of each granitic area for potential use as a high-level nuclear waste repository.

Monitoring Protocols Development Project

The purpose of the Monitoring Protocols Development Project is to develop and demonstrate methods 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 techniques, and analytical techniques derived from ecological theory are integrated and used to identify vulnerable ecosystem components and processes.

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 assessment, 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. We have evaluated existing microcosm and enclosure systems with respect to ecological realism, practicality, and cost. The following sections describe (1) a review of response parameters measured in field studies of the effects of SO_2 and photochemical oxidants on terrestrial ecosystems and (2) an evaluation and comparison of in situ enclosure systems designed for use in lentic freshwater and marine ecosystems.

Selection of Parameters to Monitor Ecological Effects of Air Pollution

The array of measurement techniques that can be applied to monitoring a field experiment or a real perturbation is restricted by technical and programmatic considerations. Institutional restrictions include the goals and concerns of the public and sponsoring agencies as well as the limitations of time and money. Technical restrictions on plant monitoring include interference by other nearby emission sources and the availability and accessibility of appropriate biotic communities. Perturbation experiments are further restricted by the limited area that can be reasonably perturbed and by interference from the mechanisms involved in producing the perturbation.

Following the application of these restrictions, the investigators must select the ecological parameters and measurement techniques that are most likely to provide sensitive and valid indicators of important responses from among those which remain available. Because very little monitoring has been performed concerning the effects of air pollutants, this selection process has necessarily been performed on the basis of professional judgement. The purpose of this study was to review the results of studies of the ecological effects of air pollutants in an effort to distinguish regularities in the results that might guide parameter selection.

This review included laboratory studies that measured multiple response parameters and any field study that was not limited to surveys of visible injury. It was restricted to studies of SO_2 and photochemical oxidants (primarily O_3). Except for two whole-ecosystem studies, the review is further restricted to effects on plants. Plants are, in general, much more sensitive to air pollution than are other components of biological communities and have been the subjects of most investigations of environmental effects. Observations in the field of the effects of air pollution on animals and microbes that are not mediated by effects on plants are not sufficiently abundant to allow generalization.

The primary lesson of this review is that generalization across pollutants and ecosystems is difficult. Each generalization about sensitivity in this analysis has at least one exception. Previous generalizations by other authors hold up no better.

The best guide to selection of monitoring parameters is specific knowledge concerning the modes of action of the pollutants of interest and the responses of the species and systems of interest. Although plants in the laboratory do not respond at the same dose as do those in the field, the rankings of species and the order of responses within organisms generally carry over to the field. This knowledge should then be used to select a set of parameters that define the end points of interest and that indicate the potential for effects on end points beyond the period of the study.

Evaluation and Critique of In Situ Experimental Systems for Investigating Effects of Stress in Lentic Ecosystems

In situ enclosures are experimental systems that are intermediate in scale between laboratory microcosms and the natural environment. These enclosures can be used (1) to study intact communities and the interactions between important community components, (2) to manipulate and control various critical environmental variables so that the effects of the controlled variable on community response can be investigated, (3) to replicate events so that variability can be quantified, and (4) to study the same communities or processes over long time periods. Published reports on the use of these systems were reviewed in order to develop recommendations and guidance for using in situ enclosures to assess effects of stress on lentic aquatic ecosystems.

It was found that the most important limitations on the use of these systems are that (1) circulation patterns inside the enclosures may be eliminated or reduced, (2) physicochemical and biological processes may be distorted because of altered circulation patterns, (3) sediment-water processes may be reduced, (4) replicability and control of smaller laboratory systems are sacrificed for larger and expensive systems, and (5) cost and maintenance may be high.

The most critical design features are volume and depth, which influence the trophic structure and complexity that can be included in the enclosure, the amount of side growth and enclosure effects that will develop (e.g., surface-to-volume ratio), and the behavior of encapsulated organisms (such as predator-prey relationships). If the behavior of communities in enclosures are to be investigated, then the system should include the representative functional relationships and should approximate the ratios of the major trophic groups in the natural system. Particular attention should be paid to the maintenance of realistic predator-prey ratios because an imbalance in this relationship could result in alteration of community structure and nutrient regimes inside the enclosures.

Even though parameters to be monitored in an experimental study are dictated by the hypothesis being tested and experimental protocols, emphasis should be on functional and aggregate responses of organisms and communities. Functional and aggregate response parameters are not only sensitive indicators of ecosystem stress, but they should reduce redundancy and cost in monitoring and should maximize efficiency of sampling and data interpretation. In addition, monitoring of the size distribution of particulates can indicate changes in the structure of stressed communities, resources available to consumers, and the efficiency of energy transfer through food chains.

Chattanooga Shale

Continuing an interest that began in the mid-1950s, the Laboratory reevaluated this past year the Chattanooga shale formation of middle Tennessee as an energy source. Part of that evaluation was an environmental impact assessment. Originally viewed as a source of uranium, the Chattanooga formation is now being viewed primarily as a source of shale oil with secondary potential for uranium, aluminum, iron, and strategic metals.

Potential impacts from liquid and gaseous effluents remain largely speculative because research is still in its early stages. Other potential impacts are quite clear, however. Viable shale oil mine and retort complexes in the eastern United States will be large, and routine impacts such as those associated with other extractive industries will be exacerbated by that size. For example, although a typical Chattanooga shale mine (underground) will be 50 times larger than the largest U.S. underground coal mine, it will produce only slightly more than half as much energy. Solid waste will be 800 times higher on an energy equivalence basis. Thus, if the impacts of a shale mine are qualitatively no worse than those of a coal mine, the total impact will be orders of magnitude greater.

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8. BIOMASS

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Introduction

The Environmental Sciences Division (ESD) assumes a major responsibility for both coordination and field work activity in biomass research sponsored by the U.S. Department of Energy (DOE) This work is divided among three basic areas: (1) Short-Rotation Woody Crops Program (SRWCP), (2) Environmental Effects of Whole-Tree Harvesting, and (3) Fertility and Tilth Effects of Fuel Crop Residue Removal. Through various ways, each of these areas of research is directed toward increasing biomass production and utilization and/or determining the environmental consequences of intensive biomass harvesting.

The ESD's role in the SRWCP is to provide technical guidance according to directives from DOE's Biomass Energy Technology Division. This guidance includes responsibility for 32 contracted projects dispersed throughout the United States (including Alaska and Hawaii) and requires (1) site visits to contract locations, (2) peer and panel reviews of research proposals, and (3) technical workshops conducted for information exchange and data evaluation. The general design of the research consists of many field-oriented, long-range projects involving growing and improving woody plants for high productivity. The research can be categorized according to three basic areas: species screening and genetic selection, stand establishment and cultural treatments, and alternate harvest, collection, transportation, and storage systems.

In contrast to exploring ways of maximizing biomass production per units of space and time as described for the SRWCP, the Environmental Effects of Whole-Tree Harvesting project is specifically designed to ascertain the environmental consequences of intensively harvesting existing stands of both naturally occurring and planted forests. This interest is based primarily upon the assumption that if wood becomes a more valuable commodity in terms of energy and as a raw material for consumer products, a possible mechanism for obtaining an additional supply of fiber could be through a more thorough harvesting technique used on areas that are currently being harvested by conventional methods. Because sawlogs and wood for paper consume only about 50% of the plant material in a forest stand typically considered ready for harvest, the residue generally left on the site could be a significant supply of wood for various uses. The environmental consequences of removing this material and, thereby, depleting the landscape of all above-stump woody material is the emphasis of this research in terms of nutrient dynamics and productivity after harvesting. The work is being done through sub-

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contracts managed by the ESD at nine sites in the United States in addition to a site on the Oak Ridge Reservation. The study at each site consists of two phases — each comparing conventional harvesting with total aboveground biomass removal through (1) assessment of direct effects of nutrient removal and ion leaching and (2) evaluation of indirect or long-term effects as determined by measuring system nutrient loss by leaching and runoff, changes in decomposition and carbon balance, and subsequent differences in succession and productivity.

The work relating to fertility and tilth effects of fuel crop residue removal has similar objectives as the whole-tree harvesting study. However, research on this project is specifically directed toward quantifying the environmental effects of and potential energy from harvesting vegetative plant material of cultivated agricultural crops heretofore left in the field. The ESD's role in this work is to provide technical management assistance to DOE for maintaining research at five sites within important agricultural regions of the United States. With emphasis upon wheat and corn crop residues, measurements include crop yield, residue yield, erosion by water, and macronutrient loss. These data are taken according to three residue removal rates and tillage vs no tillage.

Short-Rotation Woody Crops Program

The DOE's SRWCP is concerned with economically increasing woody biomass production per hectare. With increasing land and labor costs in the wood-producing market, higher productivity per unit of land area is one way of offsetting these costs. This field-oriented, long-term research program is comprised of in-house research activities and 32 subcontracted projects, which are primarily conducted at universities. The goal of this program is to evaluate and improve productivity of woody species. Total program funding in 1981 was approximately $4.5 million. Productivity is being increased through (1) genetic selection, (2) development of better stand establishment techniques, (3) determination of new and innovative stand management techniques, and (4) development of alternate wood harvest, collection, transport, and storage methods. In-house activities are centered on program administration, nutrient conservation research in short-rotation silviculture, development of economic frameworks for evaluating short-rotation systems, and regional evaluation of program results.

Since the program's inception in 1977, Oak Ridge National Laboratory's (ORNL's) ESD has technically managed woody biomass research through subcontracts and grants for DOE's Biomass Energy Technology Division. Research has focused on short-rotation intensive culture (SRIC), which refers to trees or shrubs grown at close spacings and harvested every 2–12 years. These systems are designed to take advantage of the rapid early growth and resprouting abilities of many hardwood species. The SRWCP is designed to answer basic questions about the biological potential and economic viability of short-rotation intensive silviculture by 1987. In 1981, ORNL assumed greater responsibilities in program administration by directly funding and financially monitoring all projects through Union Carbide Corporation-Nuclear Division (UCC-ND) subcontracts and interagency agreements.

The potential for production of wood from SRIC systems is not well known and varies from one geographic region to the next. For this reason, research efforts are directed to recognize and investigate the conditions and locations with the highest potential. Figure 8.1 reflects this research by showing that the regions of the South and Great Lakes states have the greatest potential. These two regions together should be able to produce over 75% of all wood coming from SRIC systems. The Southwest has a large land base with low potential rates of biomass productivity. Less intensive but widely applied management systems in this region can produce significant quantities of wood, thus causing the Southwest to rank a close third to the two better regions. Steps were taken in 1981 to better balance the SRWCP to regional potentials by (1) increasing species screening in the Southwest and South, (2) focusing on the remaining promising species of the Northwest, and (3) evaluating large-scale operations in the Great Lakes states. The program was also strengthened through the initiation of

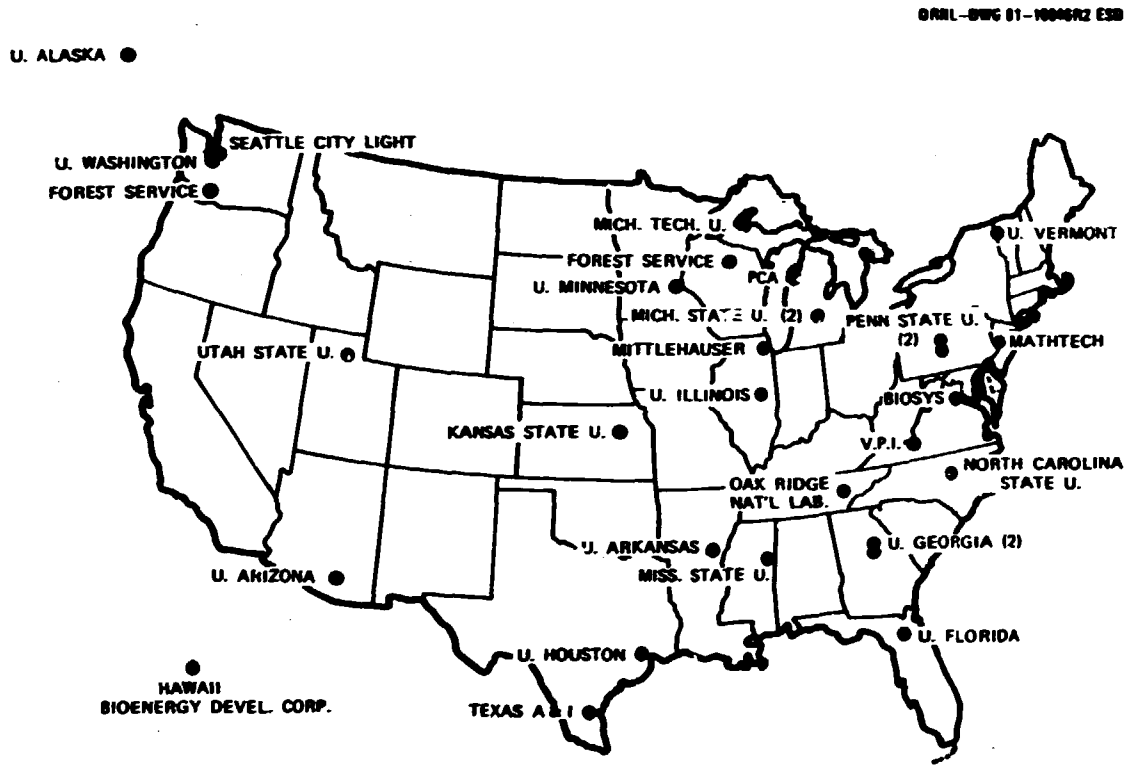

Fig. 8.1. Location of projects in the SRWCP.

economic evaluation systems that may be adapted to short-rotation plantations in each of the regions being investigated. These systems should also help in identifying the most promising areas of research.

Although the objectives of the SRWCP vary by region and type of site, the objectives may be summarized as follows:

1. Identify and develop woody species for highest biomass production potential under SRIC. These species should be evaluated on major "available and appropriate" site types for intensive management in the United States. The production potential of these species should be quantified.
2. Identify and improve management techniques to minimize wood production energy/dollar costs at the high productivity levels of the first objective so that the product is locally competitive with alternative wood production systems and other important available fuel feedstocks.
3. Convey information and cooperate with industry and the public and assess potentials and problems for short-rotation woody crops.

Since the beginning of the SRCWP, exceptional progress has been made in identifying species that are adaptable to a wide range of sites and that have high biomass production potential (Table 8.1). Successful establishment and management techniques are being developed for heretofore untested species. Although the best 25 species have been identified, over 50 other species are still being tested to be assured that (1) the best 25 species have the greatest potential, and (2) the best early performers continue to perform well beyond the first few years of age. Improvements in establishment and management of short-rotation stands have led researchers to expect 90% survival of planted stock. Appropriate levels of fertilizer applications and weed control have been tentatively identified, and insights have developed regarding the best spacings and rotation ages. Major conclusions from research to date are that (1) the regions of the South and Great Lakes states have the greatest potential

Table 8.1. Selected regional productivity rates based on results from the SRWCP

Region	Productivity (dte/ha/year)	Species	Site quality
Alaska			Moderate
Semiarid Southwest	19	Mesquite	Good with irrigation
Semiarid Southwest		Mesquite	Good without irrigation
Pacific Northwest	9	Black cottonwood	Good without fertilizer
Great Lakes states	15	Hybrid poplar	Medium with fertilizer
South	20	Sycamore	Medium with fertilizer
South	8	Chinese tallow tree	Poor with fertilizer
Northeast	10	Hybrid poplar	Good with fertilizer
Northeast	10	Black locust	Good with fertilizer
Subtropics	40	Eucalyptus	Medium with fertilizer
Subtropics	22	Eucalyptus	Poor with fertilizer

for intensive silviculture biomass production, (2) 20–30 dte/ha/year are achievable using intensively managed 8–10-year rotations on good-to-moderate sites, (3) second rotation coppice productivity should be 10–30% higher than the first, (4) productivity of hardwoods (main coppicing group) has doubled and tripled in response to management on many sites, and (5) growing wood for energy is presently economically feasible ($2.20/million Btu) in local circumstances.

The greatest research needs are in areas of (1) clonal propagation of superior plant genotypes; (2) more accurate identification of site/species relationships; (3) species performance evaluations in the range of 4 to 12 years; (4) selection of superior genotypes/provenances for productivity, disease resistance, and site adaptability; and (5) design and development of harvest/transport equipment. Tied into all of this research is the accurate economic and production evaluation of intensive culture systems in a variety of conditions across the country. The effects of scaling-up operations to commercial size and the availability and quality of land for SRICs remain of extreme concern as do possible adverse effects such as site deterioration and loss of productivity.

The role of the ESD regarding the SRWCP has been to provide technical guidance according to DOE directives and to enable the ESD to conduct in-house regional and specific studies of the effects of site manipulation on the environment. Technical guidance has included reviews and recommendations on research through the use of annual site visits, peer and panel reviews, and technical workshops. Technical assistance to DOE for program planning has been provided through quarterly, annual, and multiyear plans; weekly highlights; and listings of milestones.

In-house research in support of the SRWCP has resulted in the establishment and monitoring of about 20 ha of short-rotation hardwoods on the Oak Ridge Reservation in 1981 to assess nutrient-conserving alternatives. Recent studies have shown fertilizer costs in such systems to be high; therefore, any reduction in required site fertilizer amendments has direct economic implications. Experimentation with nutrient conservation in short-rotation hardwood systems can assist DOE in reaching research objectives. As an outgrowth of managing the SRWCP, we have been accumulating productivity figures from a wide range of short-rotation management plots. These new data are under analysis for the development of a major and well-documented perspective on SRIC in the United States.

Contractor Results

The SWRCP is comprised of many field-oriented, long-range research projects that are growing and improving woody plants for high productivity. Examples from only a few specific projects are provided to

demonstrate the types of research activities in the program. The major activities are (1) species screening and genetic selection, (2) stand establishment and cultural treatments, and (3) alternate harvest, collection, transportation, and storage systems.

Species Screening and Genetic Selection. Species screening and genetic selection studies are emphasizing the selection of promising species or genetic strains within a species for biomass production under SRIC. These species and intraspecific selections are being evaluated under a variety of management regimes for rapid growth, site adaptability, and resistance to major pests and diseases. Each of these projects is evaluating species under a variety of cultural treatments and, thus, includes spacing, herbicide, and fertilizer trials.

A variety of woody species for biomass production are being screened in projects at Michigan State University, Utah State University, and the University of Vermont. The major goal of these projects is to identify two to five of the most promising species for one or more geographic regions in the United States. The most promising species being evaluated by SRWCP projects are listed in Table 8.2. These species were selected for evaluation because they are easily established and regenerated, are adaptable to regional climatic conditions or are in-

Table 8.2. Most promising woody species in the United States for SRIC

Alaska
Birch *(Betula* spp.*)*
Aspen *(Populus* spp.*)*
Alder *(Alnus* spp.*)*
Willow *(Salix* spp.*)*
Semiarid Southwest
Mesquite *(Prosopis* spp.*)*
Leucaena *(Leucaena leucophylla)*
Tamarisk *(Tamarix* spp.*)*
Four-wing saltbush *(Atriplex canescens)*
Pacific Northwest
Black cottonwood *(Populus trichocarpa)*
Hybrid cottonwood *(Populus* spp.*)*
Red alder *(Alnus rubra)*
Great Lakes states
Hybrid poplar *(Populus* spp.*)*
Alder *(Alnus* spp.*)*
Willow *(Salix* spp.*)*
Jack pine *(Pinus banksiana)*
South
Sycamore *(Platanus occidentalis)*
Sweetgum *(Liquidambar styraciflua)*
Black locust *(Robinia pseudoacacia)*
Cottonwood *(Populus deltoides)*
Loblolly pine *(Pinus taeda)*
Northeast
Hybrid poplar *(Populus* spp.*)*
Black locust *(Robinia pseudoacacia)*
Maple *(Acer* spp.*)*
Cottonwood *(Populus deltoides)*
Subtropics
Slash pine *(Pinus elliottii)*
Sand pine *(Pinus clausa)*
Melaleuca *(Melaleuca quinquinervia)*
Australian pine *(Casaurina* spp.*)*
Chinese tallow tree *(Sapium sebiferum)*
Eucalyptus *(Eucalyptus* spp.*)*

digenous to the region of study, and are free of major insect and fungal pests. In addition, these species have dense, high-quality wood. Species may also be selected by morphological and physiological characteristics such as crown architecture and net photosynthesis rate.

Generally, hardwood species have a greater potential for SRIC than softwood (conifer) species. Hardwood species exhibit rapid juvenile growth, have denser wood, and are often more genetically diverse than coniferous species. Most importantly, hardwoods are vigorous sprouters and may be regenerated by coppicing.

At Michigan State University, over 25 species are being tested including 10 hybrid poplar clones and 9 conifers. Conifers are being tested because they are well adapted to the sandy, poorer sites widely found in the Great Lakes states even though these species do not coppice. After several years of study, the investigators have concluded that hardwood species offer the most potential on good sites in this region and that conifers (especially pines) should be planted on poorer sites. Perhaps the most promising species over all the test sites in the Great Lakes states is European black alder *(Alnus glutinosa)*. Other species with potential for biomass production in this region include hybrid poplar clones *(Populus* spp.*)*, jack pine *(Pinus banksiana)*, scotch pine *(Pinus sylvestris)*, and hybrid pine *(P. nigra* x *densiflora)*. Most of these species, however, are limited by site type.

In the Northeast, the University of Vermont has identified black locust *(Robinia pseudoacacia)* and hybrid poplar clones as the most promising species for this region. Both species grow well on a variety of sites. Productivity of hybrid poplar and black locust has been calculated at 10.4 dte/ha/year and 10.8 dte/ha/year, respectively. Conversely, sugar maple *(Acer saccharum)* and yellow birch *(Betula allegheniensis)* were consistently poor performers. These species will be replaced in the field trials by more promising species.

Utah State University is evaluating five native shrubs for potential biomass production in the semiarid west. Seedlings of five species were collected from large biotypes throughout the intermountain rangelands. The species were successfully propagated and have been growing under minimal cultivation. After two growing seasons, it has been determined that plant survival and vigor varied among the five species. One species, big saltbush *(Atriplex lentiformis)*, completely died out, while several other species had high survival rates and exhibited vigor, especially greasewood *(Sarcobatus vermiculatus)* and four-wing saltbush *(Atriplex canescens)*. The different responses may be attributed to the importance of growing plant ecotypes in areas where they are most adapted.

Results from these three projects and other SRWCP projects indicate that selection of species may be limited by site type, climatic conditions, and biotype. Future research efforts should focus on the most promising species and on the relationships between species, site, and management strategies. However, those species that initially exhibited poor growth should not be eliminated but should be evaluated under various management regimes for several growing seasons, and resprouting capabilities should be determined.

Several SRWCP projects are evaluating the genetic diversity of promising species in an effort to increase productivity. The major goal of these projects is to select or breed for traits (i.e., growth in height, resistance to disease, and hardiness to cold) desirable in SRIC systems. Species that are presently being evaluated for genetic diversity include red alder *(Alnus rubra)*, black cottonwood *(Populus trichocarpa)*, sycamore *(Platanus occidentalis)*, hybrid poplars, and mesquite *(Prosopis* spp.*)*.

The University of Washington's research effort is aimed at increasing biomass production of black cottonwood through clonal selection, seedling selection, and interspecific hybridization. Productivity rates of 14.4 dte/ha/year have been achieved with an interspecific hybrid of black cottonwood and eastern cottonwood *(Populus deltoides)*. After two years of black cottonwood clonal evaluations, the investigators have concluded that a large amount of genetic variation exists for the species. This variation may be readily exploited for increasing biomass production. One clone achieved a mean height of 6.9 m after two growing seasons.

The genetic diversity of sycamore is being investigated at Mississippi State University through provenance trials. It has been determined that significant genetic differences such as disease resistance and stem dry weight

exist among geographic sources of sycamore. Data indicate that yield could be increased by 50% at one test site by selecting the appropriate seed source. A high incidence of a canker disease was reported at one site and attributed to the presence of a susceptible provenance or provenances in the plot. Disease incidence could be reduced and productivity increased by removal of susceptible provenances.

Selection of hybrid poplars was initiated before the beginning of the SRWCP for superior wood and fiber quality. Clones are now being evaluated for biomass production at The Pennsylvania State University, Michigan State University, and the U.S. Department of Agriculture Forest Service's Forestry Sciences Laboratory at Rhinelander, Wisconsin. At Rhinelander, 14 clones are being tested for intensive culture. Criteria for selection of promising clones include net photosynthesis rate, branch angle, leaf orientation, and enzyme production.

The identification and selection of superior mesquite clones has been completed at the University of California-Riverside. The most promising clones are now being propagated and planted at Texas A&I University. The clones are being grown under SRIC. Biomass production will be determined among the clones and compared.

Stand Establishment and Cultural Treatment. Stand establishment and cultural treatment refer to the propagation, planting, initial maintenance, and long-term management of woody species under SRIC. In stand establishment, both high survival and rapid growth are important factors during the first years because productivity rates will determine the subsequent economic returns and viability of this system. The objective of this research is to identify the optimal conditions under which woody plants can be successfully and consistently established for biomass production. These conditions will vary for selected species, site types, climatic conditions, and geographic regions.

Stand establishment and cultural treatment research can be categorized as follows:

1. development of planting materials,
2. improvement of planting methods,
3. weed control,
4. fertilization,
5. spacing, rotation, and
6. pest management.

These research categories make up the largest area within the SRWCP. Overall trends and results are just now being realized.

All species being tested in the program (greater than 100) have been propagated from seed or from cuttings. Those methods have been the most economical. However, in the selection of specific clones and genotypes for field testing, it will be necessary to speed up propagation to obtain the large number of plantlets necessary for proper testing. Tissue culture research has been conducted on sweetgum *(Liquidambar styraciflua)*, sycamore, black locust, red alder *(Alnus rubra)*, European black alder, honey locust *(Gleditsia triacanthos)*, catalpa *(Catalpa bignioides)*, *paulownia (Paulownia tomentosa)*, red maple *(Acer rubrum)*, river birch *(Betula nigra)*, and various willows *(Salix* spp.*)*. Success is being achieved in all areas with species-specific hurdles remaining. Researchers at the University of Georgia have found sweetgum relatively easy to propagate via tissue culture from calluses formed from shoot and embryo cells. Sycamore has been more difficult to propagate because organisms present in seed coats and shoot tips contaminate the required purity of the cultural media. Accelerated growth of seedlings in controlled environments for faster seedling production and lower costs per seedling are also being evaluated at several locations.

High survival and fast growth of woody plants when first planted are very important in attaining high productivity in SRIC systems. In fact, the first year is a critical time that controls crop success or failure. For

example, because unusual weather at this stage can cause serious effects, weather is the source of considerable risk. Close planning and immediate attention are required when difficulties arise. Weed and pest control are also important to the success of establishment. Research has concentrated on improving the vigor and versatility of planting stock and improving site conditions for plantlet survival and growth. The aspects studied concerning the vigor of planting stock have included (1) storage conditions, (2) treatment of stock immediately before planting (e.g., soaking of cuttings), (3) inoculation with mycorrhizae, (4) effects of age and size on root development, (5) container type, and (6) time of year of planting.

