RECORDS ADMINISTRATION
R0139035

DP-1593

Environmental Transport Division

SAVANNAH RIVER LABORATORY 1980 REPORT

TIS FILE
RECORD COPY

DISCLAIMER

This report was prepared by E. I. du Pont de Nemours and Company (Du Pont) for the United States Department of Energy under Contract DE-AC09-76SR00001 and is an account of work performed under that Contract. Neither the United States, the United States Department of Energy nor Du Pont, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed herein, or represents that its use will not infringe privately owned rights. Reference herein to any specific commerical product, process, or service by trade name, mark, manufacturer, or otherwise does not necessarily constitute or imply endorsement, recommendation, or favoring of same by Du Pont or by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

Printed in the United States of America

Available from

National Technical Information Service
U. S. Department of Commerce
5285 Port Royal Road
Springfield, Virginia 22161

Price: Printed Copy A04; Microfiche A01

726929

DP-1593
UC-11

1980 REPORT
ENVIRONMENTAL TRANSPORT DIVISION

Edited by

S. E. Adams
C. B. Fliermans
A. J. Garrett
J. E. Halverson

Compiled and Approved by

T. V. Crawford, Research Manager
Environmental Transport Division

Publication Date: March 1981

E. I. du Pont de Nemours & Co.
Savannah River Laboratory
Aiken, SC 29808

PREPARED FOR THE U. S. DEPARTMENT OF ENERGY UNDER CONTRACT DE-AC09-76SR00001

ENVIRONMENTAL TRANSPORT DIVISION 1980

T. V. Crawford, Research Manager

Ecology Group

J. C. Corey, Research Supervisor

- A. S. Dicks, Programmer A - Environmental Data
- R. D. Fallon, Research Biologist - Microbial Processes
- C. B. Fliermans, Staff Microbiologist - Ecology of Microorganisms
- D. D. Gay, Research Botanist - Plutonium Cycling in the Environment
- D. W. Hayes, Research Oceanographer - Suspended Solids and Transuranics in Aquatic System
- G. J. Hollod, Research Engineer - Borrow Pit Restoration and Forest Productivity
- R. W. Holloway, Research Chemist - Transuranics in Aquatic Systems
- B. W. Hyde, Laboratory Supervisor - Laboratory Operations
- C. E. Murphy, Jr. Staff Meteorologist - Gaseous Pollutant Cycling in Forests
- C. W. Sweet, Research Chemist - Uptake of Gaseous Pollutants in Soils
- J. R. Watts, Research Physicist - Thermal Plumes and Dosimetry
- E. W. Wilde, Biologist A - Algal Studies and Biofouling

Meteorology Group

M. R. Buckner, Research Supervisor

- C. E. Bailey, Staff Chemist - JEREMIAH
- D. G. Coats, Shift Supervisor - Field Engineering
- R. E. Cooper, Research Engineer - Mathematical Models
- A. J. Garrett, Research Meteorologist - Deposition and Drainage Winds

D. D. Hoel, Meteorologist - Statistics and Wind Fields

R. A. Mueller, Engineering Assistant - WIND System

M. M. Pendergast, Staff Meteorologist - MOS Forecasts and Wind Fields

J. F. Schubert, Staff Meteorologist - AFOS and ASCOT

A. H. Weber, Staff Meteorologist - Workshop and Heavy Gas Dispersion

Chemistry Group

A. L. Boni, Research Supervisor

W. W. Bowman, Staff Chemist - Low-Level Counting

D. C. Carlson, Staff Chemist - Aerosols

W. D. Dalton, Engineering Assistant - Low-Level Counting Systems

J. E. Halverson, Research Physicist - Mass Spectrometry

M. B. Hughes, Research Chemist - Nuclear Chemistry

M. V. Kantelo, Research Chemist - Long-Lived Fission Products

J. H. LeRoy, Shift Supervisor - Laboratory Operations

W. G. McMillan, Engineer A - Field Operations

R. C. Milham, Staff Chemist - Radiochemistry

S. M. Sanders, Jr., Research Chemist - Plutonium-Bearing Particles Characteristics

R. A. Sigg, Research Chemist - Nuclear Chemistry, TRAC System

R. W. Taylor, Senior Chemist - Radiochemistry

B. Tiffany, Staff Chemist - Gas Chromatography

ABSTRACT

During 1980, the Environmental Transport Division of the Savannah River Laboratory conducted aquatic, atmospheric, and terrestrial studies and instrumentation developments, which are described in a series of articles. More details about specific studies are given in publications listed at the end of the report.

CONTENTS

Introduction 7

Key Results of ETD Studies 11

Aquatic Studies 15

Atmospheric Studies 27

Terrestrial Studies 41

Instrumentation Developments 49

References 54

INTRODUCTION

Mission

The mission of the Environmental Transport Division (ETD) is to ensure that the Savannah River Plant (SRP) operates in a cost-effective, environmentally safe manner and to aid the Department of Energy (DOE) in providing adequate energy supplies for the United States with minimum environmental impact. To accomplish this mission, ETD develops new calculational methods and data on the transport, dispersion, deposition, cycling, and effects of pollutants released from SRP operations to the atmosphere and streams. Calculational models and laboratory studies are field-tested on the 300-square-mile site (Figure 1).

This report summarizes the accomplishments of ETD for 1980. Major accomplishments and administrative changes are included in the introduction; the body of the report summarizes the studies. Details on the work can be obtained from the references listed.

Special Events During 1980

In May 1980, a potential for a large leak of H_2S from a storage tank in the heavy water production facility (D Area on Figure 1) caused ETD's meteorology group to go on shift for nine days. They provided specialized assistance to the SRP staff during the safe draining of the storage tank. This operation revealed areas for further improvement of SRP emergency response capabilities. ETD meteorologists will now be stationed at the SRP Emergency Operation Center whenever it is officially activated. Computer models for calculating dense gas dispersion and for the determination of low-level winds are under development. A low-level wind measurement system will be installed in D Area.

Further effort has been given to the installation of the AFOS (Automation of Field Operation and Service) system and the purchase of additional computing power for the WIND minicomputer system. The AFOS system, which arrived in December, will allow ETD to continue to receive National Weather Service data. Besides improving it's ability to deal with SRP releases, these planned improvements will significantly improve ETD's capability to help DOE respond to requests for assistance under the Radiological Assistance Program (RAP).

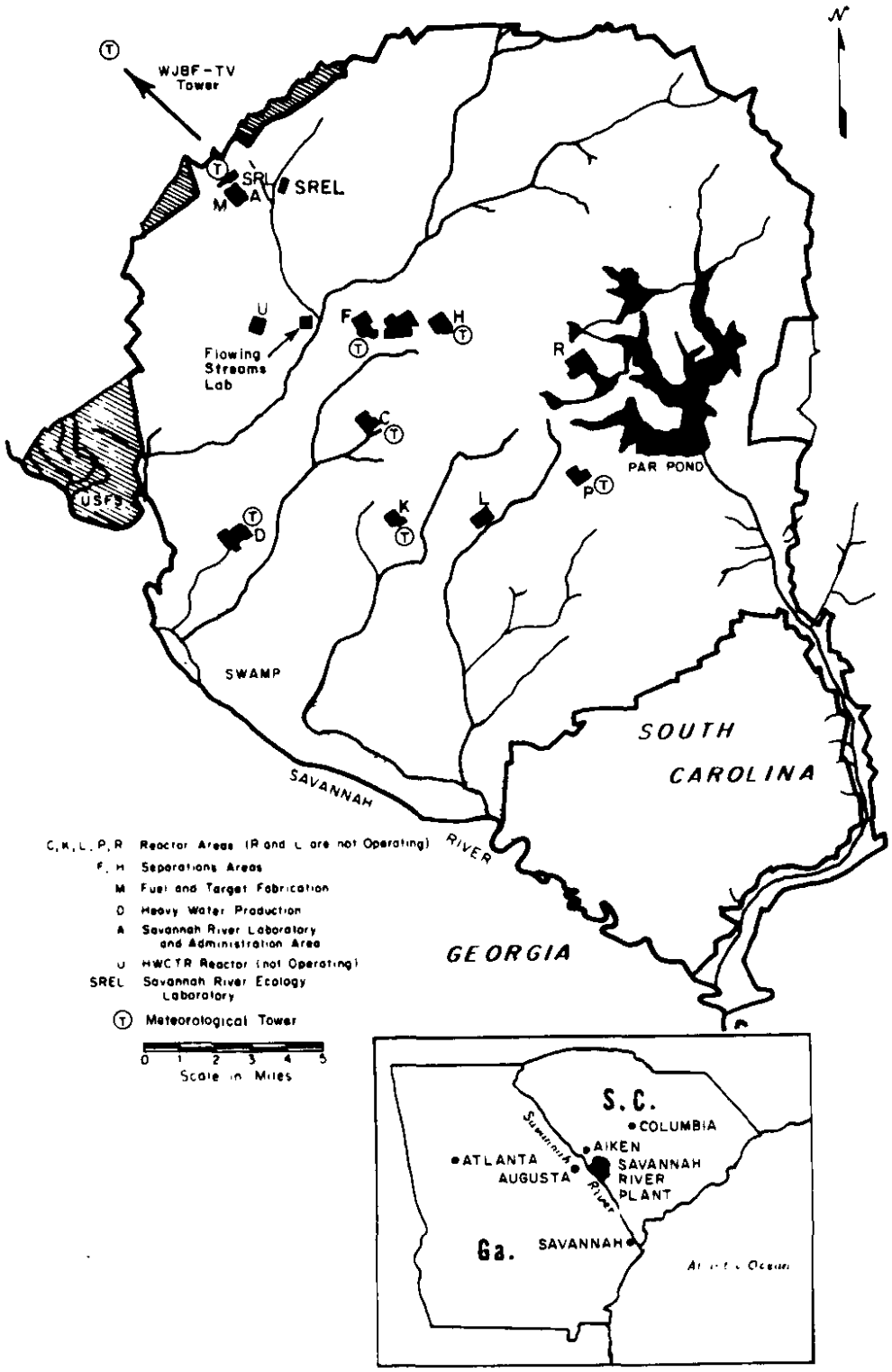

FIGURE 1. The Savannah River Plant Site. The inset shows SRP's regional location.

Detailed specifications were prepared for a mobile platform for the TRAC (Tracking Radioactive Atmospheric Contaminants) system in 1981. The TRAC system will considerably improve SRL's ability to measure, in near real time, concentrations of pollutants released from SRP in emergency response situations and will provide improved response to RAP requests.

As a result of ETD's work in emergency response, many people have visited the Weather Center in the past year. These have included people from other DOE-funded laboratories, state and local governmental agencies, nuclear industries, the Nuclear Regulatory Commission (NRC), the Federal Energy Management Administration (FEMA), and foreign government delegations.

During 1980, ETD worked with all of the DOE laboratory meteorology groups to statistically test atmospheric transport and dispersion models against krypton-85 measurements obtained from SRL. Calculations were returned to SRL for statistical analyses. SRL then hosted a workshop in November 1980 to discuss the results. The proceedings will be published in 1981.

A program to study the environmental effects of enhancing biomass productivity in the SRP pine forests with sewage sludge began in 1980. ETD was designated the coordinator of the program which involves collaborative efforts between ETD, Savannah River Ecology Laboratory, Savannah River Forest Station, and Southeastern Experiment Station of the U. S. Forest Service.

A new program to study the basic ecology of Legionnaire's Disease bacteria was started with funding from the National Institute of Health in 1980.

A central computer and data manager based on a Systems Engineering Laboratories SEL 32-77 central processor has been installed for the environmental chemistry group. The system will be connected to the electronic equipment throughout the chemistry group's facilities to automatically compile data. Researchers have access to the terminals to retrieve and work with the environmental data base, and a graphics subsystem will be added later to generate pictorial representations of the data.