All treatments are not appropriate for all species. Species being most thoroughly tested are hybrid poplar, black cottonwood, hybrid cottonwood, mesquite, Chinese tallow tree, willow, alder, sycamore, sweetgum, and black locust. A large number of species are being examined with respect to planting stock treatments at Michigan State University, North Carolina State University, the University of Florida, and Kansas State University. These projects constitute the most ambitious work of its kind in the number of species being evaluated and the diversity of evaluations in progress.

With respect to improving site conditions for better plantlet survival and growth, weed problems during the first two years have proven to be the most pressing. The focus of research in the SRWCP has been on (1) identification of kinds, amounts, and timing of herbicides for weed control and minimum damage to the biomass crop; (2) evaluation of effectiveness of alternative weed control measures such as cultivation and cover cropping (planting desired annuals between woody crops to crowd out weeds); (3) identification of the extent of weed control necessary for maximum wood production; and (4) timing and application of fertilizers to minimize weed problems and maximize wood production. Most of the contractors have found herbicides to perform satisfactorily, but few contractors have been completely satisfied with results. Researchers at the University of Illinois have conducted the most intensive herbicide trials. Their results combined with those at Pennsylvania State University and elsewhere indicate that (1) specific weed problems need identification (need to be anticipated) so that appropriate herbicides can be used; (2) because sensitivity to herbicides can vary tremendously between species and herbicides, herbicides need to be tested in greenhouses and field plots before widespread use; and (3) one should establish a reasonable weed control objective and then hope for some good luck.

Use of fertilizers in SRIC is mandatory in many cases for satisfactory productivity. However, many species under investigation have previously received little scientific testing for response to fertilizer quality, quantity, and timing. Because fertilizer is a significant item that affects both cost and productivity, fertilizer is receiving attention. Efforts have focused on the macronutrients—nitrogen, potassium, and phosphorus—although other macronutrients and micronutrients are under study. Soil nutrient budgets are currently being monitored to determine how to minimize losses to leaching, volatilization, and weeds while benefiting productivity of desired species. Furrow or strip fertilizing is more desirable than broadcast fertilizing for the first two years of stand establishment, and two to three light applications of fertilizer appear more desirable than one annual application. Annual active nitrogen fertilizer applications of 50–70 kg/ha have usually been required in very intensive management scenarios that maximize productivity, although higher levels have been tried. Program data have demonstrated that sites of medium-to-good quality respond best to fertilization, whereas poor sites tend to remain poor because of remaining overriding site limitations such as poor drainage or impermeable soil layers. The use of N-fixing tree species planted among other crop trees or in pure stands is being investigated for possible fertilizer conservation.

Irrigation has contributed to many of the highest productivity levels encountered in program research, but preliminary economic and energy evaluations indicate that irrigation in the East does not pay—crop failure reduction notwithstanding. If other factors are held constant, irrigation can increase productivity by 50–100% during unusually dry years in the East and South. Since the initiation of the SRWCP, irrigation research has gradually been deemphasized in response to early findings. However, as a risk reduction factor, irrigation is still under evaluation.

In plantations where trees are closely spaced, a strong relationship exists between the spacing of the trees at planting and the time until crowding causes plot productivity to decline. At this point, the plantation should be harvested. Research results indicate that spacing plays an important role in affecting productivity during only the first few years of a plantation's life. Also, multistemmed sprouting tends to override initial spacing after harvest. Most results have indicated rotation ages of 5–8 years or more will yield highest productivity, but at this point many of the research plots are from three to four years old and are too young to verify preliminary results. Spacing affects the amount (cost) of planting materials required, equipment access, and the duration of weed competition during stand establishment. To date, spacings of from 1.5 to 3.0 m have performed best.

Pests and diseases in short-rotation plantation systems are an area of research that has been lightly addressed because of the absence of previous research. *Septoria* spp., a canker-inciting fungus, has completely devastated plantations of hybrid poplars. This aspect of plantation management could easily break the concept if it is not appropriately addressed. The factors that must be studied include the environmental and physical conditions that affect the spread and severity of pests and diseases and the genetic resistance to pests and diseases. The greatest benefactor of a disease epidemic is crowding — an important factor in short-rotation productivity. The limited number and size of research plots have not provided a clear indication of the extent of pest problems. The disease and pest problems in plantations cannot be predicted from events in natural stands.

Alternate Harvest, Collection, Transportation, and Storage Systems. Large-scale use of woody biomass from energy plantations will require a mechanized harvesting system to sever, collect, transport, and process the woody material. Existing harvesting equipment is being evaluated for use in SRIC systems at the BioEnergy Development Corporation, Seattle City Light, the University of Florida, and the Packaging Corporation of America. The University of Georgia will use a tractor-mounted circular saw to harvest plantations, but severed material will still require collecting, transporting, and processing. Progress to date has been limited because existing harvesting equipment is designed for use in conventional silvicultural operations, not SRIC systems. Available equipment is considered unsuitable for small-diameter, closely spaced stands. In addition, the severed stump must remain undamaged after it is cut to ensure coppice regrowth.

An integrated evaluation of harvesting and transport equipment has been performed at Mathtech, Inc., Princeton, New Jersey. Extensive information has been collected on harvesting and transport equipment. This information will be incorporated into a linear model for optimization studies. The model is currently being used to determine the effects of terrain and weather on equipment usage.

Investigators at Virginia Polytechnic Institute and State University are designing and developing a short-rotation plantation harvesting system that will offer flexibility in harvestable tree size, operable terrain, and road spacing. The system will be able to handle both single stems from a seedling planting and multiple stems from coppice development. The coppicing method of reproduction differs from most forms of agricultural reproduction, and the challenge of developing a short-rotation harvesting system is fourfold: to remove the current crop, to deliver it to a processing location efficiently, to cause minimal damage to the root stock, and to encourage development of a productive and vigorous second crop. The design strategy now being developed includes compatibility between the harvesting equipment and other equipment used in plantation management. Because harvesting will be done in most plantations during the dormant season, the harvester will use base carriers that will be readily adaptable for spraying, fertilization, site preparation, and other stand management activities. The adaptable base carriers will reduce the capital investment for harvesting equipment and minimize the effect of seasonal operation on harvesting costs.

Short-Rotation Woody Crops—In-House Activities

Research is being conducted in the ESD to complement but not duplicate subcontracted program research. This research includes (1) general economic and regional evaluations of contractor results in an effort to digest and integrate a great amount of program information and (2) field studies designed to provide information on conserving site nutrients in SRIC systems.

Economic and Regional Evaluations. The ORNL Energy Division economists are assisting the ESD in devising an economic evaluation system for SRWCP projects. The objective has been to develop an economic evaluation tool that facilitates direct comparisons among approaches to SRIC and among regions across the country. A generalized economic model containing some cost accounting information is being developed from a model formerly used in evaluating geothermal projects. Parameters relating productivity and site conditions to investments (costs) are being identified from SRWCP results. Completion and testing of a computer model are scheduled within the next year.

A second economic evaluation tool is being developed through consultation with Mittelhauser Corporation and others. It is a strict accounting of very site-specific factors important in determination of farm-gate costs per ton (or per hectare) in producing woody biomass through SRIC.

Both economic approaches are considered necessary to produce effective evaluations of SRIC systems. The immediate use of the evaluations will be to conduct sensitivity analyses and adjust research to work on the most important and cost-effective factors. Results from the evaluations will be used in assessing regional capabilities in producing SRIC biomass and in trade-offs that may be necessary with other renewable resource systems.

Field Site Establishment. Maximizing woody biomass production on nutrient-poor soils in an environmentally acceptable management program is the primary emphasis of plantations recently established near the northern border of the Oak Ridge Reservation. During the 1980-1981 winter, about 20 ha were cleared of secondary hardwood-pine scrub forest that has resulted from natural succession following agricultural abandonment in the early 1940s. After the site was prepared by bogging twice during the winter, planting was completed in March 1981.

The experimental design provides a method for determining the difference in survival and growth behavior of three species under various combinations of mycorrhizal and nonmycorrhizal root infection and two regimes of commercial-grade fertilizer application. Yellow-poplar *(Liriodendron tulipifera)*, sweetgum *(Liquidambar styraciflua)*, and loblolly pine *(Pinus taeda)* seedlings were planted, and half of each species were germinated and grown under controlled conditions to limit the mycorrhizal root-fungus symbiont relationship to a particular species of the fungus. The other half of the seedlings were produced under standard nursery conditions and were naturally infected with a mixture of naturally occurring mycorrhizae. During the next three to five years, subplots within the plantation will be fertilized according to two schedules. One group of the subplots will receive a one-shot application of urea in March 1982; the other group will be given the same total amount of fertilizer, but the fertilizer will be applied at three different times during the growing season.

Lysimeters have been installed to ascertain nitrate and other nutrients leached through the soil under the different treatment combinations of seedlings being infected and, or fertilized and to compare the leaching with that of the control plots. Periodically, soil and tissue samples will be analyzed for essential nutrient uptake and depletion. Productivity will be measured on an annual basis, and comparisons will be made regarding woody biomass accumulation and the various treatment regimes. Additional evaluations will be made concerning nutrients lost from the system vs nutrients naturally present and nutrient input from the atmosphere or artificial application.

Environmental Effects of Whole-Tree Harvesting

Overview

The Biomass Energy Technology Division and the Carbon Dioxide Research Division of DOE are supporting research on the environmental effects of whole-tree harvesting. This research involves site analysis of residue removal and whole-tree utilization for several forest types on ten sites in the United States (Table 8.3). All sites have been dedicated to intensive forestry research for some time, and the effects of whole-tree harvesting are built on a broad foundation of baseline data. The overall program plan is designed to (1) measure the erosion and nutrient loss from traditionally cut watersheds with and without whole-tree removal and, thereby, quantify the effects residue removal can be expected to have on water quality; (2) quantify the changes in nutrient supply associated with residue removal; (3) assess what these changes mean in terms of subsequent (e.g., from five to ten years) biomass productivity of the areas following the different techniques of harvesting; and (4) identify whether mitigation techniques can minimize adverse aboveground vegetation removal in hardwood stands. Nutrient studies include N, K, P, Mg, Ca, and C. The sites for study were selected from geographic regions and site locales that are the most heavily forested and harvested areas in the United States. From these areas, specific sites were picked primarily because of the large data bases existing for these forests.

Table 8.3. Sites and forest types included in the Whole-Tree Harvest Research Program

Research group	Site location	Forest type
Oak Ridge National Laboratory	Oak Ridge National Environmental Research Park, Tennessee	Mixed upland hardwoods
Southeastern Forest Experiment Station	Coweeta Hydrologic Station, North Carolina	Mixed upland hardwoods
	Holt Walton Experimental Forest, Georgia	Slash pine
Northeastern Forest Experiment Station	Mt. Success, New Hampshire	Northern hardwoods
	Chesuncook Lake, Maine	Spruce-fir
	Cockaponset State Forest, Connecticut	Central hardwoods
	Hubbard Brook, New Hampshire	Northern hardwoods
Clemson University	Clemson, South Carolina	Loblolly pine
University of Washington	Charles Pack Forest, Washington	Douglas fir
University of Florida	Bradford Forest, Florida	Slash pine

The ultimate goal of this project is to provide information to the timber industry and watershed managers that will assist them in making environmentally sound decisions regarding timber harvest. In those areas of the United States where whole-tree harvesting and residue removal are possible, results from this project can be used to ascertain both the short- and long-term consequences of a given harvesting practice. In addition, results from this research can be used to narrow the set of possible negative effects resulting from forest harvesting for a particular region of the United States. Consequently, decisions can be made to ensure long-term forest productivity regarding critical element removal and replacement, practical intensity of harvest, and mitigative harvesting techniques.

Summary of Nutrient Concentration and Flux Data from all Sites

All sites are providing data on nutrient concentrations among tree species and on system nutrient budgets including system fluxes. Some systems such as the loblolly pine site in South Carolina and the Douglas-fir site in

Washington are essentially monocultures, and estimates of system nutrient totals are relatively simple to make. However, many systems such as the mixed hardwood stands in Tennessee and North Carolina are composed of many species, and generalizations about system nutrient totals must be based on species composition. This variety of systems requires a greater emphasis on species composition and nutrient concentrations of those species. From these data, long-term system impacts from repeated residue removal can be evaluated. Data were collected or will be collected at most sites for the tree species of concern for this project—primarily those of commercial interest. In addition, investigators in this project have compiled a large, region-specific data base of biomass and nutrient concentrations by species and size class. These data are from prior research conducted at the sites and from other published and unpublished sources.

Although preliminary estimates of biomass and nutrient pools on all research sites were revised with onsite data, it is premature to attempt comparisons among systems and across regions. However, some comments can be made on the available data. As was expected, total tree biomass varied considerably from one site to another, ranging from a low of 104 Mg/ha for the slash pine stands at the Bradford Forest, Florida, to 227 Mg/ha in the Douglas-fir stands in Pack Forest, Washington. Nutrient content in aboveground tree material, litter, and soil also varied from site to site. For instance, total soil potassium varied from 20 Mg/ha at the Oak Ridge National Environmental Research Park (NERP), Tennessee, to 10 Mg/ha at Mt. Success, New Hampshire. If the biomass, aboveground total nutrients, and soil total nutrients are ranked for each component nutrient total and plotted on axes of the same length (Fig. 8.2), some striking observations can be made. Because all sites are not represented, the data comparisons are somewhat distorted. In total aboveground biomass and nutrients, three sites seem to fall on the lower part of the axis. The beech-maple stand in Mt. Success and the loblolly stand at Clemson fall in the lower third of the axis, while lowest of all is the slash pine stand in Florida. The cool-temperate, mixed oak stands [Coweeta and Cockaponset (only biomass data available)] and the alder site in Washington tend to fall in a middle range, while Douglas-fir and the mixed hardwood site are on the high end of the range. Although the mixed hardwood shows the highest aboveground total calcium, calcium data are not available from all sites.

Soil data are not yet available from all sites; however, data from sites that are represented are quite different from those for total aboveground nutrients and biomass. In all but potassium content, the beech-maple system at Mt. Success, New Hampshire, is at the high end of the scale. One might expect, perhaps, that sites with lower nutrient pools would support lesser biomass and have lower nutrient totals in that biomass. However, stand age and climate also affect the amount of biomass (and total nutrients) present on the site. Two of the sites (slash pine and loblolly pine) with the least biomass are in a warm, wet climate where one might expect greater productivity. However, these are also young stands. Stand ages are not yet available from all sites, and a further evaluation of these relationships will be included in the next annual report.

For the two sites with soil nutrient data available, estimates of percent nutrient depletion caused by harvest export can be calculated using estimates of harvest losses. These data show a fairly high depletion of calcium and possibly nitrogen at the Oak Ridge site. It must be remembered that these calculations do not yet include system nutrients remaining on the site in roots and stumps (which should account for $<10\%$ of total system content), nor does it include fluxes of nutrients to and from the systems via nitrogen fixation and rock weathering. Over a period of one harvest cycle (30–80 years, depending on the site), these system fluxes may have a considerable effect on the system nutrient pools.

Direct Effects of Harvesting at Oak Ridge

In the spring of 1979, five watersheds ranging in size from 0.25 to 0.54 ha were surveyed and instrumented with precipitation, throughfall, and litter collectors; tube lysimeters (Soil Moisture Corp.); and weirs designed

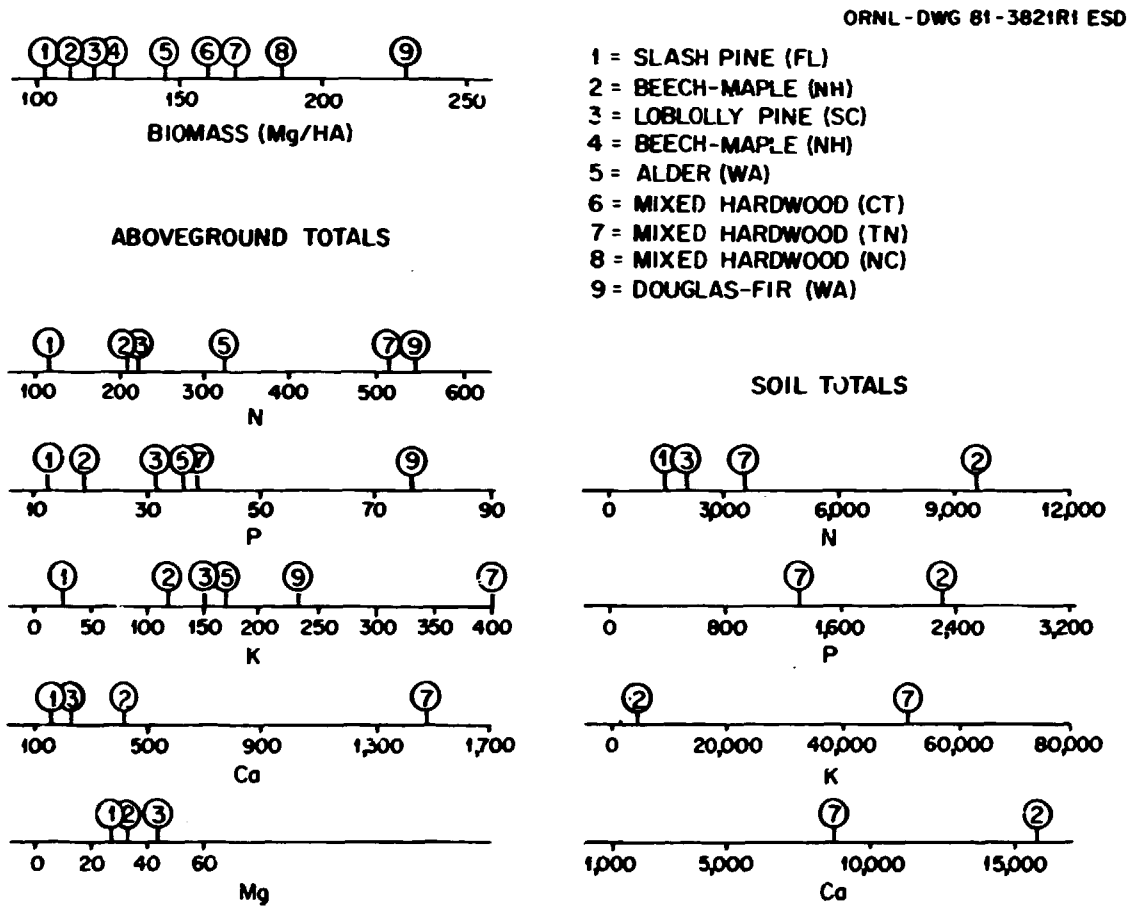

Fig. 8.2. Site-to-site comparisons of biomass and nutrient pools.

to collect surface runoff using Coshocton wheels as proportional sampling devices. In the fall of 1979, an inventory of all trees >10-cm dbh (diameter breast height) was conducted. Samples for foliar analysis of major species were taken in July 1979. Samples for branch and bole nutrient analysis were taken from major species before and during harvest. Litter and soil samples were taken before and after harvest. In the fall of 1980, watersheds 1–4 were clear-cut. All above-stump material was removed from watersheds 1 and 2, while only sawlogs were removed from watersheds 3 and 4. Weights were recorded for each log during the cutting operation. In addition, all tops and noncommercial trees >13-cm dbh were weighed from watersheds 1 and 2.

After harvesting, fresh residue was estimated within each subplot by separating according to size class (>5 cm, 1–5 cm, and <1 cm, respectively), weighing, and replacing. Subsamples were taken for moisture content. Tops and noncommercial residue remaining on watersheds 3 and 4 were estimated by subtracting total sawlog weights from dbh-derived biomass estimates. All soil water was analyzed for total N, P, Ca^{2+}, K^{+}, SO_4^{2-}, PO_4^{3-}, NH_4^{+}, NO_3^{-}, and pH.

Conventional sawlog harvesting on watersheds 3 and 4 resulted in the export of 43% of bole biomass, 33% of aboveground tree biomass, 26% of aboveground N, 24% of aboveground P, 21% of aboveground K, and 34% of aboveground Ca (Fig. 8.3). Sawlog harvesting plus residue removal of watersheds 1 and 2 resulted in the export of 100% of bole biomass, 89% of branch biomass, and 96, 81, 79, and 95% of total aboveground N, P, K, and Ca, respectively (Fig. 8.4).

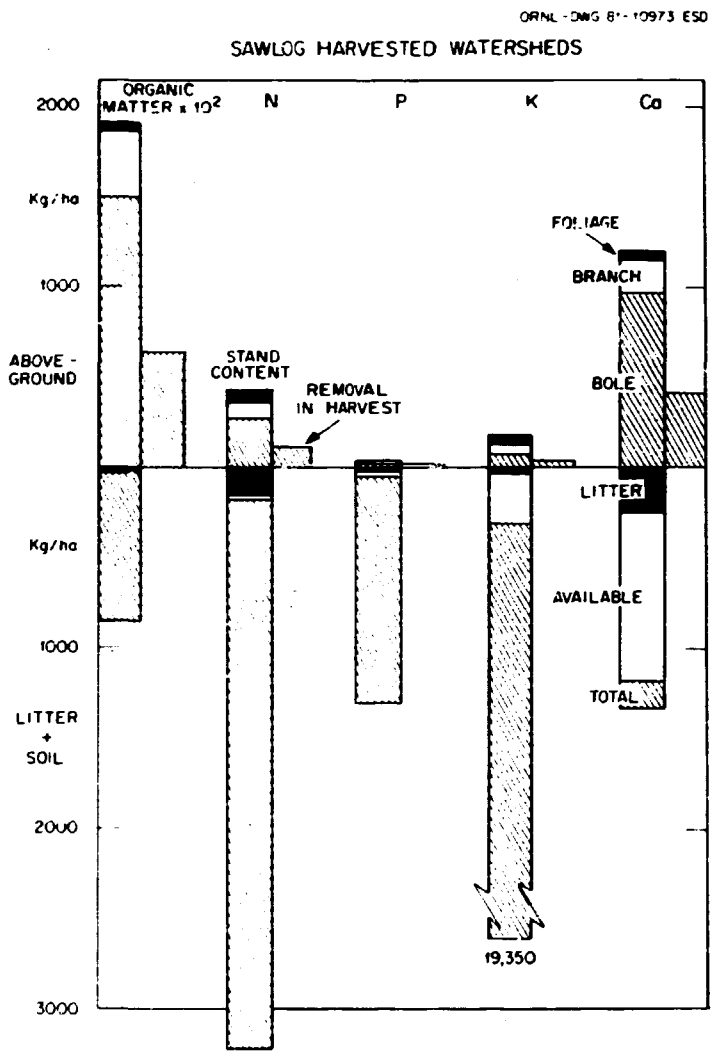

Fig. 8.3. Values of biomass and nutrient from sawlog removal.

Analysis of the data shows that nutrient drain by conventional sawlog harvesting on the Oak Ridge site had little impact on the total nitrogen, phosphorus, and potassium supplies and only a moderate impact on the total calcium supplies of the deciduous forest ecosystem studied. Sawlog harvest plus residue removal in the same area had a moderate impact on total nitrogen and phosphorus supplies, an impact that could be significantly offset by atmospheric inputs over the next rotation. Supplies of potassium and calcium are likely to be depleted permanently because atmospheric inputs of these elements will probably be exceeded by leaching outputs, particularly with continuing inputs of acid rain. Cation depletion by acid rain could equal that of sawlog harvesting and add 30 to 50% to that of residue removal over a 50-year rotation. In the case of potassium, however, the effect on total supplies is slight because of a large soil pool. In the case of calcium, as much as one-third of the total ecosystem capital was removed because of very low concentrations in the upper 45 cm of soil and high concentrations in woody tissues. Further research is needed to determine the extent to which forest vegetation can obtain calcium from beyond 45 cm in the soil.

Harvesting after leaf fall reduced the drain of nitrogen, phosphorus, potassium, and calcium caused by residue removal of 7, 7, 23, and 5%, respectively. The effectiveness of post-leaf fall harvesting in conserving

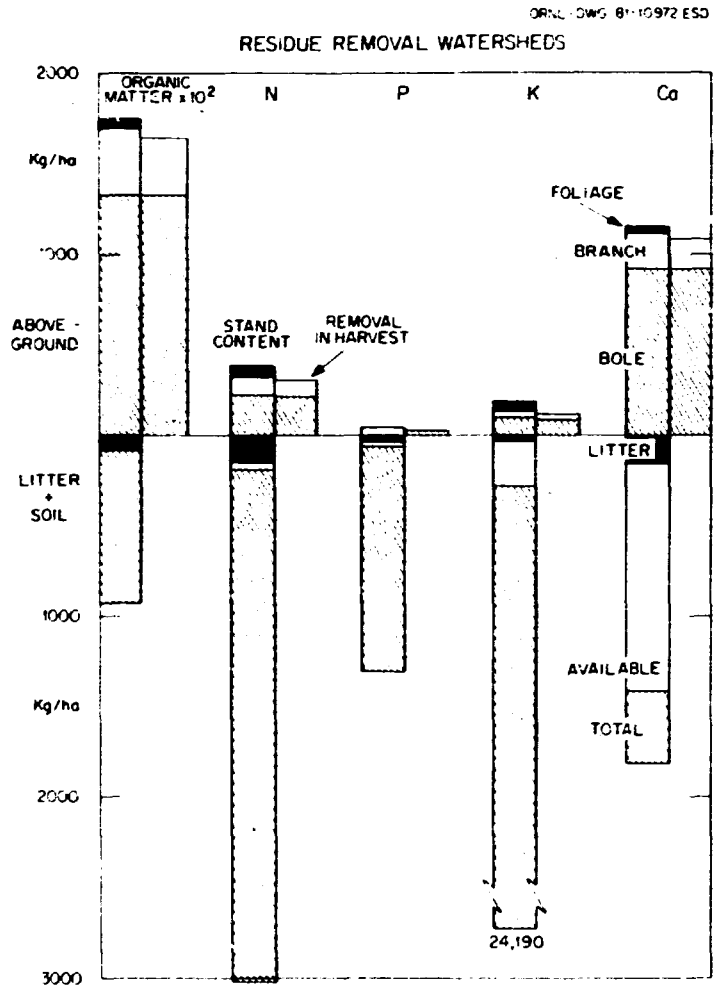

Fig. 8.4. Values of biomass and nutrients removed with total aboveground harvesting.

nitrogen and phosphorus was substantially reduced by translocation from aging foliage. Foliar calcium was not translocated, but it constituted a very small proportion of total aboveground calcium content. Foliar potassium constituted a larger proportion of total aboveground potassium content, and translocation was minimal, thus making post-leaf fall harvesting more advantageous for this nutrient than for nitrogen, phosphorus, or calcium.

Currently, results indicate that intensive harvesting in the deciduous forest at least on some sites could cause some problems with nutrient drain. Depending upon the rotation schedule and types of species being grown, some artificial application of nutrients, especially calcium, would be necessary. Further work (e.g., soil analyses at greater depths and determination of tree-root concentration) might prove calcium to be more abundant than was thought, but naturally occurring amounts sufficient to offset levels removed during harvest will probably not be found. Research is continuing with emphasis on thoroughly ascertaining system-level nutrient status and making assessments as to mitigative techniques required given various degrees of harvesting intensity.

Fertility and Tilth Effects of Fuel Crop Residue Removal

Fertility and Tilth Effects of Fuel Crop Residue Removal is a cooperative project between the U.S. Department of Agriculture (USDA) and DOE. The role of ORNL in this project is to provide technical management

assistance to the development of energy sources. The purpose of the program is to determine the amount of available residue and, thus, how much energy can be derived from the nonharvested portion of agricultural crops on a sustained basis without reducing the soil productivity. The research, which was begun in the spring of 1979, contains both field and modeling components.

As shown in Table 8.4, field research is being conducted at USDA laboratories in the Northwest (wheat) and in the Midwest and Southeast (corn). Small plot research measures crop yield, residue yield, erosion by water, and macronutrient loss as a function of three residue removal rates and conservation tillage vs no tillage. Preliminary data are consistent with short-term studies conducted elsewhere. At the maximum residue removal rate, spring wheat produced higher yields under no tillage than under conservation tillage and also produced more grain per unit of straw. Without straw removal, the results were reversed. Surface water runoff and erosion were inversely related to the amount of residue left on the surface in both tillage systems. No tillage offered greater protection from erosion than conservation tillage at any one residue removal rate.

Table 8.4. Sites and crops included in the Fertility and Tilth Effects Program

Affiliation	Location	Program component
ORNL	Oak Ridge, Tenn.	Technical management
USDA		
University of Minnesota	St. Paul, Minn.	Modeling and integration
USDA	Morris, Minn.	Corn production impacts
USDA	Pullman, W. Va.	Wheat production impacts
USDA	Lincoln, Neb.	Nitrogen fertilizer consequences
USDA	Florence, S.C.	Acceleration of impacts

These results are typical of an average water year. The prior year's results with corn were conflicting because of lack of rainfall. This year's corn results are not yet complete, but the erosion data through September show a pattern similar to that of the wheat results. Within the conservation tillage plots, erosion decreased with increasing amount of residue left on the surface. Erosion was greater for conservation tillage than for no tillage with equivalent residue cover. The field research plots are widely separated, and annual variability requires that measurements be carried out over an extended period of time. To be of practical value, interpretation must be applicable to any crop location on an annual basis. We are attempting to achieve this extrapolation by means of modeling.

Thus far, the project has collected data through two full crop years. Five critical areas affected by crop residues have been identified: nutrient removal, organic matter changes, water erosion, soil water conservation, and soil temperature. Additional data analysis and documentation will concentrate upon long-term effects of these critical areas in terms of environmental effects and productivity.

9. LOW-LEVEL WASTE RESEARCH AND DEVELOPMENT PROGRAM

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Introduction

Safe and cost-effective disposal of low-level radioactive waste is essential. Both generic work aimed to be applicable to humid eastern U.S. disposal sites and site-specific work related to the Oak Ridge National Laboratory (ORNL) have been carried out. The generic tasks have been Advanced Burial Methods Development, Remedial Action Technology Development, and Shallow Land Burial Handbook. The site-specific tasks have focused on particular disposal activities at ORNL, either by location [solid waste storage areas (SWSAs) 3, 4, and 7] or by waste disposal method [intermediate-level liquid waste (ILW) trench No. 7]. The generic and site-specific activities are mutually supportive.

Advanced Burial Methods Development

Although shallow land burial is a simple and low-cost method, it has not always been totally effective for containing radionuclides in the humid environment. To improve burial ground performance, advanced methods are needed. Two new improved procedures will be tested in the Engineered Test Facility (ETF). During 1981, the principal efforts at the ETF have involved (1) detailed site characterization – geology and hydrology of the Conasauga Group, (2) trench treatment development, and (3) verification of a computer model for application to the ETF experiments.

Site Characterization

The ETF is underlain by the Maryville limestone (a middle formation of the Conasauga group). The Maryville limestone is a highly argillaceous lime mud (micrite) with many fractures (filled and open), folds, and small faults caused by regional deformation. Petrographic and x-ray analyses identified the minerals chlorite, illite,

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and mixed-layer illite/vermiculite in addition to quartz, plagioclase, and carbonates. The soils ranged from slightly weathered rock to a silty or sandy loam.

Hydrologic studies in the ETF included monitoring of precipitation, ground water, and surface water. The precipitation total for the year was 89.7 cm (35.3 in.), thus indicating a drier year than normal. In a normal year, 143 cm (56 in.) of precipitation usually falls. Low precipitation probably has caused the well levels measured during this time to be lower than normal. In addition to observing water level changes in the ground water, quarterly water samples were obtained for radionuclide analyses. Concentrations of ^{3}H, ^{90}Sr, ^{137}Cs, and ^{60}Co were below detection limits for the methods used in routine monitoring.

Surface-water samples from gullies on either side of the ETF were also analyzed. On the side nearer closed disposal trenches, ^{3}H was found, but on the other side, no ^{3}H was found. These findings suggest that the waste trenches are releasing ^{3}H to the draw that drains the area. Weekly pH and conductivity measurements have augmented the quarterly analyses. Prolonged pump tests of several wells were performed in an attempt to better characterize the fracture-flow system. Transmissivities and storage coefficients generally agreed with those anticipated by Sledz and Huff (1981).

Treatment Development

Experimental improved disposal practices have been tested at laboratory scale, and a trench liner procedure and a grout backfill procedure have been adapted for field testing. To carry out backfill testing at laboratory scale, aquariums of the type used by hobbyists were used. Simulated waste was packed into the aquariums, and a soil cover was added. Water was poured on top of the soil, and its rate of passage through the waste mass was determined by collecting the water as it flowed out the bottom of the aquarium. The first backfill used was 15% bentonite (w/w) mixed with burial ground soil. Although this mixture substantially reduced the rate of percolation of water through the waste, the dry mixture did not effectively fill the voids between waste packages, and an alternative procedure was tried. A 7% (w/w) bentonite suspension was injected into the waste mass from below. This fluid slurry effectively penetrated the waste interstices and then gelled, thus forming an excellent water barrier. Subsequent mixture tests led to selection of a cement-fly ash-bentonite slurry for the field test. This composition has the advantage of hardening as the cement sets and forming a very stable waste mass.

For the liner, a variant of the bentonite slurry will be used. Trench walls will be sprayed with the suspension prior to waste addition. Upon drying, the suspension forms a tough membrane that is resistant to water penetration. The top of the trench will also be treated at the time of closure.

Field Site

For the field experiment, nine trenches were excavated to provide three sets of three trenches for the control, the membrane, and the grout backfill. The layout of the trenches fits a Latin square design that is intended to eliminate bias in putting one treatment in trenches that are shallower or deeper than the average trench. Thus, each row and column has one treatment. The nine trenches (3 m × 3 m × ~3 m deep) are separated by 3 m. Some trenches have been filled with compacted ORNL low-level radioactive waste tagged with chemical tracers. The trenches will be filled and closed, and additional monitoring wells will be drilled to test for tracer movement.

Demonstrative Applications of FECWATI and FECWASTE Computer Codes to Shallow Land Burial Practices

Geohydrochemical factors that affect the transport, transfer, and transformation of radionuclides in the aquifer system as a result of shallow land burial practices include (1) surface topography and its character, (2) the

extent of the aquifer, (3) nearby surface-water bodies, (4) ground-water basin divide, (5) watershed boundaries, (6) rainfall rate, (7) infiltration from surface-water bodies, (8) potential evapotranspiration, (9) hydraulic conductivity, (10) water capacity, (11) porosity, (12) compressibility of the matrix, (13) dispersitivity, (14) hydrolysis, (15) photolysis, (16) oxidation, (17) volatilization, (18) biolysis, (19) precipitation, (20) mineral composition, and (21) flow dynamics. Depending on the availability of data and detail of information desired, three levels of analyses were suggested for assessing the effect of radionuclides on the ground-water system. The first level of analysis simply considered the absorption capability of the aquifer and flow velocity of the fluid particle to obtain the arrival time of radionuclides at specific locations. The second level of analysis included dispersion in addition to those factors considered in the first level of investigation. To arrive at simple analytical solutions to the mass balance equation, many assumptions were made to simplify the problem. These assumptions include constant flow field, homogeneous soil properties, and simple geometry of the aquifer region. The third level of analysis treated all factors described above in a complete package. The parameters can be spatially as well as temporally dependent. FECWATER (Yeh and Strand 1981a) and FECWASTE (Yeh and Strand 1981b) computer codes were implemented to achieve the goal of variable parameters and complex geometrical configurations.

Two examples were used to illustrate these three levels of analyses using hypothetical parameters (Yeh and Tamura, submitted). The examples are constructed to represent the leaching from a wet water body and shallow burial, respectively. The former typifies a class of problems of gound-water contamination from coal-catching basins and uranium mill tailings. The latter represents classical examples of shallow land burials, such as solid wastes, chemical dumping, and sanitary landfill. The seepage pond problem indicates that the lower level of resolution gives the more conservative estimate of the breakthrough time for the contaminant. For example, the 100% breakthrough times are 73.81, 346.81, and ∞ (steady-state) years, respectively, for the level 1, level 2, and level 3 analyses. The 1% breakthrough times are 18.65 and 19.34 years, respectively, for level 2 and level 3 analyses. Level 1 analysis can predict only the 100% breakthrough time. Because it cannot forecast the 1% breakthrough time, comparison with other levels of analyses is prohibited. The shallow trench burial problem exemplifies that simple levels of resolution are not adequate nor possible because the flow variables and parameters cannot be determined with rational assumptions. Thus, the level 3 model must always be made available to provide the spatial-temporal distribution of flow field when the distributions cannot be adequately estimated. The level 1 model may be best for screening purposes, while level 2 analysis may be employed for ranking alternative sites. Finally, the level 3 model should be used for detailed studies of the impact of the chosen site or for predictive assessment of operational sites and decommission scenarios.

Remedial Action Technology

Remedial action technology development has the primary goal of developing and demonstrating remedial techniques for application to sites where radionuclide migration from buried low-level waste reaches undesirable levels. Two basic strategies guide this work. The first strategy involves hydrologic isolation of buried waste from the surface-water and ground-water system. This strategy involves two modes: one where surface water and ground water are diverted before entry into the waste area(s) and another where the waste itself is hydrologically sealed from potential intrusion of ground water and surface water by such barriers as surface seals, liners, covers, and grouts. The second strategy encompasses techniques that fix or immobilize radionuclides in the waste or its immediately surrounding soil without necessarily perturbing the surface-water and ground-water flow regime. In the latter case, particular attention has been paid to radiostrontium as the most mobile and hazardous radionuclide ubiquitously present in the low-level solid wastes of our experience. Chemical treatments of waste and its surrounding soil with caustic soda and soda ash have been observed to immobilize ^{90}Sr from subsequent leaching by moving ground water.

Trench Seal Evaluations

In 1975, remedial action was taken on a trench in SWSA 5, which had been observed to contribute a major proportion of the ^{90}Sr discharge from the area (Duguid 1976). The topsoil cover of this trench and those of three surrounding trenches were removed, and the continuity of its 100-m length was interrupted with a concrete dam at 55 m and a shale-bentonite dam at 82 m, respectively, from its lower end. These barriers were designed to alleviate the often sited "bathtub" effect – that is, a long sloping trench tends to accumulate water in its downslope region leading to inundation and leaching of the waste. This group of trenches was then covered with a 0.25-mm thick (10-mil) polyvinyl chloride (PVC) sheet, which was then covered with 0.6 m of topsoil and reseeded to grass. This impermeable trench cover was designed to prevent the infiltration of precipitation.

For the three years prior to this remedial action, the discharge from the tributary receiving the ground-water discharge from SWSA 5 averaged 1.58 ± 0.48 Ci/year. For the three years following this remedial action, this same discharge averaged 0.57 ± 0.09 Ci/year. The conclusion that this remedial action caused a reduction in the SWSA 5 ^{90}Sr discharge is supported by these observations. The SWSA 5, however, contains hundreds of additional trenches, many of which contribute to its ^{90}Sr discharge, although apparently none are of the magnitude of this remedial trench.

Chemical Treatment of Burial Trenches

Laboratory investigations have established that treatment of soil with soda ash and/or caustic soda can effectively immobilize ^{90}Sr (Spalding 1980 and 1981). In the unperturbed or natural situation, ^{90}Sr behaves identically to soil Ca, which is partitioned between a soluble or mobile phase as a bicarbonate and an adsorbed phase as an exchangeable cation. When this situation is perturbed by the addition of caustic soda or soda ash, additional cation exchange sites result from the ionization of surface hydroxyl sites. These new cation exchange sites are saturated with Na^+, thus creating a situation very favorable for $^{90}Sr^{2+}$ and Ca^{2+} adsorption. Moreover, the presence of carbonate anion at the resulting high pH leads to the coprecipitation of ^{90}Sr with $CaCO_3$. This phase is particularly effective at immobilizing or fixing ^{90}Sr. When columns of radiostrontium-labeled soil are treated with various precipitating Na solutions, soda ash can immobilize up to 70% of the radiostrontium from the leaching action of a simulated ground water.

A considerable effort has been made to demonstrate the field-scale effectiveness of such chemical treatments. A burial trench in SWSA 5, which was known to contain a significant inventory of ^{90}Sr, was treated with soda ash and caustic soda. The interstitial waters of this trench were treated with 3800 L of 25% NaOH through a series of gravity-feed injection wells placed along the trench. Subsequently, these same wells and others were injected with 800 kg of soda ash dissolved in a minimal amount of water. A year after initial treatment, all old wells and several new wells were again injected with 4600 L of 50% NaOH to achieve a thorough distribution of the chemical within the trench. This equitable distribution had apparently not been achieved with the previous injections because of the vagaries of the void space distribution and associated channeling of chemical flow within the trench.

Radiostrontium concentrations in the well at the lower end of the trench decreased two orders of magnitude from 125 to <1 Bq/mL following chemical treatment (Fig. 9.1), and this effect has continued up to the present. In the small sump just below this trench, ^{90}Sr concentrations have fallen off gradually over this time period from over 100 to less than 25 Bq/mL. Strontium-90 input from the trench to the sump has apparently been reduced. Thus, the chemical treatment is an effective remedial measure for ^{90}Sr-leaking trenches.

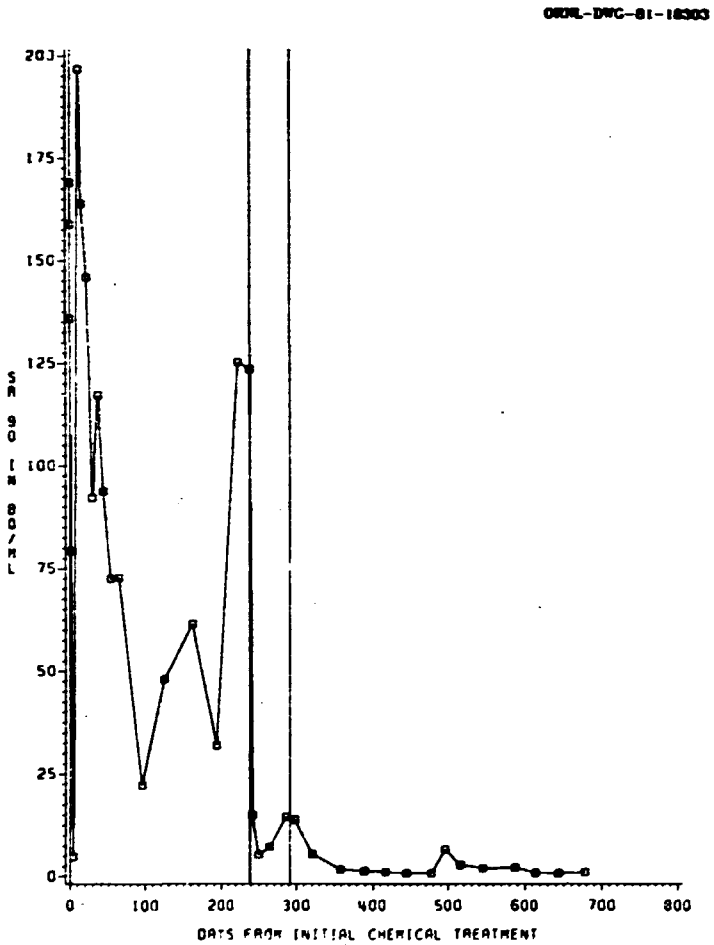

Fig. 9.1. Concentration of ^{90}Sr in the well at the lower end of trench in SWSA 5 following chemical treatment. Vertical lines indicate times when chemicals were added to the trench.

Shallow Land Burial Handbook

One of the elements of milestone C in the DOE Low-Level Waste Management Program is the preparation of a *Handbook on Shallow Land Burial of Low-Level Radioactive Solid Wastes.* This handbook provides a review and evaluation of DOE and commercial disposal practices and a description of current technology. It also presents the criteria and procedures necessary to license and operate a commercial shallow land burial facility. A draft of the handbook has been prepared and is currently undergoing review and revision. The final version of the handbook is scheduled for the end of FY 1982.

Site-Specific Projects

SWSA 4 Studies

Examination of radionuclide discharge at White Oak Dam has shown that ^{90}Sr is the only nuclide present in concentrations that approach the maximum permissible concentration for drinking water (Stueber et al. 1981a).

Actions to decrease ^{90}Sr migration from disposal areas have been given high priority in the DOE Low-Level Waste Management Program. Through careful investigations of possible sources within the White Oak Creek drainage, it has been found that SWSA 4 contributes about 50% of the annual ^{90}Sr release in an average year. In detailed studies in SWSA 4, it was also found that a zone of high ^{90}Sr concentration in soil and ground water is located just downgradient of asphalt diversion channels that were installed in 1975 (see Fig. 9.2). Based on known relationships between flow and ^{90}Sr concentration and estimated surface and ground-water runoff from the catchment that drains via the asphalt channels, expected releases of ^{90}Sr from SWSA 4 would decrease by about 80% if runoff were diverted around SWSA 4 and not permitted to flow into the asphalt channels. Plans are currently under way to design such a diversion scheme.

The results of the work to date on SWSA 4 have shown the importance of both ground-water and surface-water runoff control. The current situation illustrates that although ground-water migration was originally the key factor in creating the high concentration zone, storm runoff has now assumed a dominant role in transporting ^{90}Sr from SWSA 4. Without due consideration of both water movement pathways, effective remedial actions cannot be achieved.

SWSA 3 Studies

Observations by Stueber et al. (1981b) suggest that ^{90}Sr is migrating from SWSA 3 via ground-water flow over distances of several hundred meters to the northeast and southwest. The ^{90}Sr appears at two distinct seeps that discharge through the bed of small streams. The trend of a line connecting these seeps (N 53° E) is parallel to the strike of the bedrock. Figure 9.3 shows the location of the trend line and seeps relative to SWSA 3. The possibility exists that ^{90}Sr discharging from the seep on Raccoon Creek is moving from the contractor's spoil area rather than from SWSA 3. Observation wells in the soil mantle above bedrock show that most ground-water flow occurs in solution cavities in the underlying limestone. A dye tracer test, which was conducted at an observation well known to contain a solution cavity, showed a direct connection with the seep discharging to the Northwest Tributary. The test showed that the ground-water system is capable of transporting large quantities of water as rapidly as 45 m/h. This finding suggests the possibility of rapid movement of ^{90}Sr under certain hydrologic conditions, although monitoring of ^{90}Sr discharge in the Northwest Tributary indicates rates of only 5 to 10 mCi per month. These rates are a minor percentage of the total ^{90}Sr discharge from the White Oak Creek basin.

Studies of the Proposed SWSA 7

Ground-water levels in the newly proposed SWSA 7 were monitored in 11 wells. Quarterly ground-water samples were taken to establish the background chemical characteristics of ground water at the site. This sampling will continue. A general bedrock geologic map of the area is being prepared. Field checking of the map will be completed during the coming year. The bedrock map is based on projections of geology into the SWSA 7 site as determined from drill core data at areas adjoining the site. The longer-term objective of this work is to provide sufficient characterization of the area to allow for maximum use of the site that is consistent with acceptable disposal practices in humid environments.

Geological Research on the Conasauga Group (Middle and Upper Cambrian) in the Vicinity of the DOE Oak Ridge Reservation

Research this past year has focused on the stratigraphically lowermost formation of the Conasauga group, the Pumpkin Valley shale. The purpose of this research was to characterize the sedimentology and petrology of the Pumpkin Valley shale so that its role as the host disposal formation for the hydraulic fracturing operation at ORNL could be better evaluated.

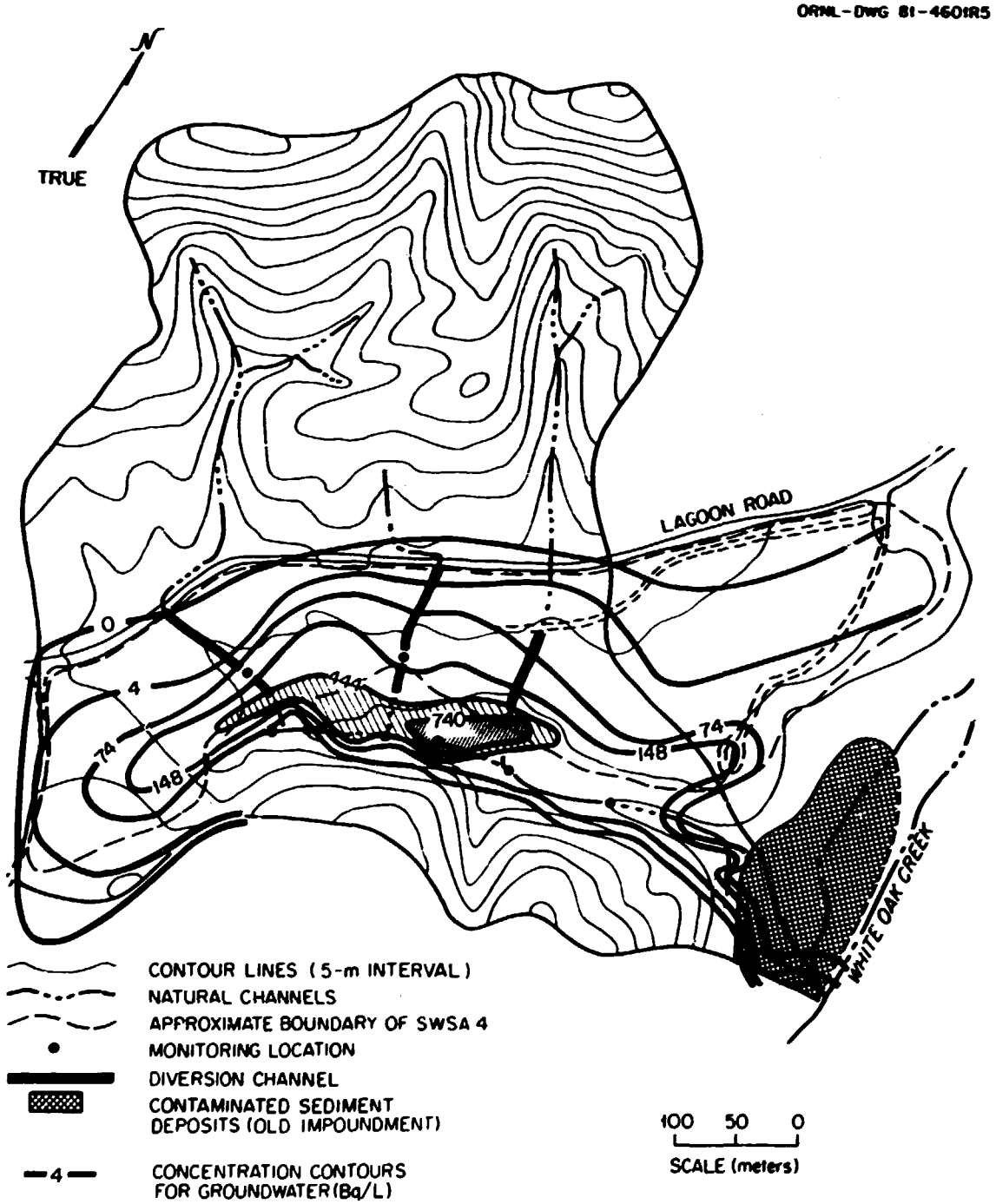

Fig. 9.2. SWSA 4 showing drainage basin, asphalt diversion channels, and zone of ^{90}Sr-contaminated ground water. Note that the discharge of the diversion channels enters the zone of contamination.

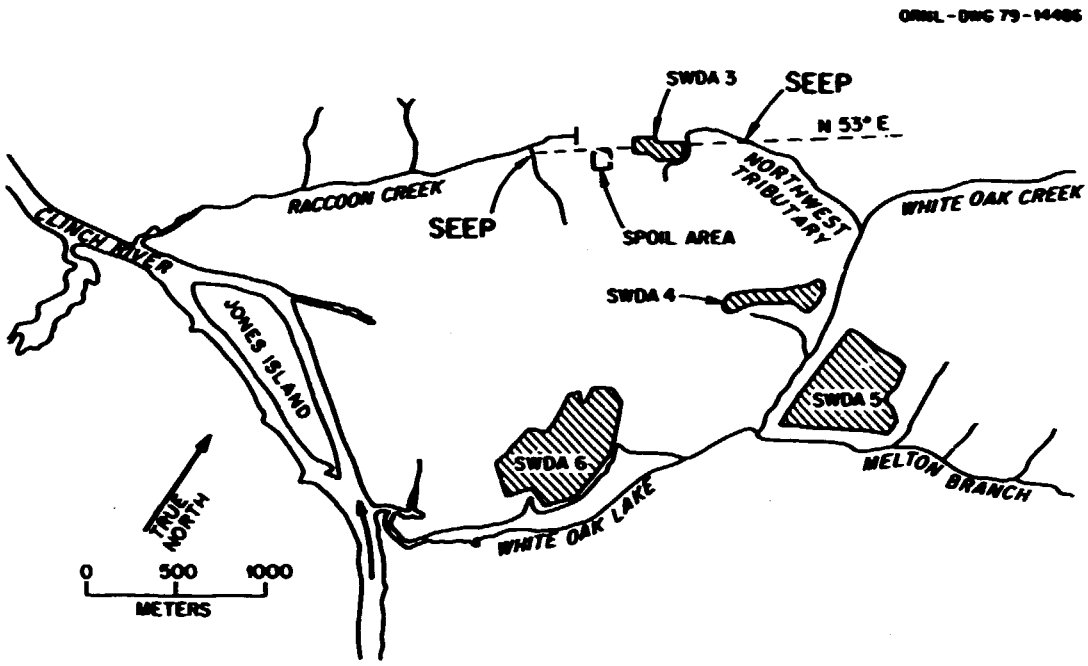

Fig. 9.3. Lower White Oak Creek and nearby section of the Clinch River showing ORNL SWSAs. SWSA 3 appears to supply ^{90}Sr to ground water that flows into the Northwest Tributary and into Raccoon Creek.

To relate the empirically measured permeabilities to petrological properties of the Pumpkin Valley shale, a comprehensive study of the formation was undertaken. A suitable host formation must have very low permeability (McClain 1969). Measurements on core samples of Pumpkin Valley Shale (deLaguna et al. 1968) and data from past hydraulic-fracturing tests and operations (Weeren 1981) indicate that the Pumpkin Valley shale has the very low permeabilities required to make it a suitable formation. Geological parameters that are used to assess the permeability characteristics of the potential host formation include (1) composition and lithology, (2) bedding characteristics, and (3) deformation. Bedrock cores were examined and logged and correlated, where possible, with gamma, neutron, and electrical geophysical logging results, and ~150 samples were taken from the bedrock cores for thin sectioning and study by (1) standard optical, (2) scanning electron microscope (SEM), and (3) x-ray diffraction (XRD) methods. The geophysical logs and relogging of the bedrock cores provided data on sedimentary structures and bedding characteristics, and the optical, SEM, and XRD analyses provide data on composition and textural relationships between the various rock components. Together, these data permit the depositional and diagenetic history of the Pumpkin Valley shale to be inferred.