Funding and Personnel

In 1980, as in 1979, ETD obtained about one-third of its funding from the Office of Health and Environmental Research of the Department of Energy. An additional one-third of ETD's funding came from the Assistant Secretary for Defense programs through the operating budget of SRP. The rest of the funds came from miscellaneous sources; many of these were short-range studies requested to support other SRL or SRP programs.

At the end of 1980, there were 38 professionals in ETD with expertise in a wide range of disciplines. Twenty-six project assistants, technicians, and secretaries support the researchers. Co-op students usually filled two positions throughout the year with additional student and faculty members present in the summer. Subcontracts for specialized studies often added another two to four people to the ETD staff for months at a time. In December 1980, M. R. Buckner became head of the Meteorology Group, as D. W. Pepper was transferred to another assignment within SRL. In 1980, one meteorologist and three chemists were hired for ETD, and two technicians were promoted to specialized positions within the professional staff.

In 1980, the Meteorology Group moved into new offices adjacent to the refurbished Weather Center in the main SRL building. The Ecology Group moved into a larger office trailer alongside the SRL building.

KEY RESULTS OF ETD STUDIES

Aquatic Studies

- Computer codes have been developed for the WIND minicomputer emergency response system to predict travel time and concentrations of pollutants released from SRP into plant streams.

- A computer model has been developed to calculate thermal plumes into the Savannah River from SRP operations.

- Concentrations of $^{238,239,240}Pu$, ^{241}Am, and ^{244}Cm have been measured in a stream receiving discharge from the separations areas, and such concentrations are orders of magnitude below drinking water standards.

- Both continuous and intermittent chlorination procedures have been shown effective in removing Legionella pneumophila from cooling towers and air conditioning systems.

- Certain commercially available organic biocides are effective in killing Legionella pneumophila in the laboratory.

- Cleaning of emergency cooling water basins causes sediment to be discharged into plant streams. The NPDES limitations for suspended solids are exceeded both by natural processes and basin cleaning.

- Biological fouling of heat exchangers significantly reduces the efficiency of the exchangers and consumes energy. Studies are determining the mechanism and control of such fouling.

- Artificial streams heated to 12.5°C above ambient have recovered from the thermal alteration.

- Fallout transuranics were measured in seafood from a North Carolina estuary. Plutonium showed the highest concentration of all the transuranic elements at 1.8 femtocuries/g of scallops.

- The largest data base ever assembled in the United States from a continuous biological monitoring program has been computerized.

Atmospheric Studies

- National Weather Service wind speed and direction forecasts are now automatically transmitted to the WIND minicomputer for use in emergency response calculations of atmospheric pollutant concentrations.

- The removal of gas and particle pollutants in the air by vegetation and rain is now included in the emergency response code calculations.

- Two models for the dispersion of dense gases, such as liquid H_2S, have been adopted for use on SRL's IBM 360-195 computer.

- The JEREMIAH system of computer codes was expanded to calculate three-dimensional wind fields from observations, and to use these wind fields to test several atmospheric models, some of which were complex three-dimensional codes.

- ETD meteorologists and technicians participated in a DOE-sponsored field measurement program in California to increase understanding of wind movement in rugged terrain.

- A DOE-sponsored workshop at SRL was held to validate atmospheric transport and diffusion models. Results showed that model mathematics are adequate, but that more wind field and turbulence information is needed to realize the full potential of the models.

- The residence time of 66 to 77 days for plutonium in the troposphere agrees with the residence time for natural aerosols.

Terrestrial Studies

- The atmospheric transport of iodine-129 from 25 years of reprocessing nuclear fuel was shown by measuring its concentrations in the terrestrial environmental. Iodine-129 in soil decreased exponentially with increasing depth.

- The oxidation of tritium gas to tritiated water in soil is caused by the activity of microorganisms and is a widespread phenomenon.

- Deposition velocities for molecular tritium onto a variety of soils were measured and shown to be in good agreement with theoretical and literature values.

- The parameters necessary for a microclimatic model to estimate pollutant uptake by forests were determined.

- The SRP burial ground trenches which contain buried solid radioactive waste were monitored, and no large-scale migration of radionuclides was found.

- Adding domestic sewage sludge has been shown to cause higher nutrient enhancement in pine and hardwood plantations, and on disturbed soil sites, than equivalent amounts of commercial fertilizers.

Instrumentation Developments

- ETD's three-stage mass spectrometer has been tuned to meet or exceed goal specifications, and a process was developed to purify plutonium samples as small as 5 femtograms (3×10^{-16} Ci) for analysis.

- A gas mass spectrometer was constructed in 1980 to measure trace-level tritium samples more accurately.

- An improved low-background proportional counter was developed to produce quick reliable measurements of tritium in environmental samples.

- A mobile laboratory was designed to aid SRP emergency response capabilities and ETD research.

- An underground low-level counting facility was designed to provide needed additional space for low-level detectors. It has a lower background than the current low-level facility, which will allow for more accurate analyses of the very low levels of radionuclides in the environment.

Emergency Response Program for Releases to SRP Streams

The SRL Weather Information and Display (WIND) minicomputer system, which provides emergency response capability for atmospheric releases at SRP, has been upgraded to include the same type of capability for releases to SRP streams and the Savannah River. The transport model WATER was designed as a user-oriented program that could be easily operated by shift Health Protection personnel familiar with the WIND system terminal. The transport model uses the standard one-dimensional advective diffusion equation to calculate the concentration and travel times of releases in plant streams and in the Savannah River (Figure 2). It is a conservative model, thus it does not take into account losses of pollutants due to sediment sorption, volatilization, or neutralization. Various types of release scenarios can be simulated (i.e., slug, continuous, or time-varying releases). The transport coefficients for SRP streams and the Savannah River have been

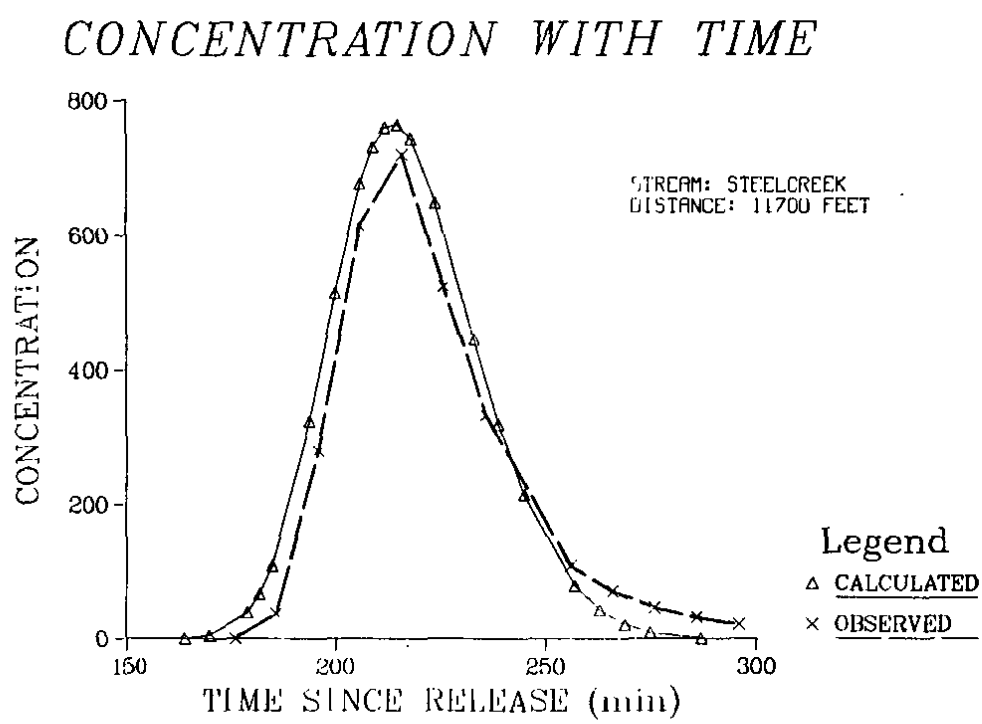

FIGURE 2. A graph generated by the computer to compare the observed concentrations of a release and the concentrations predicted by the emergency response code. The concentrations are in parts per billion.

determined by using dye and tritium tracer studies. Model predictions of maximum downstream concentrations are within 50% of data observed from dye studies conducted on SRP streams.

The "menu" type of program approach was used to simplify the task for the user. For example, the "Release Location" menu lists all SRP manufacturing sites as well as stream intersections with major SRP roads. The transport coefficients of velocity, dispersion, and flow volume that are part of a permanent data file are implemented at the time the "Release Location" is selected. Once the amount and time duration of the release have been entered, the release concentration and travel times are automatically displayed for two onsite and four offsite locations.

Modeling of Thermal Dispersion in the Savannah River

Heated effluent is discharged to onsite streams from reactors, a coal-fired power plant, and heavy water facilities, causing the stream temperatures to rise above normal. The Environmental Protection Agency requires a National Pollutant Discharge Elimination System permit for all releases which affect offsite navigable waters. The permit specifies an area (mixing zone) of the offsite river beyond which the temperature increase must be less than or equal to 2.8°C above ambient (or a maximum of 32.2°C). Quarterly measurements were made for the three SRP streams which discharge heated effluent to the Savannah River (Four Mile Creek, Beaver Dam Creek, and Steel Creek). Four Mile Creek was found to be 3.5°C above ambient river temperature at the edge of the mixing zone in the Savannah River. All other measurements were in compliance.

ETD can now model the thermal plumes to evaluate methods to reduce the temperatures at the edge of the mixing zone (Figure 3). The model consists of a finite element computer code (DISPER1) obtained from the Computational Mechanics Centre in England. The model can calculate changes in the thermal plume in the river by changing properties of the thermal effluent. The flow rates and temperatures above and below the mixing zone were measured at the mouth of Beaver Dam Creek and Steel Creek. Four Mile Creek was not measured because of unscheduled reactor shutdowns.

The calculated isothermal profiles from the tributaries agreed well with the measured values. The maximum temperature at the edge of the mixing zone downstream of Beaver Dam Creek measured 2.8°C above ambient compared to a calculated value of 2.5°C. Downstream of Steel Creek, the measured temperature was 1.1°C above ambient compared to a calculated value of 0.6°C. Longitudinal and traverse dispersion values of 10 ft^2/sec gave the best fit to measured data.

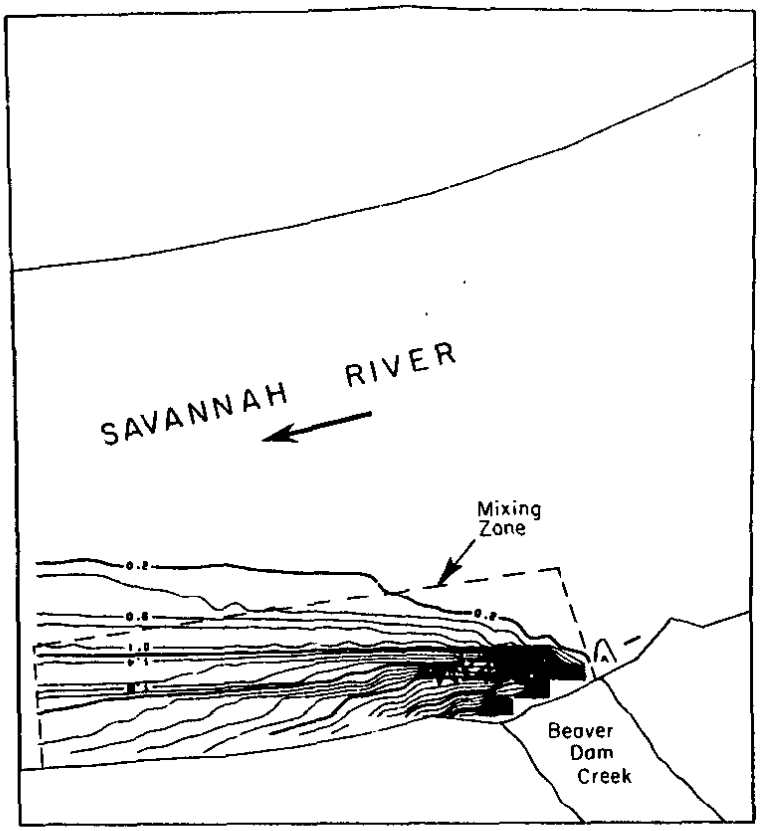

FIGURE 3. Isothermal profiles downstream of Beaver Dam Creek. The dispersion value used is 10 ft^2/sec. The profile values are °C above ambient river temperature.