The Pumpkin Valley shale in the ORNL vicinity is typically 110 m thick. It can be divided into two members: (1) a lower, generally poorly bedded, siltstone-rich member typically 60 m thick and (2) an upper, well-bedded, shale and mudstone-rich member typically 50 m thick. Bedding in the lower member is massive to medium-thick in scale and wavy to lenticular and discontinuous in character. Locally, mottled and highly bioturbated bedding zones exist. The lower member consists largely of subarkosic to arkosic or lithic arkosic siltstones and occasionally graywackes interbedded with subordinate amounts of mudstones and clay stones. Bedding in the upper member is medium thick to laminated in scale and parallel to wavy parallel or lenticular in character. The upper member consists principally of mudstones and clay stones with subordinate amounts of calcareous and noncalcareous subarkosic to lithic arkosic siltstones and, more rarely, graywackes. These data

suggest supratidal to intertidal mudflat, channel, and bar depositional environments for the lower member and tidal to subtidal nearshore bars, shoal, and shelf depositional environments for the upper member of the Pumpkin Valley shale.

Joints and fractures in the Pumpkin Valley shale are ubiquitous. They are most numerous and well developed in the siltstones and typically die out or diminish in magnitude in the interbedded mudstones and clay stones. Because of the preferential development of joints in siltstones and because of the interbedded nature of siltstones and mudstones within the Pumpkin Valley shale, any one joint or fracture typically affects only a few beds. Thus, although the Pumpkin Valley shale is highly jointed, the joint system is not connected for long distances. In the siltstones, the joints are almost always filled with calcite or, more rarely, with a coating of quartz and then calcite. In mudstones and clay stones, the joints are usually filled with calcite, although some joints remain unfilled or opened. Numerous faults and localized zones of deformation (up to 2 m wide) cut across portions of the Pumpkin Valley shale at high angles to bedding. Such features extend for considerable distances (~20 m) and have locally high porosity.

The matrix and cement content of the siltstones in the Pumpkin Valley shale indicate a complete diagenetic pattern that has resulted in the occlusion of primary and secondary porosity and, thus, resulted in a low intrinsic permeability. The fracture permeability of the Pumpkin Valley shale is likewise greatly reduced by infilling of joints by calcite and by the lack of long-range continuity of joint sets. These factors explain the previously measured low-permeability values. The permeability trends appear to be true of all the lithologies that formed in the various facies of the peritidal to nearshore shallow water depositional environment of the Pumpkin Valley shale. Thus, variations in permeability and in the petrologic aspects that control permeability can be related to a depositional facies model for the Pumpkin Valley shale. This relationship will allow permeability patterns to be predicted for portions of the Pumpkin Valley shale that have not been studied. The one potentially problematic aspect is the effect of anomalous high-permeability zones caused by cross-cutting faults, which are the subject of continuing study.

Transuranium (TRU) Waste Disposal

Introduction

This project was initiated during FY 1981 to (1) review and document the operational history of ILW trench 7, (2) identify the geochemical and environmental factors governing ^{233}U migration from the trench, and (3) locate the preferred flow pathway between the disposal trench and a surface seep where TRU-contaminated water has appeared.

Prior to the implementation of deep-well hydrofracture methods for the disposal of ILW at ORNL, a series of seepage pits and trenches were used. These waste pits and trenches were located on ridge tops and excavated in weathered Conasauga shale. The excavated trenches (but not the pits) were backfilled with crushed limestone. Waste liquids (adjusted to a pH of ~12 with NaOH) were allowed to percolate through the weathered shale, and radionuclide migration was retarded by reactions with the fill and soil.

Operational History of ILW Trench 7

Figure 9.4 illustrates the design for ILW trench 7 and the position of the water table in May 1962 (prior to excavation) and August 1981. Initially trench 7 was designed to be a composite of three sections each 30.5 m (100 ft) long, 4.6 m (15 ft) deep, and 1.2 m (4 ft) wide at the bottom, and 4.6 m (15 ft) wide at the top. The third section (trench 7C) was omitted because test wells drilled prior to trench excavation indicated that there was a general rise

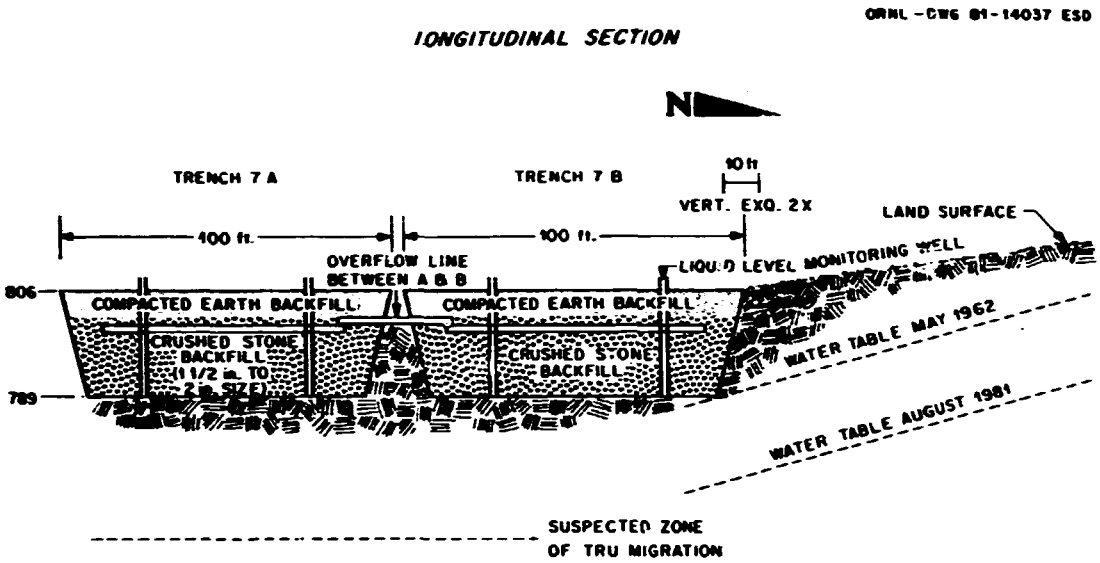

Fig. 9.4 Longitudinal section of ILW trench 7 as modified from engineering blueprints (D-52847) that were approved for use in construction.

in the water table to the north (Fig. 9.4) and that this rise caused the water level to be several feet above the proposed bottom for trench 7 C. In addition, the water level in a test hole located near what is now the northern end of trench 7 B (Fig. 9.4) was found to fluctuate as much as 4.6 m (15 ft) on a seasonal basis. Consequently, it is considered likely that the water table intersects contaminated soils near the northern end of trench 7 B during the wet season. Indeed, in May of this fiscal year, water was observed in the bottom of the northernmost liquid-level monitoring well of trench 7 B, but the water was not sampled.

Trench 7 received ILWs from October 1962 until April 1966, after which deep-well hydrofracture methods were used for ILW disposal. An inventory of the waste input to trench 7 has been summarized in Table 9.1. Data on the amounts and forms of transuranics disposed in trench 7 were difficult to obtain. Records indicate that ~150 g of ^{239,240}Pu, ~334 g of ^{233}U, and ~0.02 g of ^{242}Cm were disposed as ILW in trench 7. It should be noted that ^{242}Cm was quite mobile from the trench at the time of its disposal and that it has a short half-life (~162 d) and decays to ^{238}Pu. Thus the ^{238}Pu in the soils near trench 7 may reflect movement as ^{242}Cm rather than as plutonium. No data on the amounts and forms of other transuranics disposed in trench 7 were found.

Geochemical and Environmental Factors Governing Migration

Ground-water and soil samples were collected from wells (Fig. 9.5) and analyzed to document the extent of TRU migration in the vicinity of trench 7. Uranium isotopes were routinely measured over the course of the year, and water composition data (e.g., ΣCO_2, Ca, Mg, Na, SO_4^{2-}, NO_3^-, and PO_4^{3-}) were determined for selected samples. Several samples were also analyzed for ^{238}Pu, ^{239,240}Pu, ^{241}Am, ^{242}Cm, ^{244}Cm, ^{228}Th, and ^{230}Th.

Near the northern end of the trench and in the seep area, ^{233}U is the most abundant transuranic nuclide in the ground waters. The mobile ^{233}U species in the seep water appears to be an anionic complex of low molecular weight (mol. wt < 500). The mobile ^{233}U species maintained its anionic nature in seep water acidified to pH ~3. At pH ~1, the apparent anion complex is dissociated and the ^{233}U is retained by a cation exchange resin. The ^{233}U activities in ground-water samples collected, prepared, and analyzed in an oxygen-free environment were

Table 9.1. Radionuclide inventory in ILW trench 7[a]
(Total waste input: 8.4 × 10^6 gal)

Nuclide	Curies (at time of transfer)	Curies (Jan. 1, 1981)
^{137}Cs	223,000	152,830
Total Sr	48,060	32,330[b]
^{60}Co	1,530	170
^{106}Ru	3,200	0
^{239}Pu	9.2	9.2
^{238}Pu	?	>0.325[c]
^{242}Cm	62	0
^{244}Cm	?	?
^{241}Am	?	?
^{233}U	3.2	3.2
^{232}U	(0.38)[d]	(0.32)
^{235}U	?	?
^{238}U	(0.11)[e]	(0.11)

[a]Preliminary inventory until trench 7 is sampled.
[b]Calculated assuming 100% ^{90}Sr.
[c]Curies of ^{238}Pu resulting from the decay of ^{242}Cm.
[d]Calculated using a ^{232}U:^{233}U ratio of 0.12.
[e]Calculated using a ^{238}U:^{233}U ratio of 0.033.

identical to ^{233}U activities measured in duplicate samples collected without taking the precautions against exposing the samples to oxygen. Therefore, we conclude that the migrating chemical species is either already oxidized or else stable to oxidation.

Between 20 and 50% of the dissolved (<0.45 μm) plutonium in ground waters near trench 7 is in an oxidized (V,VI) state. Unlike the mobile uranium species, about 40% of the dissolved plutonium was retained by a 500-mol. wt Amicon filter, thus indicating some complexation with higher molecular weight substances (Bondietti, in press). A comparison of the oxidation-state distribution of plutonium in samples collected, prepared, and analyzed in an oxygen-free environment with samples collected and analyzed in the presence of oxygen is presently being conducted.

A soil and ground-water sample collected from well T7-13 (Fig. 9.5) in 1974 was analyzed for actinides and compared with activities presently observed in soil and water from the same well. These data are presented in Table 9.2. Although ^{60}Co activities were about an order of magnitude higher in 1974 ground water relative to present-day activities, the transuranic radionuclide activities in both the 1974 soil and water samples appear to be very similar to present-day activities.

At the time that trench 7 was actively being used for disposal operations, it was noted (in May 1965) that ^{242}Cm was migrating from the trench and could be detected in the seep stream and White Oak Creek (Fig. 9.5). Because ^{242}Cm has a relatively short half-life (~162 d) and decays to ^{238}Pu, it is suspected that the ^{238}Pu contamination in the seep area (Table 9.2) may actually reflect the movement of precursor ^{242}Cm at the original time of disposal rather than the migration of ^{238}Pu. Isotopic analysis of plutonium in the seep soil has yielded a 240:239 ratio of ~0.4 but no detectable ^{242}Pu. These results strongly imply that the ^{239,240}Pu found in the seep soils is also derived from curium decay rather than from plutonium migration.

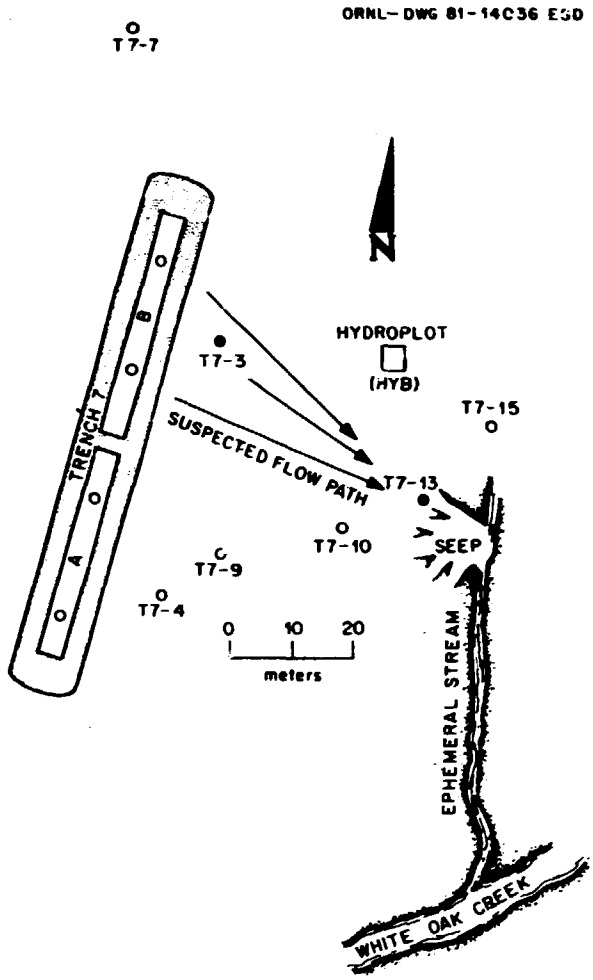

Fig. 9.5. Map showing the location of sampling wells, the seep, and the suspected migration path.

Table 9.2. Nuclide data for well T7-13

	Water (pCi/L)		Soil (pCi/g)[a]	
Nuclide	1974	1981	1974	1981
^{233}U	380 ± 6	405 ± 5	27.0 ± 2.7	25.1 ± 4.1
^{232}U		46 ± 1	3.5 ± 0.5	3.0 ± 0.8
^{238}U		1.3 ± 0.3	1.3 ± 0.3	1.3 ± 0.4
^{228}Th		0.4 ± 0.3	7.6 ± 0.5	4.1 ± 0.5
^{230}Th		ND[b]	1.0 ± 0.1	0.5 ± 0.1
^{242}Cm		ND	0.2 ± 0.2	ND
^{244}Cm		4.64 ± 0.18	108 ± 21	83.8 ± 8.1
^{241}Am		2.16 ± 0.14	64.9 ± 10.8	51.4 ± 5.4
^{238}Pu	1.22 ± 0.06	0.74 ± 0.05	24.9 ± 3.8	13.5 ± 1.8
$^{239,240}Pu$	0.03 ± 0.01	0.07 ± 0.01	1.3 ± 0.4	0.4 ± 0.2
^{60}Co	292,000 ± 7,000	46,000 ± 1,200	15,100 ± 1,000	14,000 ± 220

[a]The soil samples were analyzed by T. Scott (Analytical Chemistry Division).
[b]ND = not detected.

Ground-water ^{233}U concentrations undergo a seasonal variation. The concentrations increase from ~200 pCi/L (December), to ~300 pCi/L (April), to ~400 pCi/L (May), and then decrease to ~150 pCi/L (late August). The increase in uranium concentrations correlated with a rise in the water table and an increase in ground-water pH. This finding suggests that during the spring the water table may rise to saturate the alkaline fill in the trench or contaminated soils near the trench and, thus, promote uranium migration.

Migration Pathway

The suspected migration path of transuranic nuclides from the trench to the seep area has been identified on the basis of nuclide concentrations, ground-water composition, field seismic surveys, and geologic structure (Fig. 9.5). There appears to be a ground-water connection between wells T7-3 near the trench and T7-13 in the seep area. The ground water in each well has elevated ^{233}U and ^{60}Co concentrations relative to other wells in the vicinity. In addition, the alkalinity Na, and NO_3 concentrations in the waters from both wells are almost identical and an order of magnitude greater than waters from wells T7-10 and T7-15 or from the hydroplot (Fig. 9.5).

Field seismic surveys indicated a structural discontinuity along the suspected flow path. This discontinuity appears to be a large anticlinal fold that may cause the abrupt rise in the water table to the north of this area (Fig. 9.4). Dye and radiotracer experiments documenting this pathway and the extent of uranium retardation during its migration in this field area will be done. Once this flow route is documented, it will also be possible to determine what chemical reactions that affect TRU waste migration occur in the field. Remedial action plans for eliminating fluctuations in the water table are presently being formulated.

Summary

From October 1962 to April 1966, trench 7 was used for the disposal of ILW at ORNL. In addition to about 2.75×10^5 Ci of fission products, about 334 g of ^{233}U, 150 g of $^{239,240}Pu$, and 0.02 g of ^{242}Cm were disposed in trench 7. Mobile species of uranium and plutonium isotopes have been characterized in ground water and seep water near ILW trench 7. The ^{233}U is the most abundant transuranic isotope, and the mobile ^{233}U species is an anionic complex of low molecular weight (mol. wt < 500). Between 20 and 50% of the dissolved (<0.45 μm) plutonium in the ground waters is in an oxidized (V,VI) state. Unlike the mobile uranium species, about 40% of the "dissolved" plutonium was retained by a 500-mol. wt Amicon filter, thus indicating some complexation with higher molecular weight substances. Soil and ground-water ^{238}Pu concentrations were several orders of magnitude higher than respective $^{239,240}Pu$ concentrations, thus suggesting that the apparent mobility of ^{238}Pu may actually reflect the movement of parent ^{242}Cm at the time of disposal. Isotopic analysis has yielded a 240:239 plutonium ratio of ~0.4, a ratio that implies that the $^{239,240}Pu$ found in the seep waters is also derived from curium decay (i.e., $^{244}Cm \rightarrow {}^{240}Pu$).

Ground-water concentrations of ^{233}U vary from 100 pCi/L in the fall to 400 pCi/L in the spring. The ^{238}Pu concentrations were also found to increase by about a factor of 3 (from 0.05 pCi/L to 0.16 pCi/L) in the spring. These increased concentrations have been correlated with a seasonal rise in the water table that possibly intersects one corner of the disposal trench or adjacent contaminated soils. The suspected migration path from the trench to a nearby seep has been identified on the basis of field seismic surveys, ground-water compositions, and nuclide concentrations.

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10. U.S. DEPARTMENT OF ENERGY LOW-LEVEL WASTE MANAGEMENT PROGRAM

R. S. Lowrie

R. B. Fitts L. J. Mezga
L. E. Stratton J. E. Vath

Summary

The Oak Ridge National Laboratory (ORNL), as the associate lead contractor, has responsibility for the overall management of technology development activities for the U.S. Department of Energy (DOE) Low-Level Waste Management Program (LLWMP). In this role, with general guidance from DOE and the lead contractor, EG&G/Idaho, the ORNL office of the LLWMP drafted technical program plans; developed FY 1981, FY 1982, and FY 1983 zero-based budgets aimed at implementing these plans within DOE financial constraints; provided guidance to the participating DOE sites; and supported cooperative efforts with waste disposal programs within DOE, in other federal agencies, in the state of Tennessee, in the Federal Republic of Germany, and with the International Atomic Energy Agency (IAEA).

Introduction

In early FY 1979, ORNL was assigned the associate lead contractor role in the DOE LLWMP. This role is carried out under the overall management of the program manager at DOE's Idaho Operations Office, the lead contractor (EG&G) at the Idaho National Engineering Laboratory, and DOE's Oak Ridge Operations Office.

The overall objective of the LLWMP is to develop and promote environmentally sound techniques for safely and efficiently managing the disposal of all types of low-level wastes (LLWs). The LLWs are defined to include all radioactive wastes (1) that contain less than 10 nCi of transuranic contaminants per gram of material and contain low but potentially hazardous quantities of radionuclides but (2) that exclude uranium mine and mill tailings. The LLWs result from such activities as energy production, manufacturing, and the use of radioisotopes in medical and research activities. Specific program technology objectives include (1) the development of waste treatment and waste-packaging technology, (2) development of improved shallow land burial technology, (3) establishment of remedial measures for stabilizing and improving performance of existing burial grounds, (4) identification and evaluation of alternative methods for storage and disposal of LLWs that provide greater confinement than does shallow land burial, and (5) development of guidelines or standards for waste characterization, disposal, and monitoring. In addition, the program includes assisting DOE in developing a plan for (1) handling and disposing of LLW and (2) implementing the public and governmental interface activities necessary to prepare for the implementation of programmatic developments.

In its role as associate lead contractor for the DOE LLWMP, ORNL has responsibility for the overall management of program-funded technology development activities. In this role, with general guidance provided by DOE and the lead contractor (EG&G/Idaho), the ORNL program office is charged with the responsibility to (1) develop program plans for the major technology areas, (2) recommend allocations for the program resources, (3) review the technology development tasks to ensure that program objectives are being met, and (4) coordinate the DOE LLWMP with other ongoing U.S. and foreign waste technology programs. Although the ORNL office will generally assist the lead laboratory in management of the total program, our emphasis is on management of

research and development (R&D) for development of basic technology and to assess concepts for alternative systems of processing and disposal of LLW. Figure 10.1 shows the current work breakdown structure (WBS) for the LLWMP and identifies the areas of direct ORNL responsibility (WBS 3.5.0).

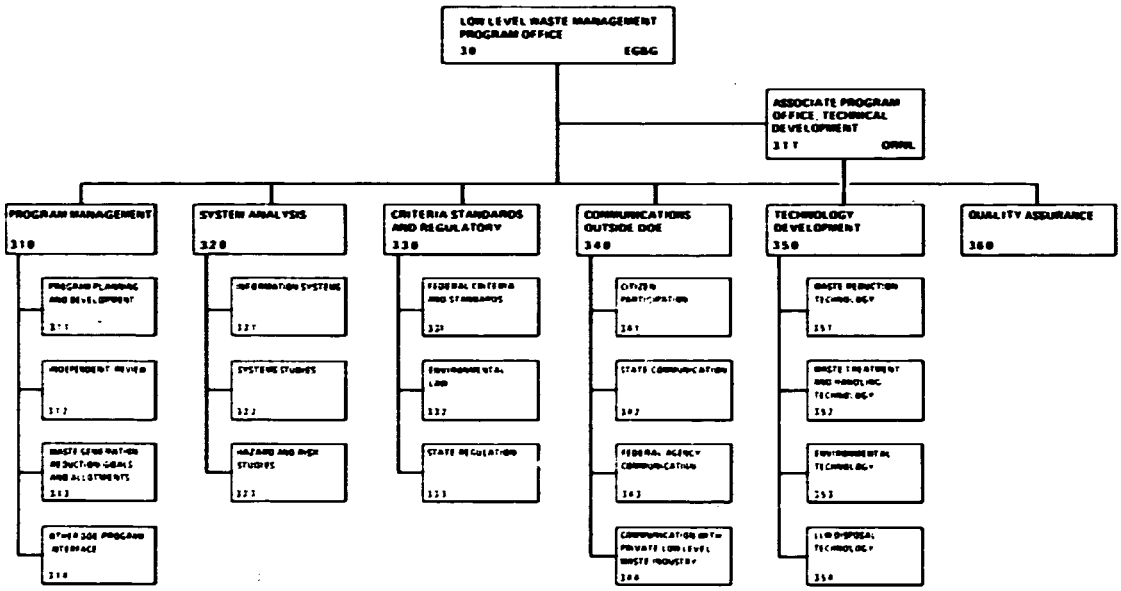

Fig. 10.1. LLWMP work breakdown structure.

Progress

Several of the more significant accomplishments in the ORNL management activity of the LLWMP are highlighted in the following sections arranged by subtask in the FY-1981 current year work plan of the program office.

Technical Planning

Details for the technology development portions of the LLWMP plan were developed and provided to EG&G/Idaho during January and July. The actual issuance of the detailed overall program plan for FY 1981 will be carried out by EG&G/Idaho. The following reviews of technology status were prepared by or for this office in support of program planning and control:

- Draft position paper, "Evaluation of the Need for Greater Confinement than Shallow Land Burial of Low-Level Wastes" (L. J. Mezga);
- Draft report, "Selection of Technology for Radionuclide Removal from Liquid Wastes for Plant Demonstration" (J. E. Vath); and
- Draft report, "Experience in Applying Remedial Actions at Shallow Land Burial Facilities" (Evaluation Research Corporation).

Resource Allocation

Major effort during FY 1981 was focused on the development and establishment of priorities for the FY-1982 and FY-1983 budgets. These activities included (1) preparation of Field Task Proposal/Agreement and budget call technical guidance, (2) evaluation and revision of FY-1982 and FY-1983 budgets, (3) evaluation and revision of the FY-1982 Current Year Work Plans, and (4) establishment of priorities for the FY-1982 and FY-1983 budgets. These were iterative processes based on changes in the proposed budgets for these years.

Program Review

Program review activities during FY 1981 included (1) conducting site visits to existing contractor facilities, (2) briefing DOE headquarters and field offices, and (3) conducting the second annual information meeting. Site visits were conducted to review and discuss current and future work in support of the LLWMP. During these visits, LLWMP staff provided guidance to the various contractors relative to program goals, anticipated funding levels, and program organization. The information gained during this exchange was used in evaluating and establishing priorities for the FY-1982 and FY-1983 budgets.

Information exchange and program coordination within the LLWMP occurred during the Second Annual Information Meeting held in San Diego, California, January 6-7, 1981. The proceedings of the annual meeting were published as ORNL/NFW-81/08. During this meeting, various contractors reported on the status of projects funded during the prior and current fiscal years (FY 1980 and FY 1981). In addition, a series of workshops were held to obtain input from the contractors regarding research needs and program approach. Program and budget guidance was provided by the lead and associate lead offices and laboratories.

Coordination of Waste Technology Programs

Information exchange and program coordination with other DOE and federal waste programs continued. Foreign program cooperation efforts were limited to a cooperative program with the Federal Republic of Germany in the area of LLW fixation and technical assistance to the IAEA in the areas of waste treatment and disposal facility siting.

The ORNL LLWMP office coordinated an interagency workshop on modeling for low-level waste applications held in Denver, Colorado, December 1-4, 1980. This meeting brought together modelers from DOE, the U.S. Environmental Protection Agency (EPA), the U.S. Geologic Survey (USGS), and U.S. Nuclear Regulatory Commission (NRC).

11. WASTE ISOLATION PROGRAM

S. H. Stow

The Waste Isolation Program, which is funded through the Office of Nuclear Waste Isolation (ONWI) at Battelle, Columbus, Ohio, currently represents a very diverse effort heavily oriented toward basic research at the Oak Ridge National Laboratory (ORNL). Activities cover eight ORNL divisions and range from studies of the geochemistry of salt recrystallization to socioeconomic analysis for waste siting. The program is managed through the Environmental Sciences Division.

The program emphasis of ONWI calls for identification of one repository site during the late 1980s; it is possible that the site will be in salt. A granitic site might also be considered in the future. Thus, research emphasis has been oriented toward these rock types. Many of the activities in the program at ORNL are germane to the ONWI plans, especially those activities dealing with salt. New work at ORNL on sensitivity analysis (started in FY 81) promises to be a significant part of the future program because it entails quantification of parameters that are considered for licensing. Another new project has involved modeling of a flooded salt repository. It is hoped that the socioeconomic program will grow and that new work (FY 81) on regional environmental characterization may provide avenues for more detailed environmental analysis. The need for geochemical research relative to licensing may be a fruitful area for increased ORNL involvement. Currently, little such work is being supported by the U.S. Department of Energy (DOE) at ORNL. However, our future plans relative to this work will be closely coordinated with ORNL's U.S. Nuclear Regulatory Office (NRC) program office.

PART III. EXTRAMURAL ACTIVITIES

12. EDUCATIONAL ACTIVITIES

Environmental Sciences Division (ESD) Seminar Program

During the past year, the seminar committee offered a diverse program of guest lectures to inform ESD staff and other interested members of the local scientific community about topics of general interest in environmental sciences (Table 12.1). The seminar series relies largely on suggestions from ESD staff members concerning the selection of outstanding speakers, an arrangement that was very successful in the past year.

Table 12.1. Environmental Sciences Division invited speakers, Oct. 1, 1980–Sept. 30, 1981

Date	Speaker	Title
3/23/81	Dr. Ray W. Drenner Texas Christian University Fort Worth, Texas	The ecological role of planktivorous fish: where limnologist meets fishery biologist
5/21/81	Dr. Irving Breger U.S. Geological Survey Reston, Virginia	Basic research in organic geochemistry applied to national energy needs
8/10/81	Dr. Anna Kajak Institute of Ecology Polish Academy of Sciences Warsaw, Poland	The effect of peatland drainage on ecosystem structure and function
9/9/81	Dr. Wallace Broecker Lamont-Doherty Laboratory Palisades, New York	Geochemistry of ^{14}C in the atmosphere and ocean
9/23/81	Dr. Peter W. Price Northern Arizona University Flagstaff, Arizona	Evolutionary biology of parasites: confounding conventional wisdom in ecology

Graduate Education Program

The ESD provides opportunities for graduate and postdoctoral research consistent with the mission of the Oak Ridge National Laboratory (ORNL). During this reporting period, 21 graduate students were supported through a contract with The University of Tennessee Graduate Program in Ecology, one by Indiana University, and one through Miami University, Oxford, Ohio. Each supported student receives stipends administered by the student's respective university, and his or her research is guided by selected ESD staff members, one of whom serves on the respective student's university academic guidance committee. In addition, research done by students not requiring ESD 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 ESD's graduate education coordinator. The purpose of the meetings was to explain ESD programs to new students and to provide a forum for comments and suggestions relating to the graduate program.

Undergraduate Education Program

Several programs for undergraduate student participation in ESD research and assessment projects provide a continuing opportunity for interaction between students and staff. A summary of these programs is provided in Table 12.2.

Table 12.2. Number of students in ESD undergraduate programs, Oct. 1, 1980–Sept. 30, 1981

Program	Number
Oak Ridge Associated Universities	8
Southern College and University Union	5
Emory University	2
Great Lakes College Association	3
Ferrum College	1

Students involved in these programs are assigned to individual ESD advisors who guide the students through an experiment or project associated with one of the ESD programs. Each student is required to document results in a report and present a seminar to the ESD staff. These experiences in research participation are designed to expose the student to the research process in a large laboratory. The greatest benefits to students are 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 12.2, six students who completed the B.S. degree were associated with ESD as part of ORNL's summer research intern program. This program provides students just entering graduate schools the opportunity to participate in research at an advanced level.

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

Title of subcontract/interagency agreement	Subcontractor	Division technical contact
Assist with the determination of differences in nutrient uptake of fungus-infected and noninfected tree species.	A & L Agricultural Laboratory, Inc.	D. C. West
Wood for energy in the Taiga—evaluation of potential species and their growth rates	Alaska, University of	J. H. Cushman
Development and testing of organic anions for use as ground-water tracers	Arizona, University of	N. H. Cutshall
Evaluation of woody plant species for biomass production potential in the semi-arid southeastern United States	Arizona, University of	R. I. Van Hook
Research to determine the nature, character, and extent of understory vegetation within uneven-aged pine and pine-hardwood southern forests and the effects of periodic harvests of such understory vegetation on site quality	Arkansas, University of	J. W. Ranney
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
Evaluation and technical review of the Alternate Fuels Programmatic Environmental Impact Statement	Battelle Memorial Institute	R. M. Reed
Fuels and chemicals from Woody Biomass Program	Bioenergy Development Corporation	R. I. Van Hook
Evaluation of the availability of land for silvicultural energy farms in the western lake states	Biosystems Corporation	R. I. Van Hook
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
Production of woody biofuels from mesquite	Ceasar Kleberg Wildlife Research Institute	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 to 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 that 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

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

Title of subcontract/interagency agreement	Subcontractor	Division technical contact
Provide an evaluation of the technical 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
Energy and chemicals from woody species in Florida	Florida, University of	R. I. Van Hook
Studies to increase the biomass production of short-rotation coppice forest	Georgia Research Institute, University of	J. H. Cushman
Material spiralling in stream ecosystems: feasibility of manipulating natural streams using pesticides	Georgia, University of	W. Van Winkle
Prepare a set of technology-specific environmental guidance documents for synfuels	Georgia Institute of Technology	R. M. Reed
Assistance in conducting an environmental compliance workshop on fuel alcohol in Federal Region IV	Georgia Institute of Technology Research Institute	J. F. McBrayer
Assistance to the Environmental Impacts Program in preparing two guidance documents being submitted to the U.S. Department of Energy (DOE)	Gilbert Associates	R. M. Reed
Cultural and management practices for the Chinese tallow tree as a biomass fuel source	Houston, University of	R. I. Van Hook
Species spacing and management alternatives for short-rotation woody biomass production	Illinois, University of	R. I. Van Hook
Studies on the mobility of organic molecules in groundwater	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. E. 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
Sedimentation and contaminant distribution in the Hudson-Raritan estuary	Lamont-Doherty Geological Observatory	N. H. Cutshall

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

Title of subcontract/interagency agreement	Subcontractor	Division technical contact
Computer-based data base in support of biomass programs as part of the larger DOE/ACT Technology Information System at Lawrence Livermore National Laboratory (LLNL)	Lawrence Livermore National Laboratory	R. I. Van Hook
Assistance in the expansion of the Geo-ecology Data Base, with the primary responsibility being development of files for the system	Lockheed Missile & Space Co., Inc.	R. J. Olson
Consistent description and energy balance studies for specific biomass conversion technologies	Los Alamos National Laboratory	J. H. Cushman
Description of the status and well-being of the Ohio River fish community to provide a background against the impacts of site-specific projects that can be assessed by regulatory agencies	Louisville, University of	S. M. Adams
Computer analysis of biomass harvesting model	Methtech, Inc.	R. I. Van Hook
Internship program	Miami University	S. I. Auerbach
A comprehensive range-wide collection of tag older seed sources	Michigan State University	R. I. Van Hook
Tree species and management strategies for biomass production in the Great Lakes states	Michigan State University	R. I. Van Hook
Application of sugar maple and black locust to the biomass/energy plantation concept	Michigan Technological University	R. I. Van Hook
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 University of Minnesota-Duluth (UMD) Gasifier Project	Minnesota-Duluth, University of	K. E. Cowser
Economic methodology for the determination of woody biomass product prices	Mittlehauser Corp.	R. I. Van Hook
Use of wetlands for production of woody plants for fuels and petrochemical substitutes	Minnesota, University of	R. I. Van Hook
Quantify genetic variation in biomass yields and disease resistance for sycamore and identify superior seed sources and parent trees	Mississippi Agricultural and Forestry Station	R. I. Van Hook

13. 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
Species selection and silvicultural systems for producing fuels from woody biomass in the southeastern United States	North Carolina State University	R. I. Van Hook
Development of a generic model that predicts the relation between plant biomass or production with selected ecosystem biological and physical components	Oklahoma, University of	M. I. Dyer
Evaluation of woody biomass production on a commercial-scale basis	Packaging Corp. of America	R. I. Van Hook
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 evaluate properly and accurately wood-energy plantations	Pennsylvania State University	J. W. Ranney
Sampling, monitoring, and analysis of meteorology, air quality, and water quality for the Pike County, Kentucky, Gasifier-in-Industry Facility coal gasification plant	Pikeville College	R. M. Cushman
Demonstrate the technical capability of the PROSE programming language for automated determination of mathematical derivatives	Prose Inc.	S. H. Stow
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
Terrestrial and aquatic ecology support for Fossil Energy Environmental Project	Science Applications, Inc.	S. G. Hildebrand
Collect, validate, and analyze data on woody biomass plant growth models in use in the United States	Science Applications, Inc.	J. H. Cushman
Provide word-processing and editorial support for preparation of proceedings	Science Applications, Inc.	J. F. McBrayer

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

Title of subcontract/interagency agreement	Subcontractor	Division technical contact
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 the 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 (ESD) of [Oak Ridge National Laboratory (ORNL)] and the University of Tennessee Graduate Program in Ecology	Tennessee, University of	R. E. Millemann
A cooperative venture between the ESD (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
Extending systems analysis in ecology	Texas, University of	R. I. Van Hook
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 the U.S. Environmental Protection Agency (EPA) in assessing the fate of organic chemicals in the environment and their risks to human and nonhuman populations	Vanderbilt University	C. C. Coutant
Production of biomass on abandoned farmlands in the Northeast	Vermont, University of	R. I. Van Hook
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

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

Title of subcontract interagency agreement	Subcontractor	Division technical contact
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
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. APPENDIXES

PUBLICATIONS,* PRESENTATIONS, THESES, AND PROFESSIONAL ACTIVITIES

PUBLICATIONS

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Baes, C. F., III, and R. D. Sharp. Predicting radionuclide leaching from root zone soil for assessment applications. IN Proc., American Nuclear Society Annual Meeting. CONF-810608-44 National Technical Information Services, Springfield, Virginia (in press).

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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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"CRRIS: A comput d methodology for assessing the human impact of radionuclides released to the atmosphere," 26th Annual Health Physics Society Meeting, Louisville, Kentucky, June 1981.

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Barnthouse, L. W.

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Barnthouse, L. W., S. W. Christensen, W. Van Winkle, and D. S. Vaughan

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Bartell, S. M.

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"Tree rings and climatic variability," Honors Colloquium, Tennessee Technological University, Cookeville, October 1980.

"Tree rings as records of environmental history," Colloquium, Graduate Program in Ecology, The University of Tennessee, Knoxville, February 1981.

Blaylock, B. G.

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"Bioaccumulation and Distribution of ^{95m}Tc in an experimental freshwater pond," IAEA Symposium on Migration in the Terrestrial Environment of Long-lived Radionuclides from the Nuclear Fuel Cycle, Knoxville, Tennessee, July 1981.

Bondietti, E. A.

"Geochemical variables, uncertainty, and long-lived radionuclide migration risk," Symposium on Uncertainty in the Disposal of High-level Radioactive Wastes, Gatlinburg, Tennessee, April 1981.

"Mobile species of Pu, Am, Cm, Np, and Tc in the environment," IAEA Symposium on Migration of Radionuclides in the Terrestrial Environment, Knoxville, Tennessee, August 1981.

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"Technetium in sulfide and ferrous iron-bearing media," Waste/Rock Interaction Technology Program information meeting, Seattle, Washington, October 1980.

Bradburn, D. M.

"Forestry as a Profession," Austin-East High School, Knoxville, Tennessee, October 1980; Fulton High School, Knoxville, Tennessee, November 1980.

Breck, J. E., and J. F. Kitchell

"PCBs in fishes: A modeling analysis of sources of variation," 44th Annual Meeting, American Society of Limnology and Oceanography, Inc., Milwaukee, Wisconsin, June 1981.

Cada, G. F.

"Ecological fate and effects research," H-Coal Environmental Team Meeting, Oak Ridge National Laboratory, Oak Ridge, Tennessee, June 1981.

Christensen, S. W.

"Methods for evaluating hazards to aquatic ecosystems from emerging energy technologies," U.S. Environmental Protection Agency Officials, Duluth, Minnesota, May 1981.

Christensen, S. W., and D. L. DeAngelis

"Effect of environmental variation on reliability of entrainment mortality estimates," 111th Annual Meeting, American Fisheries Society, Albuquerque, New Mexico, September 1981.

"Effect of Stochastic variation on estimates of the probability of entrainment mortality," U.S. Nuclear Regulatory Commission Project Review Committee, Silver Spring, Maryland, November 1980.

Christensen, S. W., and W. Van Winkle

"Modeling the long-term Impact of anthropogenic stresses on fish populations and communities," Overview and Planning Meeting for Alternate Fuels Research, U.S. Environmental Protection Agency, Duluth, Minnesota, January 1981.

Coutant, C. C.

"Comparative temperature-dependent growth rates of largemouth and smallmouth bass fry," American Fisheries Society Annual Meeting, Albuquerque, New Mexico, September 1981.

"Ecology of striped bass in Tennessee reservoirs," Oceanography Class, Oak Ridge High School, April 1981.

"Energy-Related research needs in the southeast," DOE Workshop on Aquatic Research Planning, Washington, D.C., March 1981.

"Ethical questions related to energy policies," Social Concerns Seminar, First United Presbyterian Church, Oak Ridge, Tennessee, January 1981.

"Multimedia modeling of environmental transport and fate of chemicals" poster presentation, Planning Retreat, Environmental Protection Agency, Office of Pesticides and Toxic Substances, Exposure Evaluation Division, Shenandoah National Park, Virginia, October 1980.

"Spring and summer temperature selection by smallmouth bass in a quarry lake," Tennessee Academy of Science, Oak Ridge National Laboratory, November 1980.

"Spring and summer temperature selection by smallmouth bass," East Tennessee Chapter, American Fisheries Society, Tech-Aqua Field Station, Smithville, Tennessee, May 1981.

"Stream ecology," Tremont Environmental Education Center, Great Smoky Mountains National Park, Tennessee, May 1981.

"Striped bass and the management of cooling lakes," Third Waste Heat Management and Utilization Conference, Miami Beach, Florida, May 1981.

"Striped bass: Their thermal niche in relation to power plant thermal effluents," Sixteenth Annual Junior Science and Humanities Symposium, Oak Ridge National Laboratory, March 1981.

"Thermal Pollution—What's the Status?" Sigma Xi lecture, Georgia Tech University, Atlanta, Georgia, October 1980.

"Watts Bar striped bass behavior study, 1979–80," Wildlife Society, The University of Tennessee, Knoxville, March 1981.

Cushman, J. H.

"Biomass energy systems—A regional example," Engineering Week Symposium, Florida Atlantic University, Boca Raton, February 1981.

"Biomass energy systems—Resource and technology interactions," Engineering Week Symposium, Florida Atlantic University, Boca Raton, February 1981.

"Inventory of growth models—USA," IEA Forestry Energy Biomass Systems Analysis Workshop, Dublin, Ireland, October 1981.

"The short rotation crops program—Progress and perspectives," SRWCP Contractors Workshop, Issaquah, Washington, September 1981.

Cutshall, N. H.

"ORNL low-level waste R&D program: Mechanisms of transport of radionuclides from shallow land burial sites and remedial measures," IAEA Coordinated Research Meeting, Oxford, England, June–July 1981.

Daniels, K. L.

"Research data management in government agencies," Joint Statistical Meetings of the American Statistical Association and the Biometric Society, Detroit, Michigan, August 1981.

Davis, E. C., and W. J. Boegly, Jr.

"Leachability of sulfates in coal conversion solid wastes," ACS Annual Meeting of the Division of Environmental Chemistry, New York, New York, August 1981.

Davis, E. C., C. W. Francis, W. J. Boegly, Jr., and R. R. Turner

"Leachability of sulfates in coal conversion solid wastes," ASCE Specialty Conference, Energy and the Man-Built Environment, Vail, Colorado, August 1981.

DeAngelis, D. L., W. M. Post, and M. I. Dyer

"Modeling the plausibility of plant-grazer mutualism," 32nd Annual Meeting, American Institute of Biological Sciences, Bloomington, Indiana, August 1981.

Delcourt, H. R., P. A. Delcourt, A. M. Solomon, and E. Spiker

"Holocene forest history of central Alabama," Annual Meeting of the Ecological Society of America, Bloomington, Indiana, August 1981.

Delcourt, H. R., P. A. Delcourt, and A. M. Solomon

"Forest history for the past 12,000 years at Cahaba Pond, St. Clair Co., Alabama," Annual Meeting of the Association of Southeastern Biologists, Knoxville, Tennessee, April 1981.

Duvick, D. N.

"Dendroclimatology of white oak (*Quercus alba*) in Iowa," Annual Meeting of the Association of Southeastern Biologists, Knoxville, Tennessee, April 1981.

Dyer, M. I.

"Plant-herbivore interactions: An alternative hypothesis," Duke University, Durham, North Carolina, February 1981; University of Michigan, Ann Arbor, March 1981; Western Michigan University, Kalamazoo, March 1981.

Dyer, M. I., and S. J. McNaughton

"Plant defenses against herbivores: Soft defense and the evolutionary advantages of moderate herbivory," 32nd Annual Meeting, American Institute of Biological Sciences, Bloomington, Indiana, August 1981.

Eddlemon, G. K., and V. R. Tolbert

"Chattanooga shale exploitation: Implications for sensitive aquatic species," 111th Annual Meeting, American Fisheries Society, Albuquerque, New Mexico, September 1981.

Elwood, Jerry W.

"Environmental effects of acidic precipitation," ORAU Energy Education Division, Oak Ridge Associated Universities, Oak Ridge, Tennessee, August 1981.

"Resource spiralling: An operational paradigm for analyzing lotic ecosystems," invited paper, Symposium on the Dynamics of Lotic Ecosystems, Savannah River Ecology Laboratory, Savannah, Georgia, October 1980.

Emanuel, W. R.

"Global carbon cycling and the CO_2/climate issue," Oak Ridge GLCA Seminar Series, Oak Ridge, Tennessee, October 1981.

Emanuel, W. R., W. M. Post, G. G. Killough, and H. H. Shugart

"Model calculations to estimate ranges for the influence of terrestrial ecosystems on the global carbon cycle," Symposium on the Role of Terrestrial Ecosystems in the Global Carbon Cycle, Annual Meeting of the Ecological Society of America, Bloomington, Indiana, August 1981.

Emerson, C. J., and Martha K. Nungesser

"A comparison of graphics packages used with the Geoecology Data Base," SAS Users' Group International, Lake Buena Vista, Florida, February 1981.

Farrell, M. P.

"Management of quality assurance controls: Decision support systems," Sixth Annual SAS Users' Group, International Conference, Orlando, Florida, February 1981.

"N-dimensional pattern recognition in environmental systems," DOE Statistical Symposium, Berkeley, California, October 1980.

"State-of-art review of research data management," Annual Meeting of the American Statistical Association, Detroit, Michigan, August 1981.

Farrell, M. P., and R. H. Strand

"Tracking quality assurance controls in environmental research," Meetings of the American Society of Quality Control, Tulsa, Oklahoma, October 1980.

Francis, C. W.

"The utility of extraction procedures," 2nd International Conference on Hazardous Wastes, Denver, Colorado, October 1980.

Gardner, R. H.

"Assessing model uncertainties," Symposium on uncertainties associated with the regulation of the geological disposal of high-level radioactive waste, Gatlinburg, Tennessee, March 1981.

"Error analysis," HDR Sciences Modeling Workshop, Santa Barbara, California, February 1981.

"Risk assessment," briefing for Bectal Corporation, Oak Ridge National Laboratory, June 1981.

"Risk assessment," briefing for Nuclear Regulatory Commission, Oak Ridge National Laboratory, August 1981.

Gardner, R. H., R. V. O'Neill, and F. O. Hoffman

"Uncertainty and error analysis of radiological dose assessment models," Presented to visiting delegates of the German Advisory Council on Environmental Radioecological Assessment and Radiation Protection, Oak Ridge National Laboratory, January 1981.

Gardner, R. H., R. V. O'Neill, and J. H. Carney

"Spatial patterning and error propagation in a stream ecosystem model," 1981 Summer Computer Simulation Conference, Washington, D.C., July 1981.

Garten, C. T., Jr.

"Ecological research on long-lived radionuclides at ORNL," Savannah River Ecology Laboratory, Aiken, South Carolina, June 1981.

Giddings, Jeffrey

"Ecological studies on oils from coal," Seminar on Current Topics in Environmental Toxicology, The University of Tennessee, Knoxville, November 1980.

"Environmental research on coal liquefaction products," Office of Health and Environmental Research, Department of Energy, Washington, D.C., June 1981.

Gough, S. B.

"Pathogenic microorganisms in power plant cooling systems," presented to the NRC Deputy Director of Office of Nuclear Regulatory Research, Oak Ridge, Tennessee, May 1981, presented to Enrico Conte and staff, NRC Branch for Siting and Environment, Oak Ridge, Tennessee, May 1981.

Goyert, J. C.

"Research data management in environmental consulting firms," Joint Statistical Meetings of the American Statistical Association and the Biometric Society, Detroit, Michigan, August 1981.

Haase, C. S.

"Crystal growth and the development of oscillatory compositional zoning in plagioclase feldspar," Geosciences Seminar Series, Oak Ridge National Laboratory, April 1981.

"Metamorphic petrology of the Negaunee iron formation, Marquette District, Michigan," Friends of Ore Deposits Seminar Series, U.S. Geological Survey, Reston, Virginia, September 1981.

Haase, C. S., and N. D. Vaughan

"Stratigraphy and Lithology of the Conasauga group in the vicinity of Oak Ridge, Tennessee," Geological Society of America, Southeastern Section Annual Meeting, Hattiesburg, Mississippi, March 1981.

Hammons, A. S.

"Multispecies laboratory Methods as predictive tools in environmental hazard assessment," Annual Meeting, American Institute of Biological Sciences, Bloomington, Indiana, August 1981.

Hildebrand, S. G.

"Ecological research needs for small-scale hydroelectric technology," Annual meeting, Northeast Division of the American Fisheries Society, Virginia Beach, Virginia, April 1981.

"Oak Ridge National Laboratory support activities to the DOE Division of Hydroelectric Resource Development," DOE Headquarters/Field Program Review, Alexandria, Virginia, February 1981.

"Small-scale hydroelectric development and the environment: Issues, challenge, opportunity," National Conference on Renewable Energy Technologies, Honolulu, Hawaii, December 1980.

Huff, D. D.

"Hydrologic studies capabilities at ORNL," Briefing of Bechtel Corporation Staff, Oak Ridge National Laboratory, June 1981.

"PROSPER II: A generalized model for atmosphere-soil-plant water flow," AGU Chapman Conference on Subsurface Water Contributions to Streamflow, Durham, New Hampshire, October 1980.

"Radioactive material containment in landfill areas, Nuclear Fuel Services, Inc. Invited Lecture Series, Erwin, Tennessee, April 1981.

"Trench seal evaluations," Joint NRC/DOE Review on Seals and Trench Caps; Oak Ridge National Laboratory, September 1981.

"The Water Cycle, ground water, ocean Processes," Topics in Geology—ORNL Technical Continuing Education Course C-600, Oak Ridge National Laboratory, September 1980.

Johnson, D. W.

"Acid rain forest productivity," XVII IUFRO World forestry Congress, Kyoto, Japan, September 1981.

Johnson, D. W., D. W. Cole, F.-W. Horng, and D. E. Todd

"Soil chemical properties relevant to leaching susceptibility in forest soils of different age and nutrient status," Soil Science Society of America Annual Meetings, Detroit, Michigan, December 1980

Kimmel, B. L.

"DCMU-enhanced chlorophyll fluorescene: An indicator of the physiological status of reservoir phytoplankton," Tennessee Valley Authority Engineering Laboratory, Norris, Tennessee, April 1981.

"Size Distribution of planktonic autotrophy and microheterotrophy in reservoirs: A comparative approach," International Symposium on Reservoir Ecology and Management, Laval University, Quebec, Canada, June 1981.

"The Organic matter base of reservoir foodwebs: Is allochthonous organic matter important?" Annual Meeting, American Society of Limnology and Oceanography, University of Wisconsin, Milwaukee, June 1981.

Kimmel, B. L., and J. R. Holt.

"Cyclomorphosis in *Ceratium hirundinella* during mid-summer isolation," Annual Meeting, Southwestern Association of Naturalists, New Orleans, Louisiana, April 1981.

Kirk, B. L., and B. W. Rust

"Inductive modeling of time series—A detrending approach," Environmetrics '81, SIMS-SIAM, Alexandria, Virginia, April 1981.

Kitchings, J. T.

"The Oak Ridge National Environmental Research Park," East Tennessee Chapter, Health Physics Society, Oak Ridge, Tennessee, May 1981.

Kitchings, J. T., and S. W. Seagle

"Habitat selection in a small mammal community," Association of Southeastern Biologists, Knoxville, Tennessee, April 1981.

Kroodsma, R. L.

"Bird community ecology along power-line corridors," Annual Meeting, Tennessee Ornithological Society, Montgomery Bell State Park, Tennessee, October 1980.

"Edge effect on breeding forest birds along a power-line corridor," Annual Meeting, American Institute of Biological Sciences, Bloomington, Indiana, August 1981.

Krummel, J. R.

"Agricultural y medio ambiente," IV Congreso CREA: La Argentina Frente al Interrogante Technologico, Mar del Plata, November 1980.

Kumar, K. D.

"Estimation of age structure of fish populations from length frequency data," Annual Meeting, American Statistical Association, Detroit, Michigan, August 1981.

Lee, S. Y. and E. A. Bondietti (E. A. Bondietti, S. Y. Lee, and S. K. Hall)

"Technetium in sulfide and ferrous iron, bearing media," Waste/Rock Interaction Technology Information Meeting, Seattle, Washington, October 1980.

Lindberg, S. E.

"Deposition of particles to inert and foliar surfaces in a forest canopy," invited seminar, Center for Energy and Environmental Studies seminar series, Carnegie-Mellon University, Pittsburgh, Pennsylvania, March 1981.

"EPRI research on atmospheric deposition of acids at Walker Branch Watershed," Invited presentation, Annual Review of the EPRI Integrated Lake/Watershed Acidification Study, Sagamore, New York, October 1981.

"Processes of deposition to forest vegetation," invited seminar, Department of Environmental Sciences, University of Virginia, Charlottesville, March 1981.

Lindberg, S. E., D. S. Shriner, and W. A. Hoffman, Jr.

"Interaction of wet and dry deposition components of acid precipitation with the forest canopy," invited presentation, Conference on Effects of Acid Precipitation on Ecological Systems in the Great Lake Region, Michigan State University, East Lansing, April 1981.

Lindberg, S. E., R. R. Turner, D. S. Shriner, and D. D. Huff

"Atmospheric deposition of heavy metals in a North American deciduous forest," International Conference on Heavy Metals in the Environment, Amsterdam, The Netherlands, September 1981.

Loar, J. M.

"Environmental aspects of small hydro development: Instream flow issues," and "Workshop summary: Environmental aspects of small hydro development," Engineering Foundation Conference on Small Hydroelectric Development, Henniker, New Hampshire, July 1981.

Loar, J. M., and S. G. Hildebrand

"A comparison of environmental issues related to development of small hydropower resources at new versus existing sites," Third Miami International Conference on Alternative Energy Sources, Miami Beach, Florida, December 1980.

Luxmoore, R. J.

"Elevated CO_2 effects on plant-soil systems," Duke Phytotron Research Group, Duke University, Durham, North Carolina, July 1981.

"Field determination and modeling of soil hydraulic behavior," S-124 Regional Technical Committee Meeting, Clemson, South Carolina, March 1981.

"Modeling water, carbon, and heavy metal transport in soil-plant systems," invited seminar, Savannah River Laboratory, Aiken, South Carolina, March 1981.