Transuranics in SRP Streams

The SRP separations facilities, which separate the useful isotopes from irradiated fuel elements, discharge small amounts of radioactivity to Four Mile Creek (Figure 1). Until 1971, the transuranics released were estimated by gross alpha measurements at the point of discharge, and by assuming that all of the alpha activity was caused by plutonium-239, 240. Plutonium has since been specifically measured and it was estimated that 0.3 Ci of plutonium-239, 240 has been discharged to the aquatic environment since plant startup.

To determine the concentrations and transport of transuranics, water samples were taken from six locations along Four Mile Creek, which is an SRP stream adjacent to the separations areas and one of the reactors. The isotopic compositions of the streams were determined with the three-stage mass spectrometer and alpha spectrometers. Results of this survey clearly shows that SRP contributes to the plutonium in the streams and ponds on the plantsite.

However, similar measurements of samples from the mouth of the Savannah River show that SRP does not contribute measureably to the river at that point.

The plutonium-238 concentrations in the creek decreased from 223 fCi/L at the point of discharge to 16.8 fCi/L 10 km downstream. However, the concentration of plutonium-239, 240 does not decrease at a similar rate, which implies another source of plutonium-239, 240 along the stream. Between two sample sites on the stream, there is a significant change in the isotopic composition indicating a source of plutonium with a low percentage of the 240 isotope. The exact source and mode of transport of this plutonium has not yet been determined, but studies are continuing. It should be noted that although there is a measureable change in the plutonium concentrations and isotopic compositions, the levels (<40 fCi/L for all sites) are well below the maximum permissible concentrations in water (30 nCi/L). Stream flow during sampling increased substantially with downstream distance. The decrease of plutonium-238 in the stream is due mostly to dilution, but also to sedimentation of plutonium-bearing particles and stream bed sorption.

At a site about 6 km downstream from the point of discharge, the concentration of plutonium-238 was about 39 fCi/L, plutonium-239, 240 was about 9.5 fCi/L, americium-241 was about 5 fCi/L, and curium-244 was about 7.5 fCi/L. Less than half of the transuranic activity was associated with particulate matter, probably caused by the relatively clean water (1 mg/L of suspended solids).

The plutonium found at Upper Three Runs Creek was determined to be mostly fallout debris which was transported downstream from the watershed. There also is a significant change in the plutonium isotopics composition along Upper Three Runs, but since there is no direct plant discharge into that stream, the most likely source is soil erosion from the onsite watershed.

A more complete survey of the onsite watershed which drains into Upper Three Runs Creek and an accurate, time-integrated measurement of the plutonium in Upper Three Runs Creek will yield interesting information about soil erosion and the movement of plutonium in the environment. The significant difference between the isotopic signature of the plutonium in SRP soil and the plutonium in streams as they enter the plant offers a unique opportunity to test theoretical soil erosion rate formulas.

Removing Legionella pneumophila from Cooling Systems

The bacterium which causes Legionnaire's Disease is known to be ubiquitous in natural aquatic habitats, and has been documented as a cause of human infection since 1947. Recent worldwide outbreaks of the disease have been associated with cooling towers or air conditioning systems. ETD has studied the distribution of Legionella pneumophila in SRP cooling systems and has designed techniques for controlling the bacteria.

Data from guinea pig innoculations, recovery efficiency of L. pneumophila from cooling towers, and direct fluorescent antibody enumeration of water from an infected cooling tower indicate that cooling systems with greater than 10^8 L. pneumophila per liter are potentially harmful and should be treated.

In the SRP cooling towers which were treated, continuous chlorination brought (1.0 mg/L free chlorine residual) L. pneumophila concentrations back to or below background levels within 72 hours (Figure 4). Background levels are those concentrations, generally around 10^4 to 10^5 L. pneumophila per liter, that are present in the makeup water for the system and which serve as a ready inoculum for either the towers or the air conditioning systems. Once levels were at or below background concentrations, daily chlorination at 0.7 mg/L free residual for one hour was sufficient to maintain those levels.

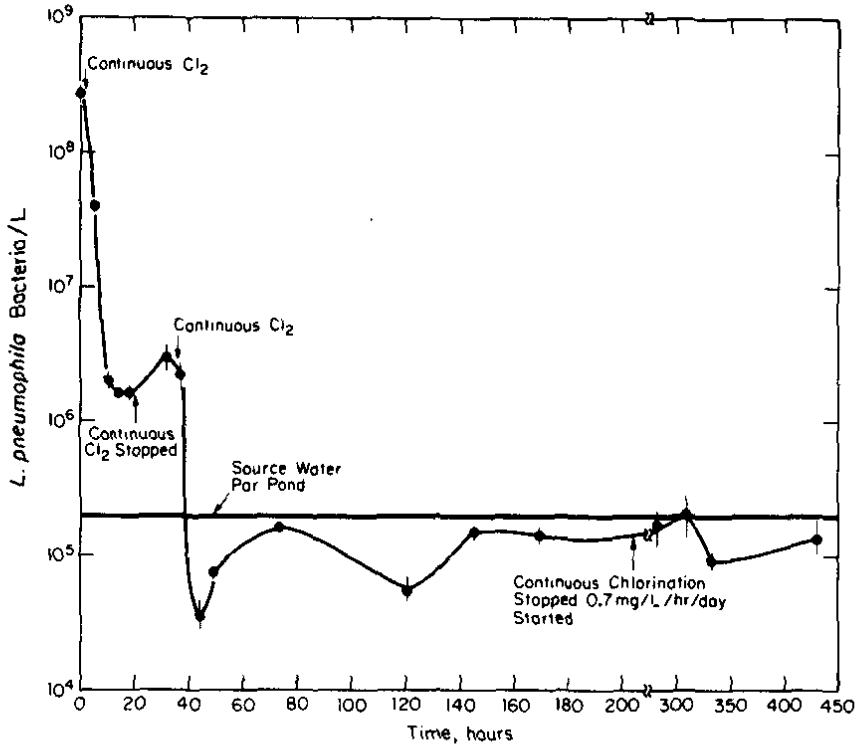

FIGURE 4. Continuous chlorination of SRP cooling towers brought Legionella pneumophila concentrations back to or below background levels within 72 hours.

Air conditioning systems were treated by shock chlorination during nonworking hours. A calculated dose of 50 mg/L was used to disinfect the extensive cooling coils and the catch basins within each of the systems. This shock chlorination was continued daily and brought L. pneumophila to background levels within two weeks.

Biocidal Testing on Legionella pneumophila

During 1980, a Rensselaer Polytechnic Institute research team, working primarily at SRL with ETD personnel, showed that several algal types will support the growth of Legionnaires Disease bacteria (L. pneumophila) in laboratory culture experiments. The effectiveness of 13 different commercially available biocides in controlling (or killing) 11 different algal strains and 9 different L. pneumophila isolates was also tested.

Actively growing cultures of each of these organisms were exposed to three concentratons of each biocide. Several biocides were found effective at concentrations down to 1/100 of the manufacturer's suggested shock dose. Each effective concentration was then checked to determine whether the biocide was acting to kill the organisms (cidal) or merely preventing further growth (static). Most were found to be cidal at the suggested dose.

Tests of one of the most promising biocides (containing an organotin compound) were performed on operating cooling towers at Rensselaer Polytechnic Institute in Troy, NY. The tests showed it to be effective in reducing the number of cells reacting to antibodies against L. pneumophila (presumably L. pneumophila) in these towers. Laboratory tests which used one L. pneumophila isolate showed that the organotin compound inhibits growth by disrupting the organism's energy conversion metabolism.

Sediment Discharge from Emergency Cooling Water Basins

There are three holding basins for emergency cooling water in each SRP reactor area, with each basin containing about 32×10^6 liters of water. The basins are drained, cleaned, and inspected annually because the accumulation of sediment in the basins creates an ideal habitat for the growth of clams (Corbicula), which can foul the reactor heat exchangers. When the basins are cleaned with firehoses, the sediment is resuspended and discharged through process sewers to onsite streams (Figure 5), causing the suspended solids concentrations to exceed the Environmental Protection Agency's daily maximum limitation of 50 mg/L. An average of about 48 tons of sediment is accumulated annually in a basin. In 1980, ETD determined that the thermal stress on the ecosystems of the reactor area creeks masks any effect due to sediment discharge and deposition.

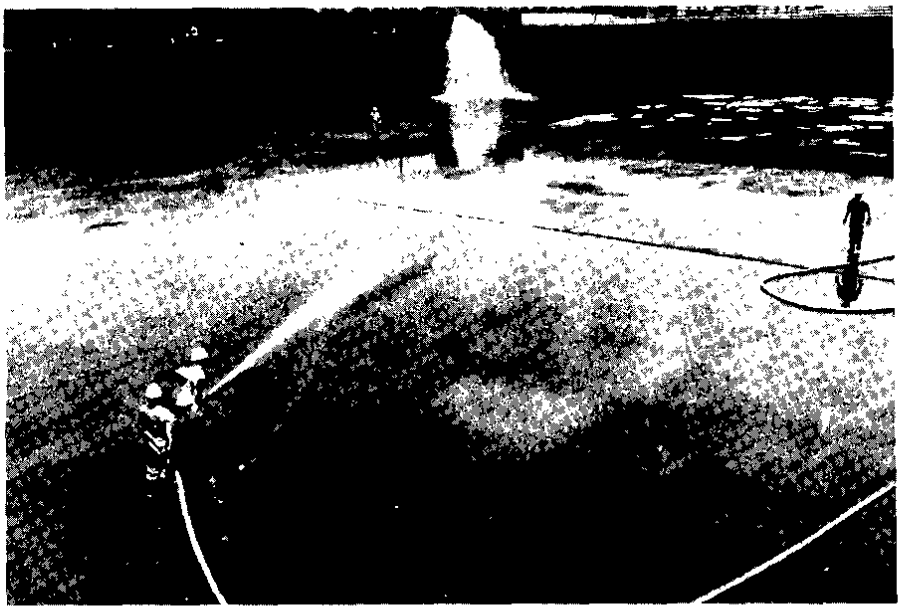

FIGURE 5. SRP personnel use firehoses to clean the sediment from large cooling water basins at each reactor area.

The maximum suspended solids concentrations in the discharge water during basin cleaning were 69 mg/L in K Area and 167 mg/L in P Area). The suspended solids concentrations are higher than the annual average values in Steel Creek and the Savannah River of 8 ±22 mg/L and 21 ±37 mg/L, respectively. However, individual daily maximum values of 101 mg/L and 64 mg/L have been reported for Steel Creek and the Savannah River, respectively.