"Simulated hydrologic consequences of soil heterogeneity, macropores, and tree farming," XVII IUFRO World Congress, Kyoto, Japan, September 1981.

Luxmoore, R. J., B. P. Spalding, and I. M. Munro

"Areal variation and chemical modification of weathered shale drainage characteristics," American Society of Agronomy Annual Meetings, Detroit, Michigan, December 1980.

McBrayer, J. F.

"Alcohol fuel—DOE programs," U.S. Environmental Protection Agency Seminar on Environmental Impacts of Alcohol-Fuel Facilities, Kansas City, Missouri, December 1980.

"Chattanooga shale environmental assessment," presented to the Office of Program Planning and Analysis, Oak Ridge National Laboratory, March 1981.

"Introduction," Moonshine to Motor Fuel: A Workshop on Regulatory Compliance for Fuel Alcohol Production. Atlanta, Georgia, March 1981.

"NEPA-compliance program for alcohol fuels," presented to E. Pyatt, Director, Office of Alcohol Fuels, U.S. Department of Energy. Washington, D.C., February 1981.

"ORNL capabilities in environmental assessment and monitoring," presented to the staff of Formerly Utilized Sites Remedial Action Program, (FUSRAP) Oak Ridge, Tennessee, June 1981.

McLaughlin, S. B.

"Air pollution effects on vegetation: Some perspectives, approaches, and recent findings," Swiss Federal Institute of Forest Research, Zurich, Switzerland, August 1981; and the Swedish Meteorological Institute, Stockholm, Sweden, August 1981.

"Carbon allocation and energy utilization in forest trees," Swiss Federal Institute of Forest Research, Zurich, Switzerland, August 1981; Swedish Agricultural University, Uppsala, Sweden, August 1981; and the Institute of Plant Physiology, University of Gothenburg, Gothenburg, Sweden, August 1981.

"Photosynthate allocation as an indicator of air pollution stress in plants," XI Annual Air Pollution Workshop, Ithaca, New York, May 1981.

"SO_2, vegetation effects, and the air quality standard: Limits of interpretation and application," APCA Specialty Conference on the Proposed SO_2 and Particulate Standard, Atlanta, Georgia, September 1981.

McLaughlin, S. B. (G. E. Taylor, D. S. Shriner, and S. B. McLaughlin)

"Sulfur gases from synthetic fuels production: Deposition to vegetation and effects on photosynthesis, XI Annual Air Pollution Workshop, Ithaca, New York, May 1981.

McLaughlin, S. B. and D. S. Shriner

"ORNL Research on ecological effects of SO_2, O_3, and acid rain on terrestrial ecosystems," EPA-EPRI Joint Review of Acid Rain Research, Atlanta, Georgia, December 1980.

McLaughlin, S. B., G. E. Taylor, D. S. Shriner, J. W. Johnston, and R. K. McConathy

"Miscellaneous studies on pollutant uptake and effects," XI Annual Air Pollution Workshop, Ithaca, New York. May 1981.

Millemann, R. E.

"Comparative toxicity of coal conversion and other solid waste leachates to *Daphnia magna* and terrestrial plants," 20th Hanford Life Sciences Symposium, Richland, Washington, October 1980.

Nungesser, Martha K.

"Assessing land management for nonpoint source runoff," 147th Annual Meeting of the American Association for the Advancement of Science, Toronto, Canada, January 1981.

Nungesser, Martha K., and C. J. Emerson

"Geoecology data base: County-level environmental data," Integrated County-Level Data Users' Workshop, Reston, Virginia, October 1980.

O'Neill, R. V.

"Population theory and ecosystem science," Workshop on Population/Ecosystem Interactions, Cornell University, Ithaca, April 1981.

Olsen, C. R., and C. S. Bard

"Assessing uncertainties associated with the geochemical aspects of high-level waste migration from deep geologic repositories," Nuclear Regulatory Commission, Washington, D.C., September 1981.

Olson, J. S.

"Global carbon cycling," DOE Reviews, Oak Ridge Associated Universities, Oak Ridge, Tennessee, November 1980; Oak Ridge National Laboratory, December 1980.

"The generic tree and carbon modeling," Oak Ridge Associated Universities, Oak Ridge, Tennessee, July 1981.

Olson, R. J.

"Data resources for assessing regional impacts of energy facilities on health and the environment," Numeric Data Workshop, Oak Ridge, Tennessee, September 1981; International Symposium for Health Impacts of Different Sources of Energy, Nashville, Tennessee, June 1981.

"Environmental analysis and assessment utilizing the Geoecology Data Base," Integrated County-Level-Data Users' Workshop, Reston, Virginia, October 1981.

Olson, R. J., K. D. Kumar, and R. L. Burgess

"Analyses of ecoregions utilizing the Geoecology Data Base," In-Place Resource Inventories: Principles and Practices, Orono, Maine, August 1981.

Peng, T.-H.

"The uptake of fossil fuel CO_2 by the ocean," invited speaker, Symposium on Carbon Dioxide Issue, ACS Annual Meeting, New York, New York, August 1981.

Post, W. M., C. C. Travis, and D. L. DeAngelis

"Evolution of mutualism between species," Conference on Differential Equations and Applications in Ecology, Epidemics and Population Problems, Pomona, California, January 1981.

Post, W. M., P. L. Zinke, A. G. Stangenberger, W. R. Emanuel, H. Jenny and J. S. Olson

"Soil carbon pools and world life zones," Bloomington, Indiana, August 1981.

Powers, C. D.

"Partitioning of PCB by Phytoplankton," 24th Conference of the International Association of Great Lakes Research, Columbus, Ohio, April 1981.

Ranney, J. W.

"Research in the fuels and chemicals from woody biomass program and future directions," Southern Biomass Working Group, Myrtle Beach, South Carolina, June 1981.

"The needs and direction of woody biomass research in DOE," Annual Technical Workshop of the Short Rotation Woody Crops Program, Issaquah, Washington, September 1981.

"U.S. Research Directions and Interests," International Energy Agency Group Meeting on Forest Growth and Production, Toronto, Canada, March 1981.

"U.S. status of clonal propagation of superior genotypes for short rotation intensive silviculture," International Energy Agency Group Meeting on Forest Growth and Production, Kyoto, Japan, September 1981.

Reed, R. M.

"NEPA—When it applies, how to comply," Moonshine to Motor Fuel: A Workshop on Regulatory Compliance for Fuel Alcohol Production, Atlanta, Georgia, March 1981.

Reed, R. M., L. D. Voorhees, and P. J. Mulholland

"Development of peatlands for energy," Annual Meeting, Annual Institute of Biological Sciences, Bloomington, Indiana, August 1981.

Reed, R. M., L. D. Voorhees, and P. J. Mulholland

"Environmental impacts associated with using peat for energy," 1981 International Gas Research Conference, Los Angeles, California, September 1981.

Sale, M. J.

"Instream flow and hydropower development: methods and strategies for impact assessment," Waterpower '81: An International Conference on Hydropower, Washington, D.C., June 1981.

Sharples, F. E.

"Spread of organisms with man-made genomes: Thoughts from an ecological perspective," American Association for the Advancement of Science, Environmental Science and Engineering Fellows Seminar series, Washington, D.C. August 1981.

Shriner, D. S.

"Acid rain and ozone effects on forest growth," OTA Workshop, Washington, D. C., March 1981.

"Acid rain effects on terrestrial ecosystems: An overview," Symposium on Acid Rain Effects in the Great Lakes Region, East Lansing, Michigan, May 1981.

"Acid rain: An environmental issue," American Society of Professional Engineers, Oak Ridge, March 1981; IEEE, Oak Ridge, April 1981.

"Acid rain: An international problem, a national responsibility," keynote address, Tennessee Academy of Sciences Annual Meeting, October 1980.

"Acid rain: International problem," briefing for plant managers' staff meeting, Oak Ridge Gaseous Diffusion Plant, January 1981.

"EPRI-funded acid rain effects on crops studies," EPA/EPRI Workshop, Atlanta, Georgia, March 1981.

Shugart, H. H. "Forest dynamics models," 32nd Annual Meeting, American Institute of Biological Sciences, Bloomington, Indiana, August 1981.

"Forest succession models," University of Florida, Department of Forestry, March 1981.

"Landscape ecosystems," University of Florida, Wetlands Center, March 1981.

Sigal, L. L.

"Lichens and SO_2, O_3, and SO_2 + O_3," XIII Air Pollution Workshop, Ithaca, New York, May 1981.

"Lichens on conifers and oxidants in southern California," 74th Air Pollution Control Association Meeting, Philadelphia, Pennsylvania, June 1981.

"Preliminary acid rain effects on lichens," 83rd Annual Meeting of the American Bryological and Lichenological Society, Highlands, North Carolina, June 1981.

Solomon, A. M.

"Pollen morphology of oaks applied to reconstruction of Quaternary environments," 32nd Annual Meeting, American Institute of Biological Sciences, Bloomington, Indiana, August 1981.

Spalding, Brian P.

"Chemical treatments of soil to decrease radiostrontium leachability," Annual Meeting, Soil Science Society of America, Detroit, Michigan, December 1980.

"Precipitation of radiostrontium in soil," Annual Meeting, Materials Research Society, Boston, Massachusetts, November 1980

"The decline in public credibility of the scientific community," Chemistry Department, Maryville College, Maryville, Tennessee, April 1981.

Story, Jay D.

"Animals and animal studies on the Oak Ridge Reservation," presented to three classes of second graders at Powell Elementary School, October 27, 1980, and to one third grade and one fourth grade class at Powell Elementary School, Knoxville, Tennessee, October 21, 1980.

"Road-killed deer on the Oak Ridge Reservation," Wildlife Techniques Class, The University of Tennessee, Knoxville, April 1981.

"Mammal studies on the Oak Ridge Reservation," Ecology Seminar, The University of Tennessee, Knoxville, October 1, 1980.

Stow, S. H.

"The pyriton massive sulfide deposit, southern Appalachians: geology and geochemistry," Oak Ridge National Laboratory, Topics in Geology—ORNL Technical Continuing Education Course C-60), Oak Ridge National Laboratory, April 1981.

"Igneous geochemistry and petrogenesis of the Hillabee Greenstone," Geological Society of America Southeastern Section Annual Meeting, Hattiesburg, Mississippi, March 1981.

Stow, S. H., and J. F. Tull

"Geologic setting, geochemistry and stratabound sulfide occurrences of the middle Paleozoic Hillabee metavolcanics of Alabama," Geological Society of America National Meeting, Atlanta, Georgia, November 1980.

Strand, K. H.

"Computer aided cinematography techniques for model validation," and "Processing PDP-11 files into IBM file structures," Association for Computing Machinery, Nashville, Tennessee, October 1980.

"Interfacing SAS/graph with an FR80 camera device," Sixth annual SAS Users' Group, International Conference, February 1981.

Strayer, R. F.

"Effects of acid precipitation on microbial activities in forest soils," Department of Microbiology, The University of Tennessee, Knoxville, May 1981.

Suter, G. W., II

"The rationale for a strawman list of risk analysis units (RAUs)," U.S. EPA Workshop: Categorization of Chemical Compounds Associated with Synfuel Technologies for Risk Assessment, Alexandria, Virginia, July 1981.

"Methods for environmental risk assessment," invited seminar, U.S. Environmental Protection Agency, Corvallis Environmental Research Laboratory, Corvallis, Oregon, September 17, 1981.

Tamura, T., and W. J. Boegly, Jr.

"Conceptual design requirements for landfill liners for nonhazardous solid wastes," presented to DOE/UMTRAP personnel at Grand Junction Site, Grand Junction, Colorado, August 1981.

Taylor, Fred G.

"Overview of ecological research conducted at Gaseous Diffusion Plants," briefing to European scientists from EURODIF, Oak Ridge National Laboratory, June 1981.

"Seasonality of cooling tower drift in vegetation at ORGDP," 1981 UCC-ND Environmental Protection Seminar, Barkley Lake State Park Lodge, Kentucky, April 1981.

"Use of CSTR chambers for hydrogen fluoride fumigations using bottle gas," XIV Air Pollution Workshop, Boyce Thompson Institute for Plant Research, Cornell University, Ithaca, New York, May 1981.

Taylor, Fred G. and Hannes Fluhler

"Fluoride and aluminum residuals in elderberry from aluminum smelting, poster session, " XIV Air Pollution Workshop, Boyce Thompson Institute for Plant Research, Cornell University, Ithaca, New York, May 1981.

Taylor, G. E., Jr.

"Air pollution stress and Vegetation response: A study at Oak Ridge National Laboratory," U.S. Environmental Protection Agency, Corvallis Environmental Research Laboratory, Corvallis, Oregon, February 1981.

"Ecophysiological studies of plant response to air pollution stress," Department of Biology, Emory University, Atlanta, Georgia, December 1980.

Taylor, G. E., Jr., S. B. McLaughlin, and D. S. Shriner

"Sulfur-containing gases from synthetic fuels: Their deposition to and effects on vegetation," Air Pollution Workshop, Ithaca, New York, May 1981.

Taylor, G. E., Jr. and D. S. Shriner

"Indicators of air pollution stress in terrestrial ecosystems," 32nd Annual Meeting, American Institute of Biological Sciences, Bloomington, Indiana, August 1981.

Tolbert, V. R.

"Growth response of creek chubs from undisturbed and mining-disturbed streams to different food rations," Tennessee Surface Mining Activities and Research Needs meeting, Oak Ridge National Laboratory, May 1981.

"Sulfur mining effects on benthic communities," East Tennessee Chapter, American Fisheries Society, January 1981.

"Trade-offs of energy production vs environment: ecological costs of surface mining," Tennessee Conservation League Public Information meeting, Cleveland Community College, Cleveland, Tennessee, September 1981.

Tolbert, V. R., H. N. Polovino, M. P. Farrell

"Sensitivity of binary similarity coefficients to differences in stream benthic insect communities," North American Benthological Society, Provo, Utah, April 27-30, 1981.

Trabalka, J. R.

"Analysis of the 1957–58 Soviet nuclear accident," ORAU Training Seminar Series, Oak Ridge Associated Universities, Oak Ridge, Tennessee, January 1981.

Tsai, S. C., J. S. Mattice, K. B. Packard, and W. K. Roy

"The effect of nitrogenous bases on the chlorine toxicity to the mosquitofish (*Gambusia affinis*)," 111th Annual Meeting of the American Fisheries Society, Albuquerque, New Mexico, September 1981.

Turner, R. R.

"Coal: The balancing act of energy production and ecological costs," Tennessee Conservation League Energy Seminar, Cleveland, Tennessee, September 1981.

Tyndall, R. L.

"Association of *Legionella pneumophila* with thermally altered water," East Tennessee Clinical Microbiology Association, Knoxville, Tennessee, August 1981.

"Associations of Legionnaires' Disease bacterium with cooling towers," Annual Meeting of the American Association of Industrial Hygiene, Portland, Oregon, May 1981.

Van Winkle, W., and R. M. Yoshiyama

"Incorporation of density-independent and density-dependent environmental variables into stock-recruitment models," Annual Meeting, American Fisheries Society, Albuquerque, New Mexico, September 1981.

Van Winkle, W., B. L. Kimmel, S. G. Hildebrand, C. C. Coutant, J. S. Mattice, R. B. McLean, S. M. Adams, and J. W. Elwood

"Evolution of reservoir research at Oak Ridge National Laboratory," poster session, International Symposium on Reservoir Ecology and Management, Sainte-Foy, Quebec, Canada, June 1981.

Vaughan, D. S.

"Section 316 (b) and modeling of ichthyoplankton entrainment," Third Conference on Waste Heat Management and Utilization, Miami Beach, Florida, May 1981.

Vaughan, D. S., and D. K. Cox

"The effect of amplitude changes in fluctuating temperature regimes on growth rates and thermal tolerance of juvenile striped bass," 111th Annual Meeting of the American Fisheries Society, Albuquerque, New Mexico, September 1981.

Vaughan, N. D.

"Engineered test facility," DOE/NRC Information Exchange Meeting, Oak Ridge, Tennessee, September 1981.

Voorhees, L. D.

"The environmental impact statement for nuclear power plants," Oak Ridge Associated University Training Institutes, Oak Ridge, Tennessee, May and June 1981.

Walton, B. T.

"Chemical impurity produces extra compound eyes and heads in crickets," Entomological Society of America Annual Meeting, Atlanta, Georgia, November 1980.

"Chemical induction of extra body parts in an insect," Department of Zoology, The University of Tennessee, Knoxville, February 1981.

"Insect teratogens: A potential environmental hazard?" Department of Entomology and Plant Pathology, The University of Tennessee, Knoxville, October 1980.

"Insect toxicants in synthetic fuels," New York Agricultural Experiment Station, Cornell University, Geneva, New York, May 1981.

"Isolation and activity of coal-derived insect teratogens," Insect Biology Seminar, Cornell University, Ithaca, New York, May 1981.

"Isolation and activity of insect toxicants from synthetic fuels," Department of Environmental Toxicology, University of California, Davis, June 1981.

"Toxicity and pharmacodynamic behavior of acridine in the cricket (*Acheta domesticus*)," The University of Tennessee, Knoxville, November 1980.

Walton, B. T., M. V. Buchanan, A. R. Jones, and C.-H. Ho

"Isolation, identification, and physiochemical properties of an insect teratogen," American Society of Zoologists Annual Meeting, Seattle, Washington, December 1980.

Watts, J. A.

"CO_2 information support—Numeric data activities," presented to Thomas Gross, Carbon Dioxide and Climate Program, Department of Energy, Oak Ridge National Laboratory, September 1981.

"Numeric data management for carbon dioxide," National Academy of Sciences Advisory Panel on Numeric Information meeting, Oak Ridge National Laboratory, December 1980.

"Vegetation classification for estimating carbon storage," IN-PLACE Resource Inventories: Principles and Practices meeting, Orono, Maine, August 1981.

Webb, J. W.

"Dynamics of canopy arthropod communities on uncut and clearcut hardwood watersheds," poster session, Annual Meeting of the Ecological Society of America, Indiana University, Bloomington, Indiana, August 1981.

Weller, D. E., R. V. O'Neill, and R. H. Gardner

"Chaotic models as representations of ecological systems," Annual Meeting of the American Institute of Biological Sciences, Bloomington, Indiana, August 1981.

Wright, L. L., and J. S. Mattice

"Factors affecting size, fecundity, and survivorship in *Hexagenia bilineata*; particularly temperature," 29th Annual Meeting, North American Benthological Society, Provo, Utah, April 1981.

Yeh, G. T.

"A multi-dimensional model for simulating Moisture and thermal transport in unsaturated aquifer systems," Twelfth Annual Pittsburgh Modeling and Simulation Conference, Pittsburgh, Pennsylvania, April–May 1981.

"Numerical solutions of navier-stokes equations in multi-dimensional space," Joint ASME/ASCE Mechanics Conferences, Boulder, Colorado, June 1981.

Yeh, G. T., and T. Tamura

"Geohydrological Considerations in Land Disposal of LLW," 1981 ANS Annual Meeting, Miami, Florida, June 1981.

Theses

Parr, P. D. 1981. Effects of Orocol TL (a corrosion inhibitor) on germination and growth of bush beans. M.S., The University of Tennessee, Knoxville.

Professional Activities

ADAMS, S. M.

Member:	Awards Committee, American Fisheries Society; American Institute of Fisheries Research Biologists.
Participant:	Annual Meeting, American Fisheries Society, Albuquerque, New Mexico, September 1981.
Advisor:	M. M. Huffman, Research Intern, ORAU, Oak Ridge, Tennessee.
Ad hoc reviewer:	*Transactions of the American Fisheries Society;* Chesapeake Bay EPA Synthesis Report; proposals: NSF.

BARD, C. S.

Participant:	Program review: Uncertainties in Assessment of Long-Term Collective Dose and Health Effects from Geologic Disposal of High-Level Waste.

BARNTHOUSE, L. W.

Member:	Funding Panel, Hudson River Foundation for Science and Environmental Research, Inc.
Participant:	Workshop on Long-Term Biological Monitoring for the Hudson River, New York, New York, July 8–9, 1981.
Ad hoc reviewer:	*Environment International, Science.*

BARTELL, M.

Chairman:	Cochairman, Savannah River Ecology Laboratory Symposium, Dynamics of Lotic Ecosystems; Coeditor of proceedings of same symposium.
Advisor:	Graduate committee member: Robert Henry, Ph.D., Institute of Ecology, University of Georgia; Alan Groeger, Ph.D., Department of Zoology, University of Oklahoma.
Ad hoc reviewer:	Ecosystem research proposals for NSF.

BLASING, T. J.

Participant:	Rapporteur, Biospheric Effects Panel, DOE Carbon Dioxide Effects Workshop, Harpers Ferry, West Virginia, June 1981.
Ad hoc reviewer:	*Arctic and Alpine Research, Ecology, Monthly Weather Review, Journal of Environmental Quality, Science;* proposals: NSF.
Other:	Treasurer, East Tennessee Chapter of the American Meteorological Society, 1980–1981; Member, ESD Computer Advisory Committee; Travelling Lecturer, ORAU.

BLAYLOCK, B. G.

Chairman:	Session Chairman, International Symposium on Migration in the Terrestrial Environment of Long-Lived Radionuclides from the Nuclear Fuel Cycle, IAEA, Knoxville, Tennessee, July 27–31, 1981.
Member:	Research Committee, Water Pollution Control Federation; Subcommittee on Toxic Substances, 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, The University of Tennessee, Knoxville.
Advisor:	Alex J. Boerner, M.S., Institute of Radiation Biology, The 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, Environment International.*

BOEGLY, W. J., Jr.

Member:	Committee on Utilities, 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; Committee D34 on Waste Disposal, ASTM; Symposium Committee for the 4th Annual Life Sciences Symposium on Environment and Solid Wastes.
Faculty:	Associate Professor, The University of Tennessee, Knoxville.
Advisor:	Douglas Allen, Ph.D., The University of Tennessee, Knoxville.
Ad hoc reviewer:	Proposals: EPRI, DOE.
Other:	Energy Conservation Coordinator, ESD, ORNL.

BRADBURN, DENNIS M.

Chairman:	Tennessee Tree Farm Association, District II.
Participant:	FORTRAN Language Course, ORNL, Oak Ridge, Tennessee, October–December 1980; Continuing Education Unit, Communication Workshop, Nashville, Tennessee, December 1980.

BRECK, JAMES E.

Ad hoc reviewer:	*Ecology.*

BROWMAN, M. G.

Participant: Planning-retreat for EPA Exposure Evaluation Division (OPTS) and its contractors; presentation of Multimedia Modeling Project results and plans, Luray, Virginia, October 29–31, 1980; trip to EPA-SERL, Athens, Georgia, discussion of status of physicochemical process formulations resulting from research, January 26–27, 1981.

Other: Mentor, Summer Research Apprenticeship Program for High School Students, June–July, 1981.

BROWN, D. K.

Participant: First ASTM Symposium on Hazardous Solid Waste Testing, Ft. Lauderdale, Florida, January 14–15, 1981; Second International Conference on Hazardous Waste Management, Denver, Colorado, October 27–29, 1980.

CADA, GLENN F.

Participant: Second National Policy Workshop on the National Hydropower Study, Portland, Oregon, November 20, 1980; Basic Use of Radionuclides in Research course, Oak Ridge, Tennessee, December 8–19, 1980; preparation of: Environmental Development Plan for the Small-Scale Hydropower Development Program, DOE.

Consultant: U.S. Agency for International Development, Washington, D.C.; National Rural Electric Cooperative Association, Washington, D.C.; Chesapeake Bay Foundation, Annapolis, Maryland.

Witness: Expert witness regarding entrainment mitigation in the matter of Delmarva Power and Light Company's Vienna Unit 9, 1981.

CHRISTENSEN, S. W.

Consultant: Salem Technical Advisory Group (EPA, Region II); Chesapeake Bay Foundation.

Ad hoc reviewer: *American Naturalist;* USFWS, National Marine Fisheries Service.

COUTANT, C. C.

Chairman: ESD Scientific Achievement Award Selection Committee; ASTM Task Force on Modeling Chemical Transport, Committee on Biological Effects and Environmental Fate.

Member: ORNL Wigner Fellowship Selection Committee; ORNL General Energy Conservation Committee; ORNL World's Fair Committee; Editorial Advisory Committee, *Environmental Science and Technology;* American Institute of Fishery Research Biologists Thompson Award Committee; American Fisheries Society, Program Committee.

Participant: Mentor, ORNL Summer Research Apprenticeship Program for High School Students; Session Chairman, American Fisheries Society Annual Meeting, Albuquerque, New Mexico, September 16–18, 1981; Session Chairman, Third Waste Heat Management and Utilization Conference, Miami Beach, Florida, May 11–13, 1981; ASTM, Committee on Biological Effects and Environmental Fate, Philadelphia, Pennsylvania, October 9–10, 1980; ASTM, Committee on Biological Effects and Environmental Fate, Indianapolis, Indiana, March 18–19, 1981; Ecological Society of America, Annual Meeting, Bloomington, Indiana, August 17–19, 1981.

Faculty: Adjunct Associate Professor, The University of Tennessee, Knoxville; Adjunct Professor, Tennessee Technological University, Cookeville.

Advisor: Bradley Pearman, undergraduate research participant, DePauw University, Greencastle, Indiana; Committee: Mark Tisa, M.S., The University of Tennessee, Knoxville; Joe Minton, M.S., The University of Tennessee, Knoxville; Marc Bruner, Ph.D., The University of Tennessee, Knoxville; Primary Research Advisor: Terry Cheek, M.S., Tennessee Technological University, Cookeville.

Ad hoc reviewer: *Southwestern Naturalist, Environmental Science and Technology, Transactions of the American Fisheries Society, Journal of Great Lakes Research;* proposals: NSF.

Other: Vice-Chairman, Applied Ecology Section, Ecological Society of America; Secretary-Treasurer, East Tennessee Chapter, American Fisheries Society; Vice-Chairman, Environmental Quality Advisory Board, City of Oak Ridge, Oak Ridge, Tennessee; Editor, Underwater Telemetry Newsletter.

CUSHMAN, J. H.

Member: Tennessee State Reclamation Committee, Rural Abandoned Mines Program.

Participant: Session Chairman, IRA Forestry Energy Biomass Systems Analysis Workshop, Dublin, Ireland, October 30–31, 1980; Energy from Biomass Conference, Commission of the European Communities, Brighton, England, November 1980; DOE Wood Commercialization Program Review, Washington, D. C., February 1981; Short-Rotation Woody Crops Program Contractors' Workshop, Issaquah, Washington, September 1981.

CUSHMAN, ROBERT M.

Advisor: Gary A. Kazlow, B.S., Emory University, Atlanta, Georgia.

CUTSHALL, N. H.

Participant: IAEA Panel on Migration of Radionuclides from Waste Disposal Sites, Oxford, England, June 29–July 3, 1981; National Low-level Waste Management Program 2nd Annual Information Meeting, San Diego, California, January 6–7, 1981.

Ad hoc reviewer: EPA; Office of Marine Pollution Assessment, NOAA; DOE; Virginia Sea Grant Program, Estuarine and Coastal Marine Sciences.

DANIELS, KAREN L.

Participant: Joint Statistical Meetings of the American Statistical Association Biometric Society, Detroit, Michigan, August 1981.

DAVIS, E.C.

Participant: ACS Annual Meeting of the Division of Environmental Chemistry, New York, New York, August 1981; ASCE Specialty Conference on Energy and the Man-Built Environment, Vail, Colorado, August 1981; ASCE Environmental Engineering Division Conference, Atlanta, Georgia, July 1981.

DeANGELIS, D. L.

Faculty: Adjunct Professor, The University of Tennessee, Knoxville.

Advisor: Patrick J. Cocke, M.S., Department of Mathematics, The University of Tennessee, Knoxville.

Ad hoc reviewer: *Ecology, American Naturalist, Mathematical Biosciences, Journal of Mathematical Biology, Theoretical Population Biology, Journal of Theoretical Biology;* proposals: NSF.

DELCOURT, H. R.

Participant: Vice-Chairperson, Paleoecology Section of the Ecological Society of America, 1980–81; Chairperson, Paleoecology Section of the Ecological Society of America, 1981–82; Coorganizer for 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; Organizer and Chairperson, the Paleoecology Symposium, "Dynamic Plant Ecology: Studies in Late-Quaternary Vegetational Change," 1981 Annual Meetings of the Ecological Society of America, August 19, Indiana University, Bloomington.

Ad hoc reviewer: *Ecology, Bulletin of the Torrey Botanical Club;* proposals: NSF.

DYER, M. I.

Ad hoc reviewer: Long-Term Ecological Reserve Program for Oregon State University.

EDDLEMON, GERALD K.

Member: ORNL review team for Environmental, Socioeconomic, Health and Safety Review for Breckinridge Project.

Participant: Seventh National Conference on Energy and the Environment, Phoenix, Arizona, November 1980; preparation of: Programmatic Draft Environmental Assessment for the Fallon Naval Air Station Geothermal Development Program, September 1981; Draft Generic Environmental Report Guidelines for Department of Energy Activities, 1981; Chattanooga Shale: An Assessment of the Resource and Technology for the Recovery of Hydrocarbons and Minerals (Draft), 1981; Draft Health and Environmental Effects Document on H-Coal, DOE, 1981.

EDWARDS, N. T.

Participant: Whole-Tree Harvest Workshop, Seattle, Washington, January 1981.

Ad hoc reviewer: *Environmental and Experimental Botany, BioScience, Forest Science;* proposals: NSF.

Other: Tour group presentations: The University of Tennessee senior ecology classes, November 21, 1980, and May 4, 1981.

ELMORE, JAMES L.

Participant: Preparation of PDEIS for Conoco Sand Rock Uranium Mine and Mill (Campbell County, Wyoming); PDEIA for Barnwell Low-Level Waste Disposal Facility (Barnwell County, South Carolina); EIAs for fuel alcohol plants (Agrifuels Refining Corp., New Iberia, Louisiana; U.S. Ethanol Corp., East Baton Rouge Parish, Louisiana; Gulf Coast Resources, Inc., Keokuk, Iowa; grant proposal to DOE biomass program, An Environmental Evaluation of Freshwater Biomass-for-Energy Systems; Coordinator for Moonshine to Motor Fuel: A Workshop on Regulatory Compliance for Fuel Alcohol Production, Atlanta, Georgia, March 3–4, 1981.

ELWOOD, JERRY W.

Member: Executive Committee, North American Benthological Society.

Faculty: Adjunct Assistant Professor, The University of Tennessee, Knoxville.

Advisor: Research advisor for Carole Hom, M.S., The University of Tennessee, Knoxville.

Consultant: EPRI, Palo Alto, California.

Ad hoc reviewer: *Ecology, Ecological Monographs, Canadian Journal of Fisheries and Aquatic Science, Science, Journal of Environmental Quality;* EPRI, NSF.

EMANUEL, W. R.

Member: ESD Graduate Student Selection Committee.

Participant: Preparation of: background statement on The Carbon Dioxide Issue for the National Petroleum Council.

FARRELL, M. P.

Participant: Organizer and Session Chairman, Annual Meetings of the American Statistical Association, Detroit, Michigan, August 1981; Sixth Annual SAS Users Group, International Conference, Orlando, Florida, February 1981; Meetings of the American Society of Quality Control, Tulsa, Oklahoma, October 1980; DOE Statistical Symposium, Berkeley, California, October 1980.

Faculty: Adjunct Professor, Miami University, Oxford, Ohio.

Advisor: Danney Lee, M.S., The University of Tennessee, Knoxville; H. N. Polovino, M.S., Miami University, Oxford, Ohio, and Ph.D., The University of Tennessee, Knoxville; J. C. Waterhouse, Ph.D., The University of Tennessee, Knoxville.

Other: Best paper, Sixth Annual SAS User's Group, International Meeting, Orlando, Florida, February 1981.

FRANCIS, C. W.

Chairman: Chairman, Working Group for preparation of summary document, "Status of Health and Environmental Research Relative to Solid Wastes from Coal Conversion," for DOE-OHER.

Member: Review team for Oil Shale Solid Waste DOE/FE/OHER Peer Review, Gaithersburg, Maryland, May 19–20, 1981; review team for Brookhaven National Laboratory Marshall Island Studies, Brookhaven National Laboratory, May 21–22, 1981.

Ad hoc reviewer: Ecological Society of America; *Journal of Environmental Quality, Environmental Science and Technology;* proposals: DOE, NSF.

FRANCO, PAUL J.

Advisor: G. A. Kazlow, B.A., Emory University.

GARDNER, ROBERT H.

Member: Advisory committee to Fertility and Tilth Effects of Fuel Crop Residue Removal, a DOE/USDA joint project.

Participant: HDR Sciences Modeling Workshop, Santa Barbara, California, February 5–6; Symposium on Uncertainties Associated with the Regulation of the Geological Disposal of High-Level Radioactive Waste, Gatlinburg, Tennessee, March 9–13; 1981 Summer Computer Simulation Conference, Washington, D.C., July 15–17.

Advisor: D. E. Weller, Ph.D., The University of Tennessee, Knoxville; Y. I Jager, M.S., The University of Tennessee, Knoxville.

Ad hoc reviewer: *Ecology, Environmental Management;* proposals: NSF.

GARTEN, CHARLES T., Jr.

Member: DOE Panel on Actinide Modeling.

Participant: Workshop on Environmental Research for Actinide Elements, Lawrence Livermore Laboratory, Livermore, California, March 1981; International Symposium on Migration in the Terrestrial Environment of Long-Lived Radionuclides from the Nuclear Fuel Cycle, Knoxville, Tennessee, July 1981.

Ad hoc reviewer: *Environmental and Experimental Botany, Journal of Environmental Quality, Ecology, Australian Journal of Ecology;* ORNL Seed Money Proposal.

Other: Section Editor, *Nuclear Safety.*

GIDDINGS, JEFFREY

Advisor: Michele Ricard, M.S., The University of Tennessee, Knoxville; Mary Ashley, B.S., Kenyon College, Gambier, Ohio; Susan Badamo, B.S., Roger Williams College, Bristol, Rhode Island; Lisa Huberty, Lawrence University, Appleton, Wisconsin.

Ad hoc reviewer: *Science, Environmental Science and Technology, Environment International;* EPA, EPRI; proposals: NSF, EPA.

Other: Ph.D. recruiter, Cornell University, Ithaca, New York.

GOUGH, S. B.

Member: Magnetic Fusion Energy Environmental Project Task Group for Materials Considerations; ESD Seminar Committee (until end of calendar year 1980); Adjuvant to ORNL Biotechnology Committee.

Participant: Proposals: DOI (OWRT), EPRI, NRC, EPA.

Advisor: Dr. Barry Batzing (on sabbatical for one year at ORNL); Dr. Raj Bahadur (ORAU Guest Appointment).

Consultant: On free-living pathogens for aquifer thermal energy storage demonstration project (PNL); ORO/LDB work; sewage oxidation pond (aquatic plant management) (ORNL); input on scope and technical content for EIP aquatic biomass pre-assessment; control of Legionnaires' Disease Bacterium at utilities.

Ad hoc reviewer: *Science, Botanical Gazette, Limnology and Oceanography, Journal of Biotechnology and Bioengineering;* ORNL Seed Money Committee; proposals: EPRI, NSF, SERI.

Other: Ph.D. recruiter, University of Wisconsin, Madison, University of Minnesota, Twin Cities.

GOYERT, JONATHAN C.

Participant: Joint Statistical Meetings, American Statistical Association Biometric Society, Detroit, Michigan, August 1981.

HAASE, C. B.

Participant: Annual Meeting of the Geological Society of America, Atlanta, Georgia, November 1980; DOE/BES Workshop on Basic Research in Organic Geochemistry Applied to National Energy Needs, St. Petersburg, Florida, December 1980; Annual Meeting of the Geological Society of America, Southeastern Section, Hattiesburg, Mississippi, March 1981; Gordon Conference on Hydrothermal Systems Related to Ore Deposits, New London, New Hampshire, August 1981.

Consultant: IAEA, preparation of: Report on Hydraulic Fracturing Method of Radioactive Waste Disposal, Oak Ridge, Tennessee, June 1981.

Ad hoc reviewer: *American Mineralogist.*

HERBES, S. E.

Participant: Workshops on Risk Analysis of Synthetic Fuel Technologies, Oak Ridge, Tennessee, May and July 1981.

Advisor: Jeffrey S. Sartin, Emory University Research Internship; Troy E. Wright and Regina M. Davis, Summer Research Apprenticeship Program for High School Students, Knoxville, Tennessee.

Ad hoc reviewer: *Environmental Science and Technology, Environment International;* Water Resources Research Center, The University of Tennessee, Knoxville; proposals: DOE, NSF.

HILDEBRAND, S. G.

Chairman: Session 14, Impact Analysis, Environmental Considerations, Waterpower 81, International Conference on Hydropower, Washington, D.C., June 1981.

Member: ORNL Ad Hoc Committee on Energy and Water; ORNL Risk Task Force; Organizing Committee for Engineering Foundation Conference on Small Hydroelectric Development; Acidic Deposition Evaluation, Synthesis and Assessment, Committee of the National Laboratories Research Consortium; Review Panel, Energy Law Institute, Franklin Pierce Law Center.

Participant: The 37th Northeast Fish and Wildlife Conference; Waterpower '81, International Conference on Hydropower, Washington, D.C., June 1981; Annual Meeting of the American Water Resources Association.

Ad hoc reviewer: *International Journal of Environmental Studies;* NSF.

HUFF, D. D.

Participant: American Geophysical Union Chapman Conference on Subsurface Water Contributions to Streamflow, Durham, New Hampshire, October 5-9, 1980; IAEA Symposium on Radionuclide Migration in the Environment, Knoxville, Tennessee, July 27-30, 1981; preparation of: Environmental Impact Evaluation, Proposed Radiological Survey of Shpack Landfill, Norton, Massachusetts.

Faculty: Adjunct Associate Professor, The University of Tennessee, Knoxville.

Ad hoc reviewer: Water Resources Research, NSF, DOE-OHER.

JOHNSON, D. W.

Member: Impact Assessment Work Group, U.S.-Canada Transboundary Air Pollution Memorandum of Intent.

Participant: Session organizer, International Conference of Energy Use Management, Berlin, West Germany, October 1981; Office of Technology Assessment Study on Long-Range Transport Air Pollution.

Faculty: Adjunct Professor, The University of Tennessee, Knoxville.

Ad hoc reviewer: NSF, Man and the Biosphere, EPA, Organization for Tropical Studies; *Water Resources Research, Soil Science Society of America Journal, Soil Biology and Biochemistry, Journal of Environmental Quality, Science.*

KANCIRUK, PAUL

Participant: Workshop on Environmental Impacts of Open-Ocean Kelp Farming, Gas Research Institute and Lawrence Berkeley Laboratories, April 1981.

KIMMELL, B. L.

Member: Board of Governors and Wilks Award Committee, Southwestern Association of Naturalists.

Participant: DOE-OHER Freshwater Research Program Workshop, Reston, Virginia, March 1981; Southwestern Association of Naturalists, Annual Meeting, New Orleans, Louisiana, April 1981; International Symposium on Reservoir Ecology and Manage-

ment, Quebec City, Canada, June 1981; American Society of Limnology and Oceanography, Annual Meeting, Milwaukee, Wisconsin, June 1981; International Symposium on Acid Rain/Fisheries, Ithaca, New York, August 1981.

Faculty: Adjunct Assistant Professor, University of Oklahoma, Norman.

Advisor: M. M. White, M.S., University of Oklahoma, Norman; A. W. Groeger, Ph.D., University of Oklahoma, Norman, DOE-ORAU Laboratory Graduate Research Participant; J. J. Elser, University of Notre Dame, Notre Dame, Indiana, DOE-ORAU Summer Research Participant.

Ad hoc reviewer: *Limnology and Oceanography, Southwestern Naturalist;* proposals: DOE-OHER, NSF.

KITCHINGS, J. T.

Participant: Associated Southeastern Biologists Annual Meeting, Knoxville, Tennessee, April 1981.

Ad hoc reviewer: NSF.

Other: Assisted U.S. Army Corps of Engineers staff with Habitat Evaluation Models; presentations on wildlife research at ORNL to various tour groups.

KROODSMA, ROGER L.

Participant: Annual Meeting, Tennessee Ornithological Society, Montgomery Bell State Park, Tennessee, October 1980; Annual Meeting, American Institute of Biological Sciences, Bloomington, Indiana, August 1981; Preparation of: FEIS, Memphis Light, Gas, and Water Division, Industrial Fuel Gas Demonstration Plant; FEIS, Solvent Refined Coal—I Demonstration Plant; FEIS, Solvent Refined Coal—II Demonstration Project; Environmental Report Guidelines for DOE projects.

Advisor: Secondary Advisor of Steven Seagle, Ph.D., The University of Tennessee, Knoxville.

Ad hoc reviewer: *The Auk, Wildlife Monographs.*

KRUMMEL, JOHN R.

Consultant: Association Argentina de Consorcios Regionales de Experimentacion Agricola, Buenos Aires, Argentina.

Witness: Hearings before the Tennessee State Water Quality Board; expert witness for the Environmental Defense Fund on the issuance of a water quality permit for the TVA Duck River project.

Ad hoc reviewer: *BioScience.*

Other: Secretary-Treasurer, Society for Human Ecology.

LEE, S. Y.

Participant: Waste Rock Interaction Technology Information Meeting, Seattle, Washington, October 1980.

Ad hoc reviewer: *Journal of Environmental Quality, Soil Science Society of America Journal.*

LINDBERG, S. E.

Chairman: Cochairman, National Atmospheric Deposition Program Committee on Data Management and Interpretation; Cochairman, Technical Session on Metals in and from the Atmosphere, International Conference on Heavy Metals in the Environment, September 1981, Amsterdam, The Netherlands.

Member: MAP3S Network for Precipitation Chemistry; DOE Program Review Team, Illinois State Water Survey; National Atmospheric Deposition Program Committee on Dry Deposition Methodology.

Participant: Plant Canopy Structure Workshop, Oak Ridge, Tennessee, April 1981; Annual Review of EPRI Integrated Lake/Watershed Acidification Study, Sagamore, New York; Conference on Effects of Acid Precipitation on Ecological Systems in the Great Lakes Region, East Lansing, Michigan, April 1981; International Conference on Heavy Metals in the Environment, Amsterdam, The Netherlands, September 1981; National Field Experiment on Oxidation and Scavenging Characteristics of April Rains, April 1981; EPA Dry Deposition Methodology Intercomparison Study, Champaign, Illinois, September 1981.

Ad hoc reviewer: *Journal of Environmental Quality, Environmental Science and Technology, Environmental and Experimental Botany, Geophysical Research Letters, Science;* proposals: NRC, DOE, EPA, EPRI.

LOAR, JAMES M.

Chairman: Workshop on Environmental Aspects of Small Hydroelectric Development, Engineering Foundation Conference, Henniker, New Hampshire, July 1981.

Participant: Third Miami International Conference on Alternative Energy Sources, Miami Beach, Florida, December 1980; Instream Flow/Negotiations Short Course, U.S. Fish and Wildlife Service, Boston, Massachusetts, April 1981; Session Chairman, Engineering Foundation Conference on Small Hydroelectric Development, Henniker, New Hampshire, July 1981.

Ad hoc reviewer: U.S. Army Corps of Engineers.

LUXMOORE, R. J.

Member: S-124 Regional Technical Committee on Soil Water Research; Rural Abandoned Mines Program Committee for Morgan County, Tennessee; ESD representative on the ORNL Committee on Meteorological Data Users; Ad Hoc Committee on Soil Porosity Terminology, Soil Science Society of America.

Advisor: Mary H. Ward, M.S., The University of Tennessee, Knoxville.

Ad hoc reviewer: *Transactions of the American Society of Agricultural Engineers, Water Resources Research, Agronomy Journal;* proposals: NSF.

McBRAYER, J. F.

Member: Review panel, USDA herbaceous biomass awards.

Participant: EPA Seminar on Environmental Impacts of Alcohol-fuel Facilities, Kansas City, Missouri, December 2, 1981; Session Chairman, Moonshine to Motor Fuel: A Workshop on Regulatory Compliance for Fuel Alcohol Production, Atlanta, Georgia, March 3-4, 1981; Environmental Assessment of producing oil from the Chattanooga Shale; Project Manager, Generic Environmental Assessment Report for Conventional Fuel Alcohol Plants; Project Manager, Generic Health and Safety Analysis Report for Conventional Fuel Alcohol Plants.

Ad hoc reviewer: *American Midland Naturalist;* proposals: DOE, NSF.

McLAUGHLIN, S. B.

Member: TE-2 Agricultural Effects Committee, APCA.

Participant: Program Reviewer for EPA Air Ecology Program, December 1980; Chapter Reviewer for Acid Rain and SO_2 and Particulate Chapters of EPA's Criteria Document; Scientific Coordinator for EPA's Research Program on Acid Rain Effects on Natural Terrestrial Systems within the United States; Comoderator of session on Effects of SO_2 on Vegetation at XI, Air Pollution Workshop, Ithaca, New York.

Advisor: Roger Walker, Ph.D., The University of Tennessee, Knoxville.

Ad hoc reviewer: *Science, Journal of Environmental Quality;* proposals: DOE.

Other: Scientific Award: 1980 Annual Scientific Achievement Award, ESD, ORNL.

MILLEMANN, R. E.

Chairman: Education Committee, ESD.

Faculty: Professor, The University of Tennessee, Knoxville.

Advisor: Sterling O. Ullrich, Jr., M.S., Ohio State University, Columbus; Daniel S. Ehrenberg, B.A., Earlham College, Richmond, Indiana; Santa J. Tumminia, B.A., St. Joseph's College, Brooklyn, New York.

Ad hoc reviewer: *Canadian Journal of Zoology, Environment International.*

MULHOLLAND, PATRICK J.

Ad hoc reviewer: Proposals: NSF.

NEWBOLD, J. D.

Participant: Symposium on Dynamics of Lotic Ecosystems, DOE, Savannah River Ecology Laboratory, October 19–22, 1980, Savannah, Georgia.

Advisor: Carole L. Hom, M.S., The University of Tennessee, Knoxville.

Ad hoc reviewer: DOE symposium proceedings; proposals: NSF.

NUNGESSER, M. K.

Member: Environmental Quality Subcommittee, Tennessee-Tombigbee Corridor Study, U.S. Army Corps of Engineers, Nashville and Mobile Districts; Environmental Quality Subcommittee Task Force, Tennessee-Tombigbee Corridor Study, U.S. Corps of Engineers, Nashville and Mobile Districts.

Participant: Integrated County-Level Data User's Workshop, Reston, Virginia, October 1980; The 147th Annual Meeting of the American Association for the Advancement of Science, Toronto, Canada, January 1981; The Sixth Annual SAS User's Group International Conference, Lake Buena Vista, Florida, February 1981 (Judged papers at the graphics session); Environmental Quality Subcommittee activities, U.S. Army Corps of Engineers meeting at Mobile, Alabama, August 1981; meeting and tour of Tennessee-Tombigbee Waterway, May 1981.

OAKES, KATHLEEN M.

Member: ORNL Ad Hoc Committee for Unconventional Gas.

Participant: Seminar on Management Skills for Women Supervisors, The University of Tennessee, Knoxville, April 1981; Preparation of: Final Environmental Impact Assessment for the Heber Geothermal Binary-Cycle Demonstration Project, Imperial County, California, October 1981; Draft Environmental Impact Assessment for the Southern

California Edison (SCE) Geothermal Loan Guaranty Project, Imperial County, California; Biological Assessment of Effects of the SCE Project on a Candidate Endangered Species. the Flat-tailed Horned Lizard, submitted to USFWS; Environmental Evaluation for the Boise Geothermal Limited Geothermal Loan Guaranty Project, Ada County, Idaho; Technology-Specific Guidance for Preparing Environmental Reports: Tar Sands; Technology-Specific Guidance for Preparing Environmental Reports: Unconventional Natural Gas Recovery; Eastern Oil Shales Critical Environmental Issues Document.

Other: Coordinator for the ORNL Colloquia Series for 1981.

OLSEN, C. R.

Ad hoc reviewer: *Deep-Sea Research, Environment International.*

OLSON, JERRY S.

Chairman: Cochairman and Organizer, Environmental Consequences of Energy Development: Global CO_2, Third International Conference on Energy Use Management.

Member: National Academy of Sciences, Climate Research Board, Committee on International Programs on Climate; Panel to Review Ecology and Hydrology of Cowles Bog, Indiana Dunes National Lakeshore, and Related Matters of Impact of Bailey Coal and (formerly proposed) Nuclear Power Plants, DOI, October 1980; Panel to Review AAAS Criteria and Priorities for Social Science Research Related to CO_2 and Climate; International Union of Forest Research Organization (IUFRO) Research Group S 1.01.06: Tropical and Subtropical Forest Ecosystems.

Participant: Workshop to Review Previous Large-Scale Assessment of Climate Change; Workshop on Plant Canopy Modeling, NOAA and Science Applications Inc.

Faculty: Professor, The University of Tennessee, Knoxville; Special Course Lecturer, Quaternary Problems (Geology and Ecology) and Mineral Cycling Seminar.

Advisor: Richard Busing, M.S., The University of Tennessee, Knoxville.

Ad hoc reviewer: *Ecology, Science, Climate Change.*

Other: Editorial Board, *Ecological Studies,* Springer-Verlag, Inc.

OLSON, R. J.

Member: Planning Committee, 1981 Integrated Data Users Workshop, DOE Ecological Task Force.

Participant: Workshop Chairman, 1980 Integrated County-Level Data User's Workshop, Reston, Virginia, October 1980; Impacts of Atmospheric Alteration Workshop, Washington, D.C., March 1981; International Symposium for Health Impacts of Different Sources of Energy, Nashville, Tennessee, June 1981; In-Place Resource Inventories: Principles and Practices, Orono, Maine, August 1981.

O'NEILL, E. G.

Participant: American Arachnological Society International Meeting, Knoxville, Tennessee, August 5-8, 1981.

O'NEILL, R. V.

Faculty: Adjunct Associate Professor, The University of Tennessee, Knoxville; Visiting Scientist, Ecosystem Research Center, Cornell University, Ithaca, New York.

Ad hoc reviewer: *Ecology, American Naturalist;* proposals: NSF, EPA.

Other: Associate Editor, *Ecology.*

PARR, P. D.

Participant: Tennessee Academy of Science Workshop on Tennessee Flora—A Review of Rare Plants, Oak Ridge, Tennessee, November 22, 1980; Association of Southeastern Biologists Meetings, Knoxville, Tennessee, April 9, 1981; 1981 UCC-ND Environmental Protection Seminar, Cadiz, Kentucky, April 20-23, 1981.

Other: Biology Division Judge for St. Mary's School Science Fair, Oak Ridge, Tennessee, May 19, 1981; Concept of National Environmental Research Park Logo selected as basis of official sign, October 1980.

PENG, T. -H.

Participant: Workshop on geochemical tracers in the ocean, Woods Hole, Massachusetts, March 23-26, 1981; ACS Annual Meeting, New York City, New York, August 24-28, 1981.

Ad hoc reviewer: *Journal of Geophysical Research.*

Other: Technical interaction with Carbon Dioxide Research Division, DOE, Washington, D.C.

POWERS, C. D.

Chairman: ESD Aquatic Ecology Section Personnel Search Committee; Cochairperson, ESD 1981 United Way Campaign.

Member: ESD Seminar Committee.

Participant: Society of Environmental Toxicology and Chemistry Annual Meeting, Arlington, Virginia, November 23-25, 1981; invited paper, 24th Conference of the International Association for Great Lakes Research, Columbus, Ohio, April 28-30, 1981; preparation of: Blessing (Texas) Geopressured Prospect DEA, Shpack Landfill (Massachusetts) FEI Evaluation, Teton-Nedco Joint Venture (Wyoming) PDES.

Advisor: Gavin Thompson, M.S., Indiana University, Bloomington.

Ad hoc reviewer: Proposals: National Sea Grant Program, National Oceanic and Atmospheric Administration.

Other: Ph.D. recruiter, The University of Michigan, October 2-3, 1980.

RANNEY, J. W.

Chairman: Managing agent for international project on clonal propagation of superior genotypes in short-rotation intensive silviculture, International Energy Agency, Working Group on Forest Growth and Production.

Member: U.S. representative to International Energy Agency Group on Forest Energy Growth and Production; American Forestry Association's National Resources Policy Team concerning energy.

Advisor: John Schutt, Ph.D., The University of Tennessee, Knoxville.

Consultant: Guest lecturer, United Nations—Man and the Biosphere Program, International Training Division, The University of Tennessee summer course on Ecological Basis of Natural Management.

Ad hoc reviewer: *Biotechnology and Bioengineering Journal, Journal of Forestry;* Forest Products Research Society.

REED, ROBERT M.

Participant: Preparation of: Supplement No. 2, Final Environmental Statement, Allens Creek Nuclear Generating Station, Unit No. 1; Draft Technology-Specific Guidance for

	Preparing Environmental Reports on Western Oil Shale, Tar Sand, and Fuel Ethanol.
Witness:	NRC, Atomic Safety and Licensing Board, Hearings on Allens Creek Nuclear Generating Station Construction Permit Application.

REICHLE, D. E.

Chairman:	World's Fair Committee, ORNL.
Member:	Associateship Selection Panel, National Academy of Sciences; Committee on Alternative Programs for Beltwide Cotton Insect Management, Board on Agriculture and Renewable Resources, NSF; Admissions Committee, Graduate Program in Ecology, The University of Tennessee; Advisory Subcommittee for Ecosystem Studies, NSF, Air Quality Task Group, Committee on Environmental Conservation, National Petroleum Council; Landscape and Architectural Review Committee, ORNL.
Participant:	Chairman, External Review Team of the Program in Ecology, Rutgers University, New Brunswick, New Jersey, January 1981; National Research Council Commission on Human Resources Site Review of Naval Ocean Research and Development Activity (NORDA), New Orleans, Louisiana January 1981.
Faculty:	Adjunct Professor, The University of Tennessee, Knoxville.
Advisor:	Christopher Craft, M.S., The University of Tennessee, Knoxville; Steven W. Seagle, Ph.D., The University of Tennessee, Knoxville.
Ad hoc reviewer:	Ecological Society of America; *BioScience;* proposals: NSF, NOAA, EPA, U.S. Department of Commerce.
Other:	Editorial Board, *Pedobiologia;* Consulting Environmental Editor, Springer-Verlag, Inc.; Chairman, ORNL World's Fair Planning Committee.