Reforestation of the SRP site since 1954 has reduced sediment transport from 25 tons/day to 0.3 ton/day for each 10 mi^2 of watershed area. This reduction more than offsets the averaged annual addition of 0.7 ton/day for basin cleaning operations. Sediment added to the SRP streams as a result of the basin draining and cleaning operation is deposited in streams before they reach the swamp. Thus, the suspended solids concentrations during cleaning are typical of naturally occurring values and will not cause any additional problems to SRP creeks, even though the concentrations exceed the EPA limit only during the annual cleaning.

Since L Reactor was placed on standby in 1968, the Steel Creek ecosystem has recovered from the previous thermal stress, and is typical of streams of the Upper Coastal Plain of South Carolina.

Biofouling of Reactor Heat Exchangers

ETD initiated a biofouling research program during the latter part of 1980 to evaluate the process by which microorganisms cause material to become attached to submerged surfaces such as heat exchanger tubes. Small amounts of this undesirable insulation can greatly impair heat transfer efficiency and accelerate corrosion processes. Chlorination is being used at SRP to minimize biofouling, but daily additions of chlorine may contribute to corrosion and may cause environmental problems.

Stress corrosion cracking of reactor heat exchanger tubes has become a significant problem. Repair and replacement costs are high, and leaking tubes result in the loss of heavy water and radioactive materials to the environment. The major goal of this program is to develop environmentally acceptable procedures to reduce or eliminate problems associated with biofouling. Specific objectives are to (1) biologically and chemically characterize material attached to heat exchanger tubes, (2) determine corrosion processes, including the role of microorganisms, and (3) evaluate alternative tube alloys and biocides.

Laboratory and field experiments are in progress. Model heat exchangers have begun operating with water from a large cooling water reservoir, and samples have been collected and analyzed from one of the reactor heat exchangers. Results from the initial collections revealed the following:

- Material attached to the tubes was primarily inorganic (80 to 90% of dry weight).
- Biomass was mostly bacteria with few algae or fungi.
- Corrosion-inducing (sulfate-reducing) bacteria were isolated from the biofilm and found to be at least two orders of magnitude more abundant on the hot water end of the exchanger tubes than on the cold water end.

Bimonitoring of Process Sewers

A recent modification to the EPA National Pollution Discharge Elimination System (NPDES) permit issued to SRP requires a biomonitoring program to evaluate the toxicity of SRP process sewer effluents. A one-year study consisting of quarterly static (24-hour) bioassays of fathead minnows (Pimphales promelas) was subsequently approved by EPA. Testing began in June 1980 and was repeated in September and December. Eight sites representing process sewer effluent from seven plant operating areas were

studied. Two of the eight effluents revealed toxicity problems, and corrective action to bring them into compliance with EPA standards has already begun.

Significant test organism mortality was observed in the effluent from one area during June and September. The toxic agent was tentatively identified as chlorine. Total residual chlorine measurements near 0.3 mg/L were recorded at the sampling site during much of the 24-hour collection period in September. Chlorine measurements during December were lower and no mortality occurred in the static bioassays using process sewer effluent from the area.

Effluent from another area was found to be too acidic for test organisms to survive. Thus, the pH of these samples was adjusted to between 6 and 9 before testing, and no toxic influence other than pH was indicated.

A new *in situ* biomonitoring procedure was developed by ETD and tested during the September and December sampling periods. Results from *in situ* sampling indicated that the method is much more sensitive to short-term lethal factors, such as residual chlorine and temperature stress, than is the standard EPA laboratory procedure.

Responses of Attached Algal Communities to Thermal Pollution Cessation

Artificial streams previously subjected to three continuous years of thermal pollution were studied for 20 months at the ETD Flowing Streams Laboratory (Figure 1). The objective was to determine the post-thermal recovery rate for some previously reported thermally induced alterations in attached algal community structure. These alterations were (1) a reduction in the yellow-green alga *Vaucheria* and an increase in the blue-green alga *Schizothrix* in response to the amount of heating, and (2) a prompt removal and continued absence of epilithic red algae (*Rhodochorton* and *Tuomeya*) in a stream heated 12.5°C above ambient even though these algae annually remained abundant in streams heated 0-7°C above ambient.

Post-thermal recovery of *Vaucheria* occurred rapidly and no substantial difference between previously heated and unheated streams was observed after 4 weeks. Within a few weeks of thermal cessation, no visible quantitites of *Schizothrix* were observed in any of the artificial streams. However, during the summer, larger quantitites of *Schizothrix* were detected in the stream previously heated 12.5°C compared to the other recovered streams. Less pronounced, but still noticeably above-normal quantities of *Schizothrix* were observed during the second summer of post-thermal

operation, 18 months after the cessation of thermal pollution. Post-thermal recovery of red algae in the stream previously heated 12.5°C required three months for Rhodochorton and five months for Tuomeya. Similar periods were required for initial colonization by the two taxa on clean rocks placed in all of the streams at the beginning of the post-thermal study.

25 Years of Biological Data on the Savannah River

The Academy of Natural Sciences of Philadelphia has headed a monitoring program of the Savannah River since before SRP operations began over 25 years ago. The biological data collected since 1951 have been compiled by the Academy and computerized by the Environmental Transport Division to generate a 25-year Savannah River Data Base. This data base is the longest, continuously monitored biological data base ever assembled in the United States. It includes over 200,000 environmental entries.

There are two sets of data which comprise the data base. The first set of data was collected during 16 surveys between 1951 and 1976 at four plant site locations. This data represented the presence or absence of species of protozoans, fish, diatoms, other algae, insects, and macroinvertebrates. The second set of data, which consisted of diatom numerical counts, was collected on regular intervals between 1953 and 1976. The diatom data have 95 surveys at upstream, midsite, and downstream locations. The data base lists 2157 species that were present at least once in the river during the 25-year study.

The four major data sets in the data base are:

- A master taxonomic nomenclature coding structure.
- Presence/absence data of all species.
- Numerical counts of the diatom data.
- Water chemistry data.

Data are retrieved from the data base by the JOSHUA System Segment subroutines in Fortran programs. A data report discussing and documenting the 25-year Biological Data and Data Base on the Savannah River will be prepared by the Academy of Natural Sciences of Philadelphia and Savannah River Laboratory.

Transuranics in Marine Biota

The behavior of plutonium in the marine environment has been studied extensively in the past twenty years, but little work has been done on americium or curium in marine settings. ETD analyzed a large selection of marine organisms from the Newport River Estuary for plutonium, americium, and curium to determine the concentrations found in local seafood. Since the Newport River Estuary has no nuclear installations located on it, global weapons fallout is the only likely source of transuranics.

Plutonium was detected in almost all of the marine organisms sampled, with concentrations ranging from 0.02 fCi/g in scallop meat to 1.8 fCi/g in the viscera of whelk and scallops (dry weight). Oysters, clams, menhaden, mullet, pinfish, spot shrimp, crab, and menidia had plutonium concentrations between those values. As expected, the concentration of americium and curium was lower than plutonium in the same organisms. Curium was not detectable in any sample while americium ranged between 0.02 and 0.35 fCi/g.

ATMOSPHERIC STUDIES

SRP Emergency Response System

In 1975, the Weather Information and Display (WIND) computer system began operating at SRP to predict the path of a pollutant cloud in case of an accidental atmospheric release. The WIND system collects meteorological data from seven onsite towers and the nearby 330-m WJBF-TV tower in Beech Island, South Carolina (Figure 1). Until 1979, the computer codes that calculate pollutant trajectories generally used the latest observed wind information to predict the future path of a pollutant. However, calculations based on the assumption that meteorological conditions in the future will be the same as the latest obvervations (a "persistence" forecast) will be inaccurate when wind conditions change.

In 1979, the WIND system was improved by including forecasts of wind and turbulence for up to 30 hours. These forecasts are based on Model Output Statistics (MOS), which is a technique that takes area forecasts and statistically relates them to the meteorology of a particular site. The wind forecasts originate at the National Weather Service headquarters and are transmitted by the National Meteorological Center to SRP twice daily. Initially, the forecasts were fed into the WIND emergency response system manually, but in 1980 a technique was developed and implemented to automatically transmit and use the MOS forecasts into the WIND system (Figure 6). The technique is used to automatically generate forecasts seven days a week, day or night. Wind speed and turbulence forecasts have been shown to produce smaller root mean square errors than forecasts of persistence for time periods over about two hours. For wind direction, the adjusted MOS forecasts produced smaller root mean square errors than persistence for periods greater than four hours. By entering a single character, SRP shift personnel can use any one of the WIND computer codes to make predictions of pollutant dispersion.

The MOS forecasts at SRP represent the nation's first fully automated meteorology forecasts used in an emergency response program. To retain this leadership role, SRL meteorologists are investigating several means of improving the forecasts through use of a boundary layer model and the development of a regional boundary layer model using input from hourly airport observations.

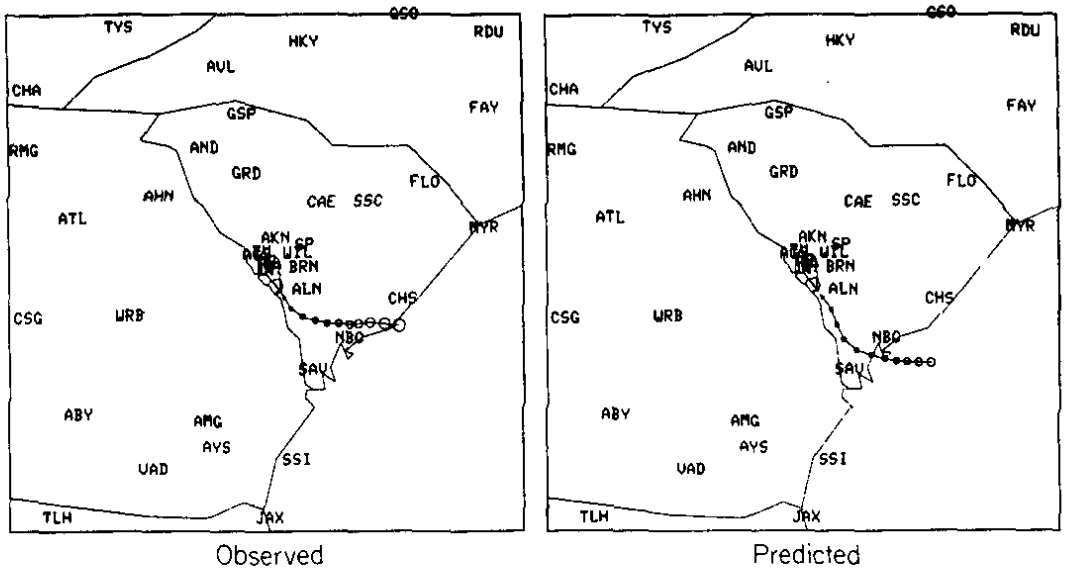

FIGURE 6. This figure shows an example of a prediction of a plume trajectory compared with the observed path. The agreement between observed and predicted trajectories is typical of most 12-hour forecasts.

The emergency response code was improved in 1980 by including the effects of pollutant deposition to the earth's surface and scavenging by rain. Because atmospheric concentrations of a pollutant are now reduced by deposition and rain as well as dispersion, dose estimates will be more accurate.

Studies of plutonium-bearing particles, and tritium uptake by vegetation and soil as a function of forest climatology and plant physiology were used to model the removal of pollutants from the atmosphere. Deposition calculations for radionuclides are particularly important because the material deposited on the vegetation and soil can be recycled through the air, soil, and water long after the initial cloud is dispersed.