RICHTER, D. D.

Member:	Secretary, Southern Forest Environment Research Council, 1982–1983.
Participant:	Fourth Annual Madison Conference on Applied Research and Practice on Municipal and Industrial Waste, Madison, Wisconsin, September 1981; Fire Research Committee on DOE NERPs, Gaithersburg, Maryland, September 1981.
Ad hoc reviewer:	Proposals: NSF, DOE.

SALE, R. J.

Participant:	Instream Flow Computer Analysis Workshop, Ft. Collins, Colorado, February 1981; Waterpower '81: An International Symposium on Hydropower, Washington, D.C., June 1981; preparation of: FEIS, Solvent Refined Coal-II Demonstration Project; PDEIS, Illinois Coal Gasification Group Pipeline Gas Demonstration Plant; Draft Technology-Specific Guidance for Preparing Environmental Reports: Tar Sand, Western Oil Shale, and Coal Gasification and Liquefaction.
Other:	Technical advice to NEPA Affairs Division, DOE, related to interagency review of NEPA-related documents.

SALK, MARTHA S.

Chairman:	Cochairman, Moonshine to Motor Fuel: A Workshop on Regulatory Compliance for Fuel Alcohol Production, March 3-4, 1981, Atlanta, Georgia.

SHARPLES, F. E.

Chairman: Cochairman, Moonshine to Motor Fuel: A Workshop on Regulatory Compliance for Fuel Alcohol Production, March 3–4, 1981, Atlanta, Georgia.

Participant: EPA workshop on environmental impacts of fuel alcohol plants, Kansas City, Missouri, December 1980; annual meeting, American Association for the Advancement of Science, Toronto, Canada, January 1981; preparation of: EIS, Conoco's Sand Rock Mill/Moore Ranch Mine project, Campbell County, Wyoming; Environmental Impact Appraisal on proposed licensing amendments for use of raffinate, Kerr-McGee Nuclear Corporation Uranium Hexafluoride facility, Sequoyah, Oklahoma; EA, Circle Research Corporation's fuel alcohol production plant, Garden City, Kansas.

Ad hoc reviewer: Proposals: DOE-OHER.

SHRINER, D. S.

Member: Technical Council, TE-2 Agricultural Effects Committee, Air Pollution Control Association; Scientific Advisory Board, National Atmospheric Deposition Program; Technical Advisor, NAS/NRC Committee on Atmosphere and the Biosphere, Sulfur Oxides Subcommittee; Pollution Effects on Plants Committee, American Phytopathological Society.

Participant: Symposium on Acid Rain Effects on Ecosystems in the Great Lakes Region, East Lansing, Michigan, May 1981; Annual Meeting, Air Pollution Workshop, Ithaca, New York, April 1981.

Faculty: Adjunct Professor, Department of Plant Pathology and Physiology, Virginia Polytechnic Institute and State University, Blacksburg.

Advisor: Matthew Mahoney, Ph.D., VPI&SU, Blacksburg, Virginia; C. I. Klarer, M.S., North Carolina State University, Raleigh.

Ad hoc reviewer: *Science, Journal of the Air Pollution Control Association, Journal of Environmental Quality, Environmental and Experimental Botany;* EPA; proposals: NSF, DOE, EPRI, EPA.

Other: Editor, Effects Division Environmental Report, Air Pollution Control Association.

SHUGART, H. H.

Faculty: Part-time Associate Professor, Graduate Program in Ecology and Botany Department, The University of Tennessee, Knoxville.

Advisor: T. M. Smith, Ph.D., The University of Tennessee, Knoxville; D. A. Weinstein, Ph.D., The University of Tennessee, Knoxville; J. Saldarriage, Ph.D., The University of Tennessee, Knoxville; J. Schutt, Ph.D., The University of Tennessee, Knoxville; D. Weller, Ph.D., The University of Tennessee, Knoxville; D. Moorhead, Ph.D., The University of Tennessee, Knoxville; S. Seagle, Ph.D., The University of Tennessee, Knoxville; A. Hansen, Ph.D., The University of Tennessee, Knoxville.

Other: Panel Member (representing the United States), UNESCO Expert Panel on Systems Ecology; Board of Editors, Ecological Society of America; Editor, *Ecology* and *Ecological Monographs.*

SIGAL, L. L.

Participant: Practical Environmental Law course, Berkeley, California, October 1980; The 13th Annual Air Pollution Workshop, Ithaca, New York, May 1981; The 83rd Annual

Meeting of the American Bryological and Lichenological Society, Highlands, North Carolina, June 1981; The 74th Air Pollution Control Association Meeting, Philadelphia, Pennsylvania, June 1981; preparation of: DEIR Arthur Kill Power Plant, New York, New York, March 1981; DEIR Ravenswood Power Plant, New York, New York, April 1981; PDEIR Salem Harbor Generating Station, May 1981; Preliminary Draft of the Health and Environmental Document of H-Coal Liquefaction, August 1981; Preliminary drafts of Air Quality sections of Units I, II, and III for the Tenn-Tombigbee Corridor Study, September 1981; Acid Deposition Regional Proposal, August 1981.

Ad hoc reviewer: *The Bryologist, Canadian Journal of Botany.*

Other: Editor, Tennessee Native Plant Society Newsletter.

SOLOMON, A. M.

Participant: Annual Meeting, Botanical Society of America, Ecological Society of America, American Institute of Biological Sciences, Bloomington, Indiana, August 16-21, 1981; preparation of: Environmental Impact Assessment, Oak Ridge Gaseous Diffusion Plant Site, August 1981; Final Environmental Statement, Operation of Virgil C. Summer Nuclear Station, Columbia, South Carolina, May 1981; Terrestrial Ecosystems, Climate, and the Global Carbon Cycle, a renewal proposal to NSF, January 1981; Addendum to DEB-8115316 Terrestrial Ecosystems, Climate, and the Global Carbon Cycle, a renewal proposal to NSF, June 1981.

Other: Editor, American Quaternary Association Newsletter, 1979-present; Ex-officio Member, AMQUA Council; Secretary, Paleoecology Section, Ecological Society of America, 1980-1982; Murray F. Buell Award Committee and Judge, Ecological Society of America, 1981.

SOUTHWORTH, G. R.

Participant: Spills Research Planning Workshop, EPA, Narragansett, Rhode Island, January 28-30, 1981.

Ad hoc reviewer: Proposals: ORNL Seed Money, NOAA.

SPALDING, BRIAN P.

Member: USDA Technical Committee No. 59.

Ad hoc reviewer: *Soil Science Society of America Journal, Journal of Environmental Quality, Soil Biology and Biochemistry, Soil Science;* proposals: NSF.

STORY, JAY D.

Other: Continuing numerous 10-30-minute talks to tour groups.

STRAND, R. H.

Chairman: Program Chairman, Statistical Computing Section, American Statistical Association Annual Meetings, August 1981; Chairman-elect for 1982, Statistical Computing Section, American Statistical Association.

Member: ORNL Subcommittee on Future Computing Technology.

STRAYER, R. F.

Ad hoc reviewer: *Applied and Environmental Microbiology;* report for Water Resources Research Center, The University of Tennessee, Knoxville.

STOW, S. H.

Member:	International Geologic Correlation Program on Volcanic Rocks; ORNL Materials Recommendation Committee; Student Support Committee, Geological Society of America.
Participant:	National Geological Society of America Annual Meeting, Atlanta, Georgia, November 1980; Office of Nuclear Waste Isolation, NTS, Annual Meeting, Columbus, Ohio, December 1980; Principles of Groundwater Contamination Seminar, Pittsburgh, Pennsylvania, December 1980; IAEA Conference on Migration of Radionuclides, Knoxville, Tennessee, July 1981; Southeastern Section Geological Society of America Meeting, Hattiesburg, Mississippi, March 1981; Symposium on Uncertainties Associated with Regulation of the Geologic Disposal of High-Level Nuclear Waste, Gatlinburg, Tennessee, March 1981.
Advisor:	L. Long, M.S., University of Alabama, Tuscaloosa; D. Whittington, M.S., University of Alabama, Tuscaloosa; K. Rheams, M.S., University of Alabama, Tuscaloosa; L. Bundschv, M.S., University of Alabama, Tuscaloosa; M. Steltenpohl, M.S., University of Alabama, Tuscaloosa; K. Fronabarger, Ph.D., The University of Tennessee, Knoxville.
Other:	Secretary-Treasurer, Southeastern Section Geological Society of America; Advisor to City of Farragut, Tennessee, on drainage and erosion control ordinances.

SUTER, G. W., II

Chairman:	ORNL Workshop on Risk Analysis Units for Synfuels Risk Assessment, ORAU, Oak Ridge, Tennessee, May 20-21, 1981.
Participant:	EPA Workshop, Categorization of Chemical Compounds Associated with Synfuel Technologies for Risk Assessment, Alexandria, Virginia, July 1981; ORNL workshop, Methods for Environmental Risk Assessment, ORAU, Oak Ridge, Tennessee, May 1981; Environmental Evaluation of Federal Actions in the Blessing Geothermal Prospect, Matagordo County, Texas.
Advisor:	Patricia Gregory, M.S., Miami University, Oxford, Ohio.
Ad hoc reviewer:	*Pedibiologia, American Naturalist;* proposals: EPRI, USFWS.

TAMURA, T.

Member:	EPRI Solid Waste Advisory Committee; UMTRAP/DOE Liners Task Group; Site Selection Committee of NLLWMP; Executive Committee, Environmental Division/ANS; NAEG Site Cleanup Committee.
Participant:	IAEA Consultants Meeting on Radioactive Waste by Hydraulic Fracturing, ORNL, Oak Ridge, Tennessee, June 8-12, 1981; IAEA Advisory Group Meeting on Safety Analyses for Radioactive Waste Repositories in Shallow Ground, ORNL, Oak Ridge, Tennessee, August 3-7, 1981; NRC Workshop on Maxey Flats Remedial Action, Frankfort, Kentucky, July 22-23, 1981.
Faculty:	Adjunct Professor, Graduate Program in Geology, The University of Tennessee, Knoxville.
Advisor:	Donald V. Crider, M.S., The University of Tennessee, Knoxville; A. K. Fronabarger, Ph.D., The 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, Environmental Science and Technology Journal;* proposals: EPRI.

TAYLOR, F. G.

Chairman:	Cochairman, Workshop, Impacts of Vegetation on Building Microclimates, Pennsylvania State University, State College, Pennsylvania, February 1981.
Participant:	The 16th National Air Pollution Workshop, Boyce Thompson Institute for Plant Research, Cornell University, April 1981; UCC-ND and Goodyear Atomic Environmental Protection Seminar, Cadiz, Kentucky, May 1981; DOE Accidental UF_6 Release Workshop and Seminar, Oak Ridge Tennessee, June 1981; Impacts of Vegetation on Building Microclimates Workshop, Pennsylvania State University, State College, Pennsylvania, February 1981.
Advisor:	Patricia D. Parr, M.S., The University of Tennessee, Knoxville.
Other:	Recording Secretary, Tennessee Native Plant Society, 1981; ESD Coordinator for Air Pollution Studies in Great Smoky Mountains National Park, National Park Service.

TAYLOR, GEORGE E., Jr.

Member:	Executive Steering Committee, Air Pollution Workshop.
Participant:	The 13th Annual Air Pollution Workshop, Ithaca, New York, April 1981; American Institute of Biological Sciences Annual Meeting, Bloomington, Indiana, July 1981.
Advisor:	Eloise B. Carter, Ph.D., Emory University, Atlanta, Georgia.
Consultant:	EPA, Criteria Assessment Office, Research Triangle Park, North Carolina.
Ad hoc reviewer:	*Plant Physiology, Journal American Society of Horticultural Science, Ecological Research Series;* proposals: EPA, USFWS.

TOLBERT, V. R.

Chairman:	Tennessee Surface Mining Activities and Research Needs ESD, ORNL, Oak Ridge, Tennessee, May 1981; Session Chairman, Aquatic Ecology, Association of Southeastern Biologists, Knoxville, Tennessee, April 1981.
Member:	State Reclamation Committee, Rural Abandoned Mines Program, 1979-present; Review Committee for Glossary of Surface Mining and Reclamation Technology, American Council for Reclamation Research, June 1981.
Participant:	North American Benthological Society, Provo, Utah, April 1981; Tennessee Surface Mining Activities and Research Needs, Oak Ridge, Tennessee, May 1981; Synfuels and the Environment, Washington, D.C., October 1980; preparation of: DEIS related to the TVA Decommissioning of the Edgemont Uranium Mill, Fall River County, South Dakota, NRC; PDEA, Chattanooga Shale Development, ORNL Seed Money Committee; Mitigation Measures for Erosion and Sedimentation Control for Geothermal Development, DOE; DEA, Geothermal Energy, Heber Geothermal Binary-cycle Demonstration Project, DOE.
Advisor:	Erin E. Brewer, B.S., University of the South, Sewanee, Tennessee, Southern College University Union Science Semester Student at ORNL, January-April 1981.
Ad hoc reviewer:	*Entomological Society of America, Journal of Microscopical Society.*

TRABALKA, J.R.

Member:	ORNL Seed Money Proposal Review Committee; ORNL Professional Education Resource Committee for Life Sciences.
Participant:	Transuranics Workshop, DOE, Livermore, California, March 1981.
Advisor:	L. K. Rood, Eastern Kentucky University, Richmond, Kentucky, 1981 Southern College Union Science Semester Student at ORNL.

TURNER, R. R.

Chairman:	ESD Seminar Committee.
Member:	ESD Hazardous Chemical Safety Committee.
Participant:	NBS/DOE Workshop, Environmental Speciation and Monitoring Needs for Trace Metal-Containing Substances from Energy-Related Processes, May 18–20, 1981.
Ad hoc reviewer:	*Environment International, Environmental Science and Technology, Journal of Sedimentary Petrology;* NSF, EPRI, Smithsonian Institution Environmental Science Program, Argonne National Laboratory Energy and Environmental Systems Division.

TSAI, S. C.

Member:	Equal Opportunity Committee in Fisheries, American Fisheries Society.
Participant:	American Fisheries Society Annual Meeting, Albuquerque, New Mexico, September 16–18, 1981.
Advisor:	K. B. Packard, B.S., Centenary College of Louisiana, Shreveport.

TYNDALL, R. L.

Participant:	Invited Speaker, The 21st Annual American Industrial Hygiene Association Conference, Portland, Oregon, May 24–29, 1981.
Faculty:	Research Associate Professor, The University of Tennessee, Knoxville.
Advisor:	Audrey Nicholson, M.S., The University of Tennessee, Knoxville; Lycurgus Muldrow, Ph.D., The University of Tennessee, Knoxville.
Consultant:	Northern States Power, Minneapolis, Minnesota; Duke Power Company, Charlotte, North Carolina; and Exxon Company, Baton Rouge, Louisiana.
Ad hoc reviewer:	*Cancer Research.*

VAN HOOK, R. I.

Participant:	Industrial Research Institute—Project Management Course, Washington, D.C., May 1981.
Member:	ORNL Graduate Selection Panel; International Energy Agency Biomass Working Group.
Reviewer:	EPA Biomonitoring Program Review, Environmental Research Laboratory, Corvallis, Oregon, March 1981.

VAN WINKLE, W.

Member:	Committee on Professionalism, American Fisheries Society.
Participant:	Overview and Planning Meeting for Alternate Fuels Research, EPA, Environmental Research Laboratory, Duluth, Minnesota, January 1981; Workshop for Freshwater Research Program Plan Development for DOE-OHER, Ecological Research Division, Dulles Marriott, Virginia, March 1981; OHER Program Directors Meeting, Germantown, Maryland, June 1981.
Faculty:	Adjunct Faculty, Graduate Program in Ecology, The University of Tennessee, Knoxville.
Consultant:	Department of Fish and Game, State of California.
Ad hoc reviewer:	*American Naturalist, Canadian Journal of Fisheries and Aquatic Sciences, Ecology, Fisheries Bulletin, Transactions of the American Fisheries Society.*

VAUGHAN, DOUGLAS S.

Participant: Third Conference on Waste Heat Management and Utilization, Miami Beach, Florida, May 1981; The 111th Annual Meeting of the American Fisheries Society, Albuquerque, New Mexico, September 1981; Grammar and Mechanics of Technical Writing, ORNL in-house course, Fall 1980; Frontiers in Biological Sciences, ORNL in-house course, Spring 1981.

Ad hoc reviewer: *American Naturalist, Journal of Great Lakes Research, Ecology.*

VAUGHAN, N. D.

Participant: Management Skills for Women Supervisors and Administrative Assistants, Knoxville, Tennessee, April 27-29, 1981.

Ad hoc reviewer: Presentations for American Nuclear Society 1981 Spring Meeting.

VOORHEES, L. D.

Member: Committee on Roadside Maintenance, Transportation Research Board for the National Research Council; Task Force on Wildlife and Fisheries Issues, Board on Agriculture and Renewable Resources for the National Research Council.

Participant: Bird Census Symposium, Asilomar, California, October 1980; Annual Meeting of the Transportation Research Board, Washington, D.C., January 1981; National Research Council Meeting of Task Force on Wildlife and Fisheries Issues, April 1981; Midwest Conference on Wetland Values and Management, St. Paul, Minnesota, June 1981; preparation of: DES for decommissioning of the Edgemont uranium mill; DEIA for Kerr-McGee Nuclear Corporation uranium hexafluoride facility.

WALTON, B. T.

Participant: Annual Meeting, Entomological Society of America, Atlanta, Georgia, November 1980; Annual Meeting, American Society of Zoologists, Seattle, Washington, December 1980; Annual Meeting, Society of Environmental Toxicology and Chemistry, Washington, D.C., November 1980.

Advisor: Nancy Youtsey, B.S., Center College, Danville, Kentucky; E. R. Merchant, M.S., The University of Tennessee, Knoxville.

Ad hoc reviewer: *Journal of Economic Entomology, Environmental Entomology.*

Other: Visiting Scientist, Cornell University, Ithaca, New York, May 1981.

WATTS, J. A.

Participant: 1980 Integrated County-Level Data User's Workshop, USGS National Center, Reston, Virginia, October 1980; IN-PLACE Resource Inventories: Principles and Practices Workshop, University of Maine, Orono, August 1981.

WEBB, J. WARREN

Participant: Annual Meeting, American Institute of Biological Sciences, Bloomington, Indiana, August 1981; preparation of: programmatic DEA for the Fallon Naval Air Station Geothermal Development Program, Fallon, Nevada; DES related to the operation of the Federal-American Partners Project, NRC, August 1981; EA, Rorabough Lease Development Geothermal Loan Guaranty Application; EA, Geothermal Energy, Geopressure Subprogram, Gulf Coast Well Drilling and Testing Activity (Frio, Wilcox and Tuscaloosa Formations, Texas and Louisiana).

Advisor:	Christopher Craft, M.S., The University of Tennessee, Knoxville.
Ad hoc reviewer:	*Annals of the Entomological Society of America, Environmental Entomology;* proposals: NSF.

WRIGHT, L. L.

Participant:	Preparation of: DEIA for Barnwell Low-Level Waste Disposal Facility.
Ad hoc reviewer:	*Journal of Freshwater Ecology.*

YEH, G. T.

Chairman:	Environmental Modeling Committee.
Member:	Environmental Impact Effects Committee.
Participant:	Workshop on Modeling and Low-Level Waste Management, Denver, Colorado, December 1-4, 1980; Workshop on Modeling the Fate of Chemicals in the Aquatic Environment, Pellston, Michigan, August 17-21, 1981.
Ad hoc reviewer:	ASCE Committee on Hydrologic Transport and Dispersion.
Other:	Editor, The state-of-the-art Report on Physics-based Environmental Modeling of Material Releases and Disposals for New Technologies.

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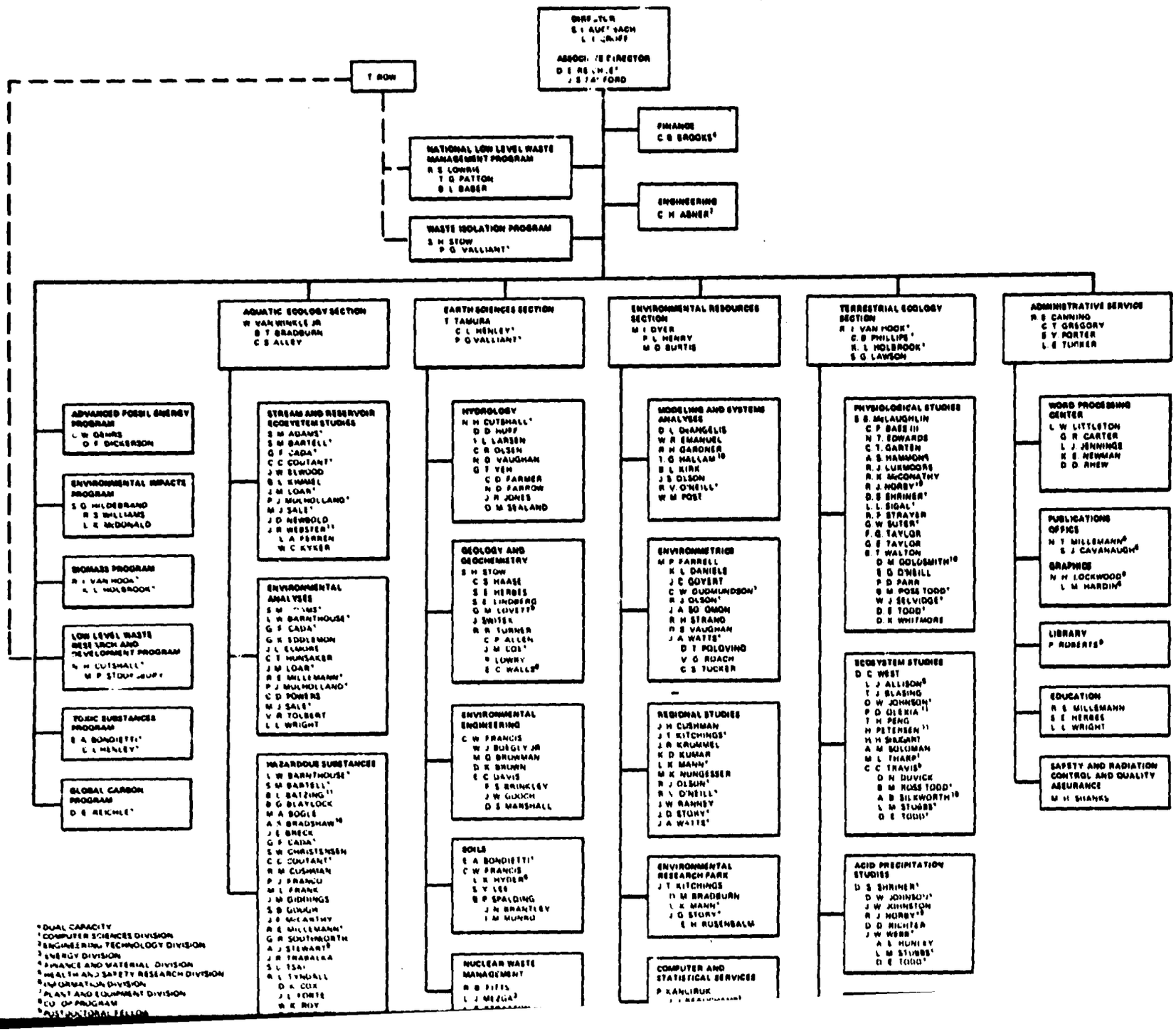

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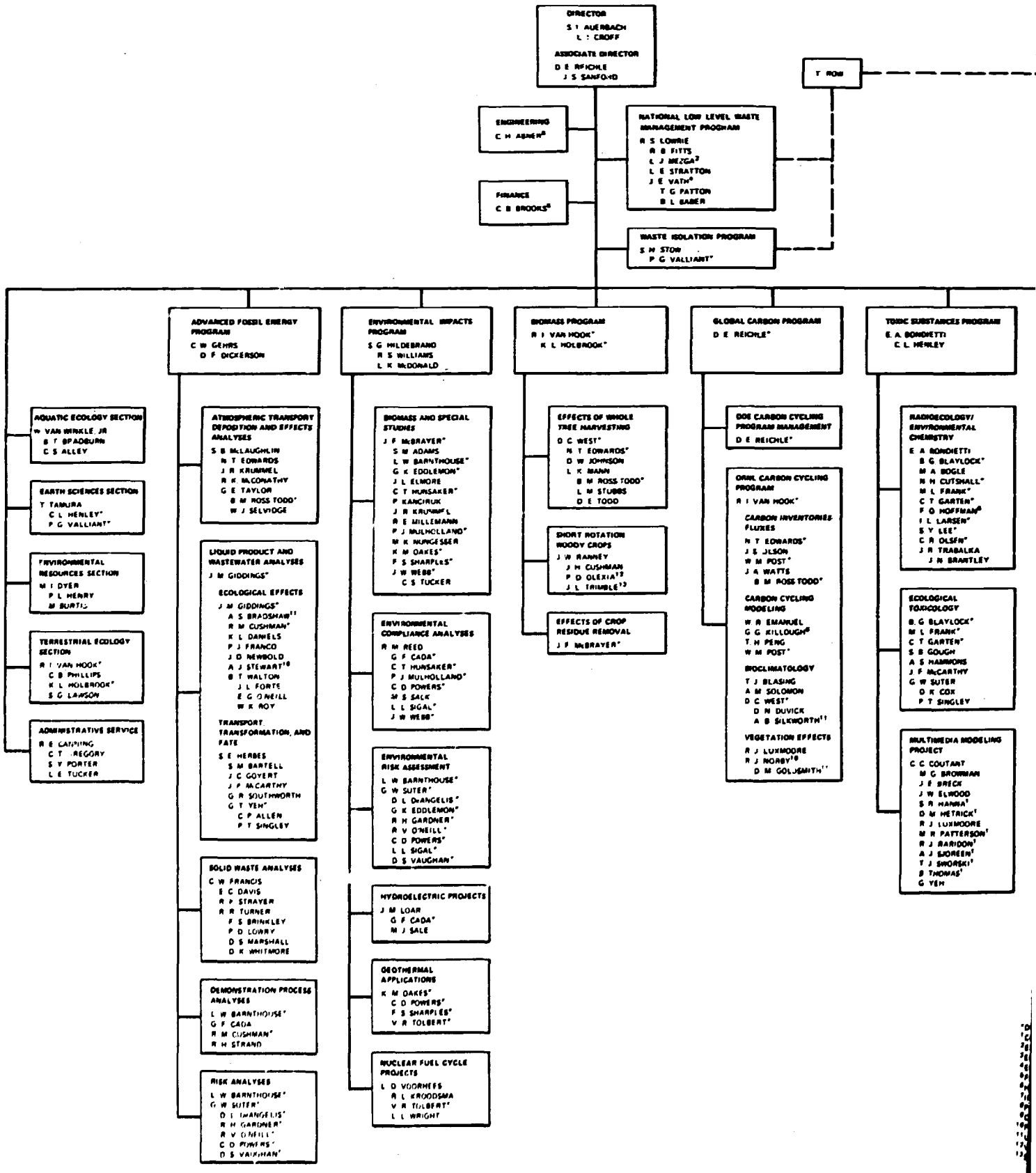

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