In the event of a pollutant release, the emergency response code simulates (1) the initial spreading phase as the pollutant cloud is dispersed into the air, (2) the well-mixed phase as the pollutant concentrations become nearly uniform with height except

near the ground, and (3) the logarithmic decrease of the concentrations as the pollutant near the ground is deposited (Figure 7). Current weather information for the area is continually fed into the computer, so that the only information SRP shift personnel must provide the code is the amount of pollutant released. This saves valuable time when an emergency response decision must be made. Continuous monitors located on the SRP exhaust stacks help plant personnel determine the pollutant emission. Maps can be quickly generated by the emergency response code to predict the pollutant cloud dispersion path, concentration, and deposition. From this information, the potential dose to the population can be determined.

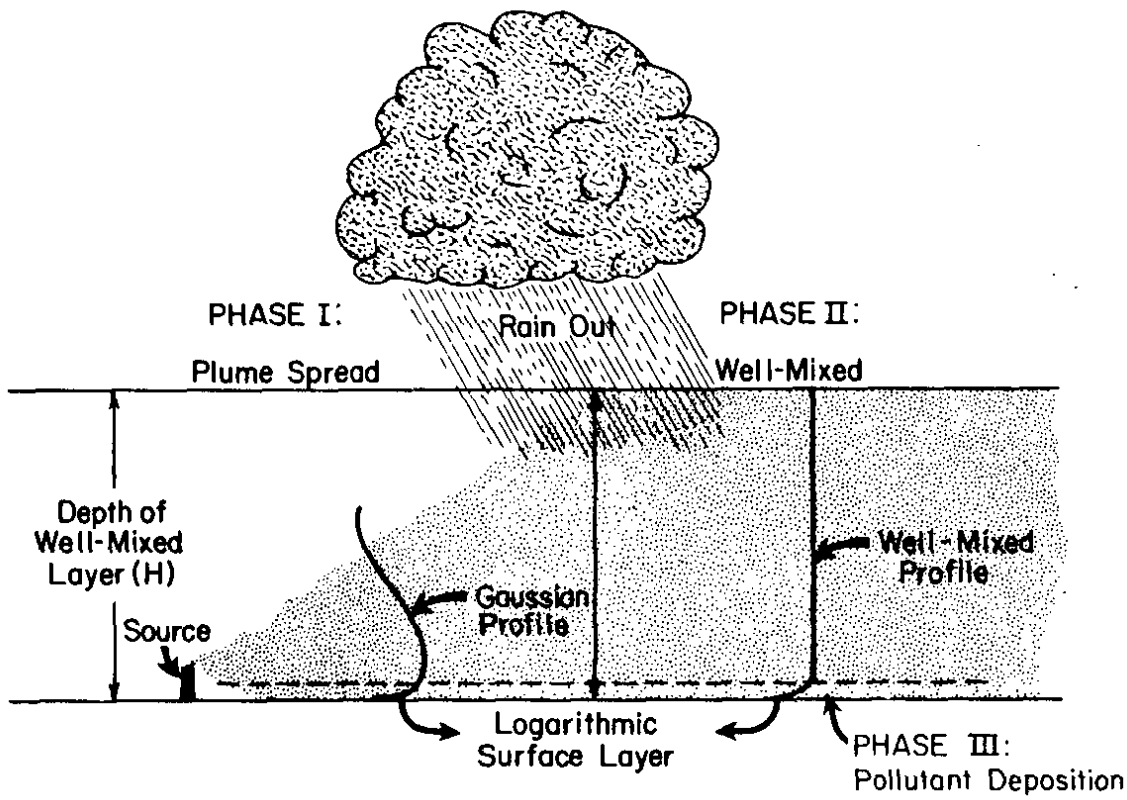

FIGURE 7. **Pollutant plume spread phase, the well-mixed phase, and the concentration decrease as the pollutant is deposited are all taken into account in the emergency response code to make accurate dispersion and dose predictions.**

AFOS System

The National Weather Service (NWS) is phasing out the weather data transmission system, which consisted of teletype and facsimile map circuits. That system is being replaced by the AFOS (Automation of Field Operations and Service) system. AFOS is a computer-controlled communication and query system with a minicomputer at each NWS office. ETD had the AFOS system installed to continue receiving meteorological data from NWS (Figure 8).

AFOS transmits large volumes of data and forecasts to the NWS offices which were not previously available. Yet each office is free to select only that information needed for a particular situation. Raw data, graphs, and maps can be displayed on color graphics terminals and copied by color printers.

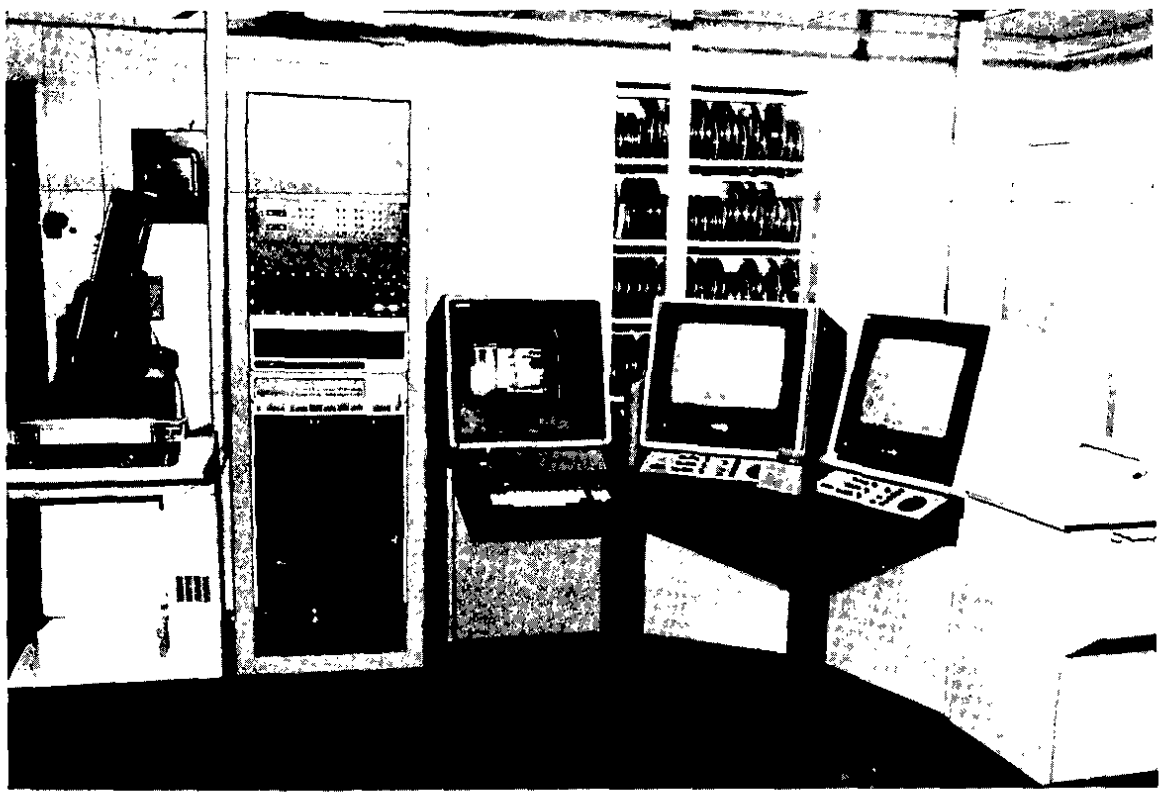

FIGURE 8. ETD installed the AFOS system in 1980 to receive weather information quickly from all over the country. These data are needed for SRP's Emergency Operating Center, ETD's research programs, and mathematical models used to predict pollutant transport.

The AFOS data and forecasts support the Emergency Operating Center of SRP, and are used in mathematical models to predict atmospheric pollutant transport and in research programs. The SRL-AFOS system is smaller than that used at NWS forecast offices, but is similar in scope to that recently installed to support DOE activities at the Nevada Test Site. The sophisticated data system and communications allow SRL to obtain weather information within one minute from any point within the national distribution AFOS circuit. The national network of AFOS offices has an automatic fail-safe capability in the event of a communications failure between stations.

Dispersion Models for Dense Gas Release

Two models for the dispersion of dense gases have been adopted for use on SRL's IBM 360-195 computer. These models are important because several hundred tons of liquid H_2S are stored at SRP for use in the extraction of heavy water. The first model is used in case a gas puff results from a release of liquid H_2S on the ground. The second model would apply to a dense gas plume from an unignited elevated release of H_2S (from a flare tower).

The puff model assumes four stages in the growth of the puff: (1) formation of a cylindrical source, (2) slumping of the cylindrical source cloud, (3) entrainment with growth in the vertical dimension, and (4) transition to a passive puff. Slumping refers to the vertical spreading of the cloud.

The principal differences of the dense gas model over a passive gas model are that the puff grows laterally much more rapidly, and the depth of the cloud first diminishes until sufficient ambient air is entrained to counteract the slumping tendency.

Figure 9 shows the vertical growth of a dense gas cloud released in different ambient atmospheric stability conditions. The lateral growth is almost identical for all stability conditions.

The dense gas plume model is based on wind tunnel simulations of dense gas plumes at Colorado State University. Empirical equations describe the concentration at the earth's surface and the horizontal distance from the stack to the point of plume touchdown and beyond.

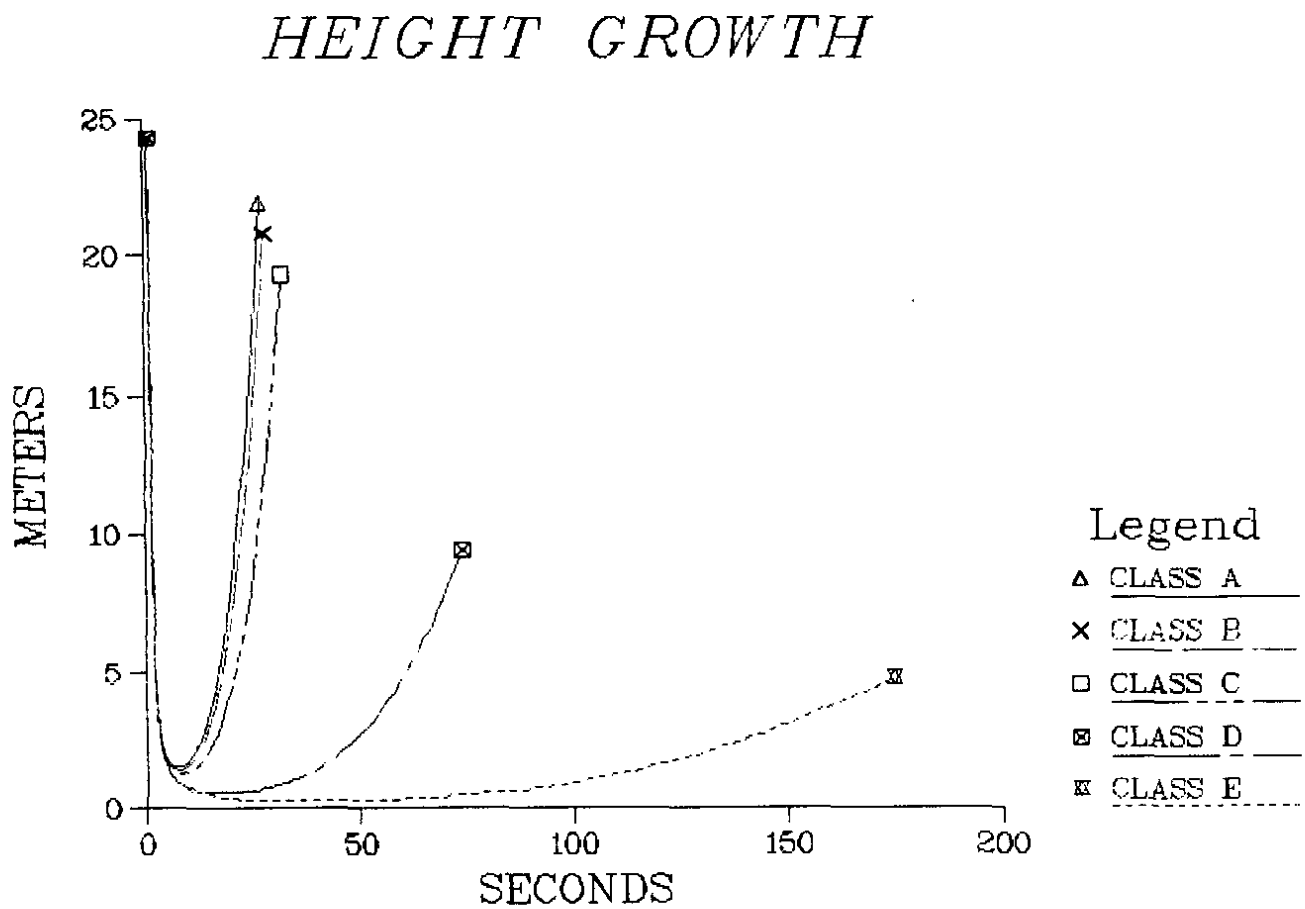

FIGURE 9. The vertical and lateral growth of a dense cloud released under different conditions can be illustrated by the dense gas models. The above graph shows how the model predicts the vertical growth of a dense cloud in winds ranging from high turbulence (Class A) to lower turbulence (Class E) conditions.

JEREMIAH System

A data-based computational system (JEREMIAH) has been developed over several years to assess the radioactive dose to man from atmospheric radionuclide releases. This system calculates the transport and dispersion of radionuclides and their ultimate dose to man through various pathways. The JEREMIAH system is constructed so a user has easy access to any of the codes available in the system.

During 1980, four three-dimensional atmospheric transport and diffusion codes, each based on different numerical techniques, were tested (see page 37). Each of these codes requires a time-varying, three-dimensional wind field as part of the problem input Development of programs to generate these three-dimensional wind fields constitute the major additions to the JEREMIAH system in 1980.

The three sources of raw data for the SRP area were National Weather Service (NWS) surface stations, upper-air stations, and a variety of privately owned meteorological towers. The upper-air stations were sparse, so considerable interpolation in time and space was required to match the surface station density. First, the twice-daily upper-air winds were linearly interpolated in time to provide hourly wind data, in accordance with the surface stations and towers. These hourly data were then interpolated in space to each tower and surface station location. After these atmospheric soundings were constructed, vertically interpolating polynominals were fitted to the sounding data at each NWS surface station and meteorological tower. The polynomials were used for three reasons: (1) they allowed the wind data to be stored efficiently, (2) they forced some vertical consistency into the wind profiles, and (3) they provided a simple interpolation of winds to grid levels.

After the vertical profiles were completed, a mass conservation constraint was applied to the wind fields at each grid level. This constraint minimized the more serious problems caused by the errors in the sparseness of the wind measurements. Without the mass constraint, there are spurious sources and sinks of mass in the calculated wind fields that cause large errors in computed air pollution concentrations. An example of a completed horizontal wind field at one grid level is given in Figure 10. The arrows point toward the direction of flow, and the length of the arrow is proportional to the speed.

Subjective evaluations of the three-dimensional analyses led to the conclusion that the analyses reliably reflected the true atmospheric flow. However, it was also clear that much small-scale detail was lost, some of which was crucial to accurate prediction of air pollution concentrations. Future research on wind field analysis will concentrate on retrieval of as much of the small-scale detail as possible.

A series of programs was written to enable the measured surface winds, the measured winds as a function of height, and the gridded wind fields to be displayed and copied on color, or black and white graphics terminals and plotters. These figures were quite helpful in data checking and program debugging in the generation of three-dimensional wind fields.

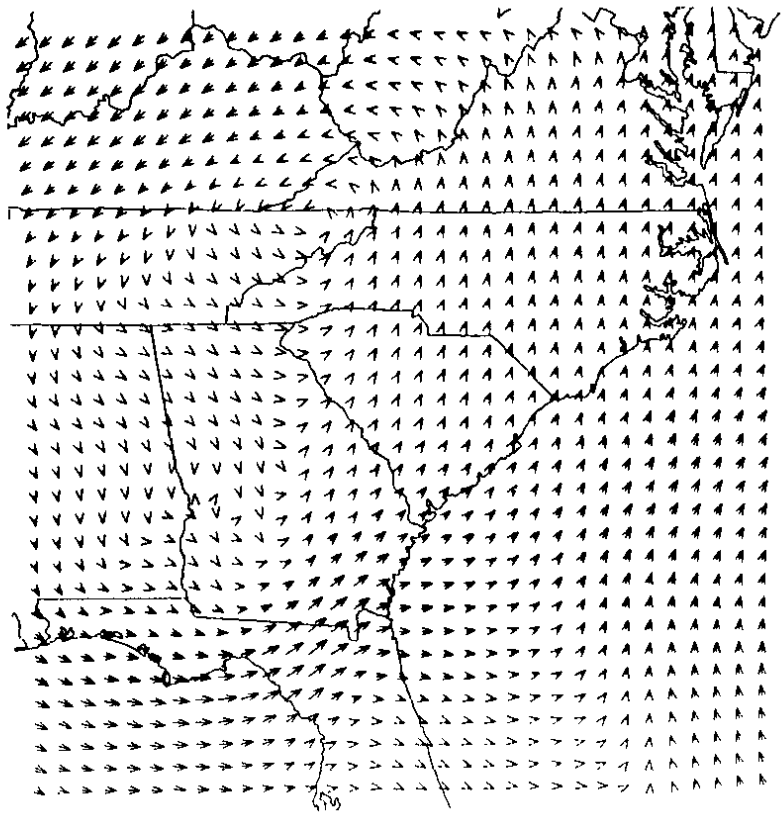

FIGURE 10. Objective computer analysis of regional surface wind fields.

Atmospheric Studies in Complex Terrain (ASCOT)

Many of the past studies of pollutants generated from energy power production have been conducted in areas with relatively flat, uniform terrain. However, many of the power production facilities and large fuel reserves are located in areas with irregular terrain. The irregular terrain effects the atmospheric boundary layer by disturbing the large-scale wind patterns and also by generating local wind systems. Therefore, complex terrain has an effect on the transport and dispersion of pollutants.

The ASCOT (Atmospheric Studies in Complex Terrain) program was developed by DOE to identify and understand the effects of characteristic local terrain features (ridges, canyons, valleys, seacoasts) and meteorological regimes (inversions, nocturnal drainage flow, sea breezes) on atmospheric dispersion processes. The goal of the ASCOT program is to apply this information to a wide range of locations. ETD participated in the DOE field program at the Geysers Geothermal Area located 130 km north of

San Francisco, California, in September 1980. Measurements of the nocturnal boundary layer were made during seven nights with a doppler acoustic echosonde and a tethered ballon (Tethersonde) sounding system.

The doppler acoustic echosonde provided continuous information on the temperature and turbulence structure of the boundary layer, while also providing a vertical profile of the wind speed and direction to altitudes in excess of 600 meters. The tethersonde was used to obtain hourly profiles of air temperature, relative humidity, wind speed, wind direction, and pressure altitude every 17 seconds, up to altitudes of 600 meters above the ground surface. These data have been checked for quality assurance and will become part of the ASCOT data archive.

ETD is also developing an operational boundary layer computer code for short-term predictions of boundary layer winds and temperatures. This modeling effort complements the field measurements described above. At present, the code solves a system of equations which describes conservation of mass, momentum and energy in the atmosphere, heat transfer in the soil, radiative energy transfer, and vegetative effects on winds and radiation fluxes. The computer code has been successfully tested with boundary layer meteorological data from hilly, irregular terrain. The testing of this computer model will continue as the ASCOT data become available. The model will ultimately be used as a forecasting tool for electric utilities and other industries located in complex terrain. Model predictions will be used to determine permissible emission rates for a specific site and set of meteorological conditions.

Model Validation Workshop For Atmospheric Transport and Diffusion

Since the enactment of the Clean Air Act and its amendments, the use of mathematical models for preparing environmental assessments has become required by legislation. Due to the setting of environmental quality criteria, the accuracy of models is critical when they are used to establish particular emission requirements. Models that predict pollutant dispersion for the mesoscale distance range (10-100 km) are of special interest to DOE and the Nuclear Regulatory Commission because population doses have to be evaluated over these distances from nuclear sites. In order to test the accuracy of many of these models, a Model Validation Workshop, sponsored by the Department of Energy and hosted by the SRL Meteorology Group, was held in November 1980.

The meteorological, source-term, and krypton-85 concentration measurement data base for SRP separations area emissions from 1975 to 1977 was used to compare calculations from various atmospheric dispersion models (Figure 11). Participants included representatives from nine DOE-funded laboratories including SRL. Observers from the Environmental Protection Agency, Electric Power Research Institute, Nuclear Regulatory Agency, and others were also present.

Several months before the workshop, meteorological data consisting of wind speeds and directions, temperatures, and turbulence data, along with krypton-85 emission rates, were provided to each participant. With these data, atmospheric transport and diffusion models developed by the DOE Laboratories were run for annual, monthly, weekly, and twice-daily sampling periods. The results were then sent to the SRL Meteorology Group for statistical comparison with the krypton-85 measurements. The models that were used ranged in complexity from simple wind-rose and Gaussian models to more complex two-dimensional and three-dimensional models.

At the workshop, representatives from each of the DOE laboratories described their models and the results. The SRL three-dimensional and Gaussian models demonstrated accuracy at least equal to similar models that are used at other DOE laboratories. The more complex three-dimensional models provide only marginal increases in accuracy, given the typical limited meteorological data base for mesoscale transport and diffusion. The increased costs of running these codes are only warranted for short-term releases or for conditions of complex meteorology and terrain. The overriding factor in the accuracy of predictions by these models, as well as the simple Gaussian models, is the calculation of the advective wind fields. Better knowledge of diffusion parameters would also contribute to improving the accuracy of many of the model calculations. Further improvement in the numerical accuracy of the complex models is not nearly as important as accurate calculations of the meteorological transport and diffusion conditions. Based on these conclusions, the use of hybrid techniques was suggested as a possible alternative. These techniques would combine a simple three-dimensional model for predicting local transport with a Gaussian model for regional-scale calculations.

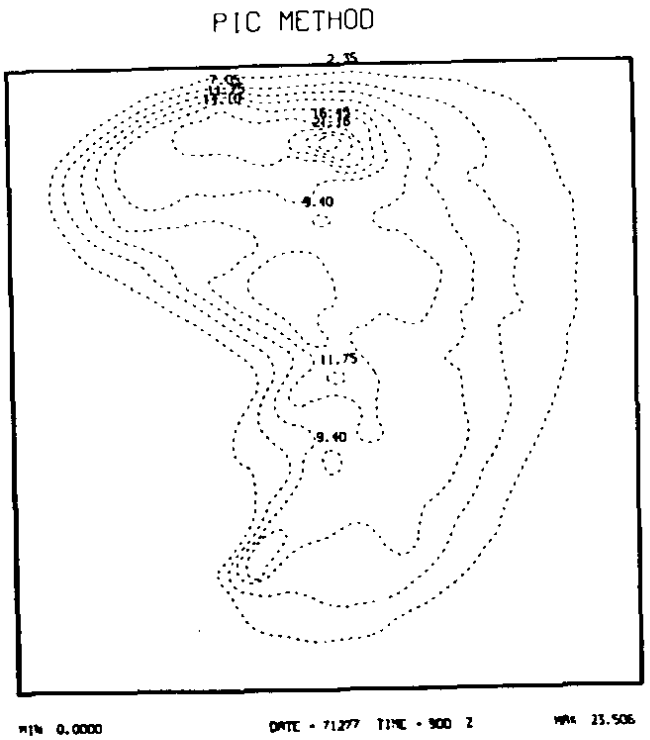

FIGURE 11. Surface concentrations of krypton-85 integrated over 10 hours as calculated by the Particle-in-Cell (PIC) model.

Performance of Three-Dimensional Atmospheric Transport and Diffusion Codes

Four three-dimensional atmospheric transport and diffusion codes, each based on different numerical techniques, have been tested with the SRL 2-year experimental krypton-85 data base and an archived meteorology data base. The four codes are CHAPEAU, FOURIER, MOMENTS, and PIC. CHAPEAU was developed from a one-dimensional finite-element algorithm by linear basis functions (CHAPEAU functions). A time-splitting numerical technique was used to solve the three-dimensional problem. The FOURIER code solves the three-dimensional problem by directly evaluting spatial derivatives of the pollutant distribution by Fourier transform pseudospectral methods. The MOMENTS code is based on a conservation of the zeroth, first, and second moment of the pollution distribution within cell boundaries. This method has minimal numerical dispersion (due to advective transport) and allows subgrid-scale resolution. The PIC method is an Eulerian-Lagrangian scheme (particle-in-cell) that represents pollutant distribution by discrete particles which are advected and dispersed individually according to local conditions.

Comparisons of measurements and computed results are shown in Table 1. The values in the table are integrated ground-level concentrations for a 10-hour period beginning at the time specified for each line. These data show reasonably good agreement between measurement and calculations for some periods, but very poor agreement for other periods. It is suspected that limitations on the meteorological data may account for significant error because there is better agreement between the computational methods than there is between computations and measurement.

Various statistical analyses are being performed to provide additional information on these evaluations. Once completed, the codes that are selected as candidates for further study will be refined to include improved boundary conditions and expanded facilities for treating various pollutant types.

TABLE 1

Measured vs Estimated Integral Concentrations of Krypton-85

			Integral Ground-Level Concentration*, pCi				
Day	Hr	Station	Meas	CHAPEAU	FOURIER	MOMENTS	PIC
100576	2200	12	360	0	6	0	0
100576	2200	14	660	1595	1077	410	673
40677	1000	7	184	189	-	242	106
40677	1000	8	616	302	-	134	125
40677	2200	7	128	215	-	59	260
40677	2200	8	157	186	-	107	178
40777	2200	10	147	348	-	347	240
40777	2200	11	-	151	-	168	357
71077	2100	8	-	390	202	159	184
71077	2100	9	-	98	73	68	106
71077	2100	10	-	121	69	9	0
71077	2100	14	0	0	12	0	0
71177	900	7	3	174	-	304	162
71177	900	8	15	6	-	0	0
71177	900	9	111	16	-	40	6
71177	900	10	27	0	-	0	0
71277	900	8	0	640	-	722	426
71277	900	9	10	536	-	347	291
71277	900	10	146	531	-	739	864
71277	900	11	59	598	-	616	874
71277	900	12	-	168	-	266	202
71277	900	13	95	111	-	109	154

* No data available where the entry is (-)

The Mean Residence Time of Plutonium in the Troposphere

Large atmospheric thermonuclear explosions from weapons testing cause plutonium to be injected into the stratosphere. When aerosols bearing plutonium re-enter the troposphere, they are transported to the ground by rainfall and by sedimentation. Because knowing the amount of time these aerosols usually remain airborne is necessary when studying atmospheric pollution, ETD analyzed previously recorded data from the northern hemisphere for plutonium-239, 240 concentrations.

The method of analysis was based on the observation that very little fallout is transported from the stratosphere to the troposphere during the fall and summer months. A large inventory of plutonium usually exists in the troposphere during the spring months, so the decrease of airborne plutonium could be analyzed for the mean tropospheric residence time between July and October. The fallout from July through October from the stratosphere appears to be only 1% of the spring tropospheric inventory.

The mean residence times were calculated from plutonium-239, 240 monthly surface air concentrations, reported by the Environmental Measurements Laboratory of DOE. These resident times ranged from 66 to 77 days and showed little variation from year to year or with geographic location. The residence time calculated by this method is not necessarily identical to that of natural aerosols, because the particles bearing plutonium may not be typical of natural tropospherical aerosols. However, the calculated residence times for plutonium agree with some higher estimates obtained by other methods for natural aerosols.

Tracer Background Estimation

Background concentrations must sometimes be determined for ETD to test atmospheric models with tracers. A method was developed to make reasonable estimates of the background by normalizing the concentration data and removing concentration anomalies. The atmospheric concentrations which can be sampled over varying time periods are normalized by a mathematical relationship to obtain a background concentration for a specified time period, e.g., 24 hours.

Concentration values which are obviously above background are removed from the data by an iterative procedure. The geometric mean and geometric standard deviation of the data are determined, and values are removed which are larger than the geometric mean plus some multiple of the geometric standard deviation.

After the last iteration, all of the concentrations which were removed are replaced with the last calculated geometric mean. Finally, the background is determined by calculating a running geometric mean on the modified data set for a specified length of time. For example, data samples may be collected and normalized to a 24-hour period, and after the data set is modified, the background could be determined for the data set by calculating a 51-day running geometric mean.

In addition to providing background estimates, this method can be used to help determine causes of varying concentrations of the tracer in the atmosphere.

TERRESTRIAL STUDIES

Iodine-129 Distribution Surrounding SRP

During the first twenty-five years of reprocessing nuclear fuel at the Savannah River Plant, an estimated 4.7 Ci of iodine-129 was released to the atmosphere. The distribution of the iodine-129 concentration deposited onto the terrestrial environment surrounding the plant was determined in 1980 by analyzing samples of vegetation, litter layer, and surface and soil depth profile from sites at radial distances of 20 to 180 km along 5 directions from the center of the reprocessing area.

The atmospheric transport of iodine-129 was demonstrated by the decrease in the terrestrial concentration with increasing radial distance from the reprocessing area (Figure 12). Terrestrial concentrations decreased from about 150 pCi/m^2 at 20 km to about 7 pCi/m^2 at 180 km. This distribution was generally uniform along all directions except to the south-southeast, which was the minimum atmospheric transport direction (at 180 km the concentration was 3 pCi/m^2). The concentration patterns indicate that SRP is the source of the deposited iodine-129. Of the estimated 4.7 Ci released to the atmosphere, about half (2.1 Ci) can be found in the region ranging in radial distance from about 7 to 200 km (concentrations extrapolated to these distances). Predicted deposition, based on 1976 to 1978 meteorological data applicable to the 25-year release history, agrees reasonably well with the observed deposition.

At a given site, the concentration in soil was found to decrease exponentially with increasing depth. The half-depth, the depth required to decrease the iodine-129 concentration to one-half the soil surface concentration, ranged from 3 to 10 cm with a mean of 7 cm. This indicated that the deposited iodine-129 is efficiently retained near the surface and is not rapidly transported into the soil profile. The iodine-129 content in surface vegetation and litter was typically less than 10% of the soil content at a given site.

The 1979 dose from iodine-129 within 80 km was calculated to be 0.093 man-rem compared to 100.3 man-rem from all SRP emissions and to 54,400 man-rem from natural sources within the same 80 km radius. Additional sampling at greater distances is planned to better determine the relationship between deposited iodine-129 concentration and distance.

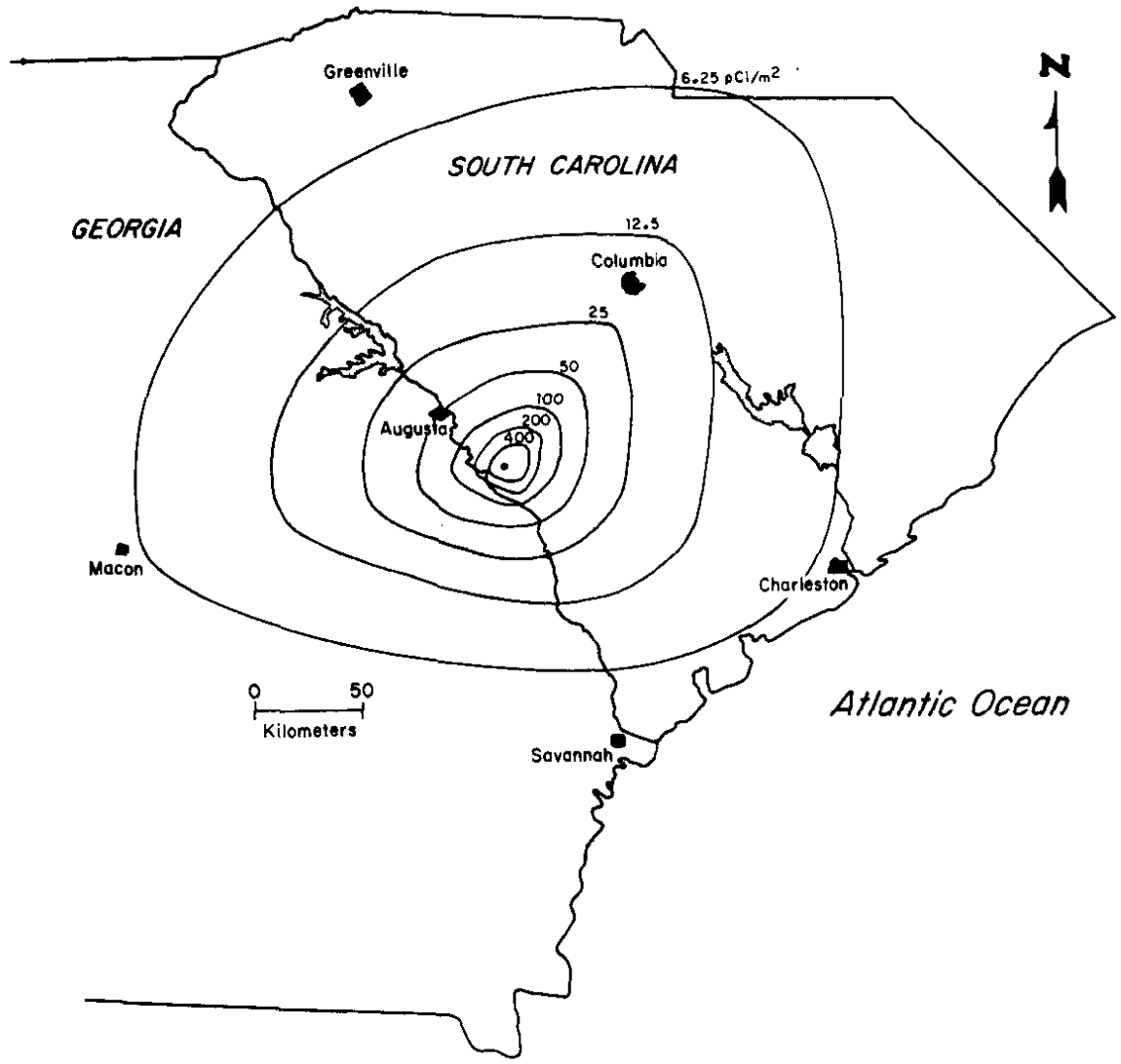

FIGURE 12. The isopleths shown radiating from the SRP site illustrate the decrease in iodine-129 concentration with distance. The dot inside the 400 pCi/m^2 isopleth represents the reprocessing area.

Tritium Uptake in Soil

Molecular tritium (T_2) is a radioactive pollutant released from chemical separations plants used for nuclear fuels and potentially from fusion power reactors. Soil microorganisms can oxidize T_2 to tritiated water (HTO) which is readily absorbed by plants and animals, and can be an important contributor to human radiation dose. The distribution of tritium in soil and vegetation around nuclear facilities can be better predicted if the method and ability of soil to make the exchange to tritiated water were known. Previous studies showed that microorganisms are responsible for the exchange activity. However, ETD wanted to determine the effects of different nutrients and soil conditions on tritium uptake, because a variety of active surfaces will adsorb tritium and promote its exchange to tritiated water.

In a study on soil nutrients, sandy, loam soil (6% organic matter content) was measured for tritium uptake activity, and then sterilized and treated with substances known to stimulate certain kinds of microbial organisms. The treatments included a phosphate-buffered saline suspension with (1) proteose-peptone, (2) starch, (3) $NaNO_3$, and (4) starch + $NaNO_3$. The soil samples were reinoculated with unsterile soil and observed for 36 days for recovery of tritium uptake activity. During recovery, days 3 to 11 had doubling times of 2.7 days, 4.0 days, and 3.7 days for the proteose-peptone, starch, and unamended treatments, respectively. On day 36, the level of activity in the proteose-peptone treatment was much greater than the other two treatments where growth occurred, and was within the range normally seen on local surface soils.

Because tritium uptake activity did not occur in certain soil samples, it can be concluded that microbial activity is a necessary, but not sufficient requirement for tritium uptake in soil. Tritium uptake activity never developed in the sterile control, and although microbial activity developed on treatments receiving $NaNO_3$, no tritium uptake activity was observed. Nutritional factors influenced the development of the microorganisms responsible for uptake. Development was quicker and yield was greater in the presence of a good nutrient source such as proteose-peptone compared to a poor nutrient (starch) or no nutrient source. The identity of the organisms responsible for uptake remains to be determined. A doubling time of 2 to 4 days does not rule out either fungi or bacteria as the biological mediator.

Another study on the effects of temperature and moisture levels on tritium uptake in soil showed that under dry conditions, deposition occurred deeper in the soil profile for all soil types examined, but deposition rates remained unchanged. Maximum deposition velocities were about 0.03 cm/sec for all soils tested. Under high moisture and low temperature conditions, deposition velocities were reduced to between 0.005 and 0.01 cm/sec.

Gas exposures were done in a field exposure chamber which isolates an intact soil core (Figure 13). When T_2 was injected into the air above the soil, 80 to 90% of the T_2 added disappeared in one hour. Control experiments with no soil present showed that very little gas was lost through the chamber itself. After exposure, the tritium was recovered from the soil by freeze-drying and combustion. Virtually all of the tritium was recovered as HTO or exchangeable organic hydrogen in the upper 5 cm of soil and litter.

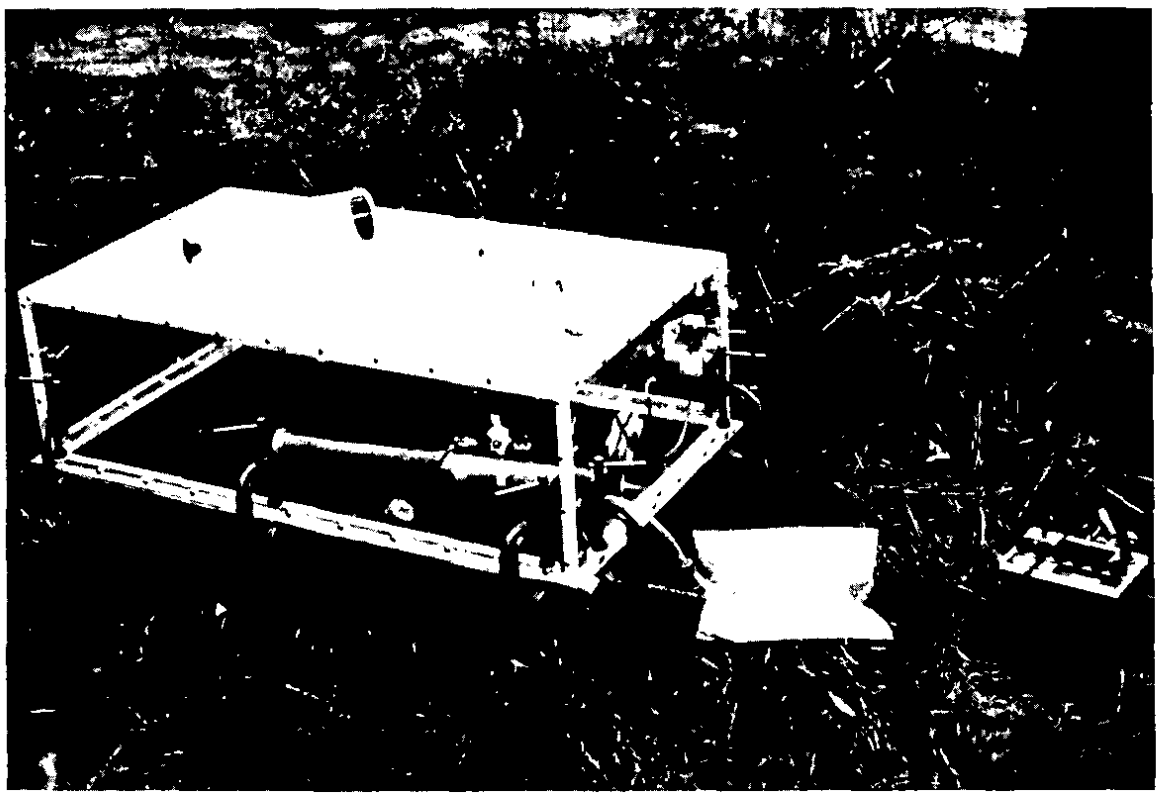

FIGURE 13. Chamber used to expose soil cores to tritium gas.

Water Vapor and Carbon Dioxide Exchange in a Forest

Water vapor and carbon dioxide transfer in crops and forests have usually been studied because of their importance in plant growth. A model of these fluxes has been modified and improved to better estimate pollutant uptake by forests. To determine the parameters for this model, ETD measured the water vapor and carbon dioxide flux density over a loblolly pine planatation.

Air temperature, dew point temperature, and carbon dioxide concentration were measured at four levels above the canopy. From these data, potential temperature, water vapor flux density, and carbon dioxide flux density were calculated. Net radiation was measured by a pair of net radiometers, soil heat flux density was measured by two sets of thermopiles buried at four soil depths, and wind speed was measured at five levels above the canopy.

The data were taken for at least one period of 1 to 3 days in every month of 1980. The summer data was taken during one of the longest droughts in the area for 50 years. The diurnal pattern of evaporation and net carbon dioxide flux density showed some depression during the late afternoon. However, the maximum rate of carbon dioxide uptake (1 mg/m^{2-5}) was similar to that previously reported. Canopy resistance to water vapor transport increased throughout the day reaching 4 sec/cm during the afternoon. Net carbon exchange appears to be affected by the increase in canopy resistance, but the decrease in net carbon flux to the surface during the afternoon is much more than can be explained by canopy resistance. Further analysis of the data is planned. The desired final product is a group of functional relationships linking the gas exhange of the forest stand to easily obtained meteorological data. A preliminary version of this model has been incorporated into the WIND system emergency response codes.

Burial Ground Gamma Activity Distribution

Solid radioactive waste from SRP operations and from occasional special shipments from offsite are stored in the burial ground in 20 x 20-ft trenches covered with a minimum of 4 ft of soil. Throughout the original 76-acre burial ground which was filled in 1972, wells and boreholes have been installed to monitor the possible migration of radionuclides from the burial trenches towards the groundwater table at a depth of 45 ft. A high-resolution gamma-ray spectrometer, ancillary equipment, and procedures developed by ETD were used to measure gamma activities as a function of depth in the soil surrounding the wells. Gamma ray spectra were acquired at 6-inch-depth intervals in 54 of the 4-inch-diameter monitoring wells. Data reduction was completed in 1980 by using a series of computer programs to produce a count

rate versus depth profile for each detected radionuclide in each well. The spectra and profiles are stored on magnetic tape to form a data base for comparisons with future similar surveys as a part of long-term migration studies of radionuclides in the SRP environment.

As expected, high count rates were observed in some of the burial trenches. Below the burial trench bottom, the only man-made radionuclides detected were small amounts of cobalt-60 and/or cesium-137 in 11 wells. Therefore, no large-scale migration occurs, and the small quantities of activities that were measured did not exceed the levels of natural uranium decay series observed in the soil.

Plutonium-Bearing Particles

Minute airborne plutonium-bearing particles which result from SRP operations have been studied to determine their physical and chemical compositions. These particles contain small amounts of plutonium (about 10^{-18} g), but have been analyzed to better understand their pathway through an ecosystem adjacent to a nuclear facility.

Three air samplers were used in 1980 to collect particles during normal operation of a plutonium chemical separation facility. The particles were found to be about ten times larger (ranging from 1 to 10 micrometers) than particles collected by impaction following an accidental release.

While the particles collected immediately following an accidental release were between 89 and 99% $^{238}PuO_2$, those obtained during normal operations contained other elements. About 70% contained silicon as a major constituent; others contained mostly aluminum, copper, or iron. Therefore, plutonium-bearing particles normally in the plutonium fabrication facility appear to be small pieces of plutonium-238 agglomerated on larger dust particles.

Forest Productivity Program

The nation's demand for nonrenewable energy sources, such as oil and coal, might be reduced by converting renewable plant biomass into useful chemicals, liquid and gaseous fuels, process steam, and electric power. ETD has begun a forest productivity program to investigate the environmental effects of using sewage sludge as a fertilizer and soil conditioner for growing trees as energy resources.

Pine and hardwood plantations are being used in studies to evaluate the environmental impact of sludge application on the nutrient and mineral cycle, the hydrologic cycle, soil quality, and the disease rate in forest ecosystems. Applying the nutrients and organic matter associated with the sludge to the soil decreases the impact of the continual tree removal on the nutrient and carbon budget in soils.

The sludge was applied to hardwood and loblolly pine plantations to provide total nitrogen at an equivalent rate of 0, 400, and 800 lbs/acre (Figure 14). The loblolly pines were planted on light- and medium-textured soils in 1953, 1972, 1978, and 1981. The hardwood plantation was planted with five species in early 1980. Before the sludge was applied, the stand conditions were characterized by tree height, diameter at breast height, basal area, stem volume, and incidence of disease. Composite vegetation, litter layers, and subsoil samples were collected to determine initial chemical conditions.

A preliminary nutrient budget was calculated for harvest of tree stems and application of sewage sludge on two 27-year-old loblolly pine experimental plots at SRP. Removal of all loblolly pine stems per acre (180 trees) would result in a depletion of 12 lb of nitrogen, 18 lb of phosphorus, and 91 lb of potassium per acre. Application of sewage sludge at a rate of 5.5 dry tons/acre would result in a net gain of 438 lb of nitrogen, 42 lb of phosphorus, and a net loss of 69 lb of potassium per acre.

Studies are also being done to evaluate the cost effectiveness and environmental effects of using sewage sludge to aid in restoring disturbed lands. There are about 1500 acres of land on the site that have been disturbed since construction began in 1952. Studies by the Southeastern Forest Experimental Station have already demonstrated that the nutrients and organic matter in sewage sludge increase the fertility of poor soils and improve growing conditions for re-establishing vegetative cover on the disturbed soil sites. About 40 acres of borrow pits have been treated with 500,000 gallons of treated domestic sewage sludge. The treated borrow pits will be planted with a variety of hardwood trees and loblolly pine beginning in early 1981.

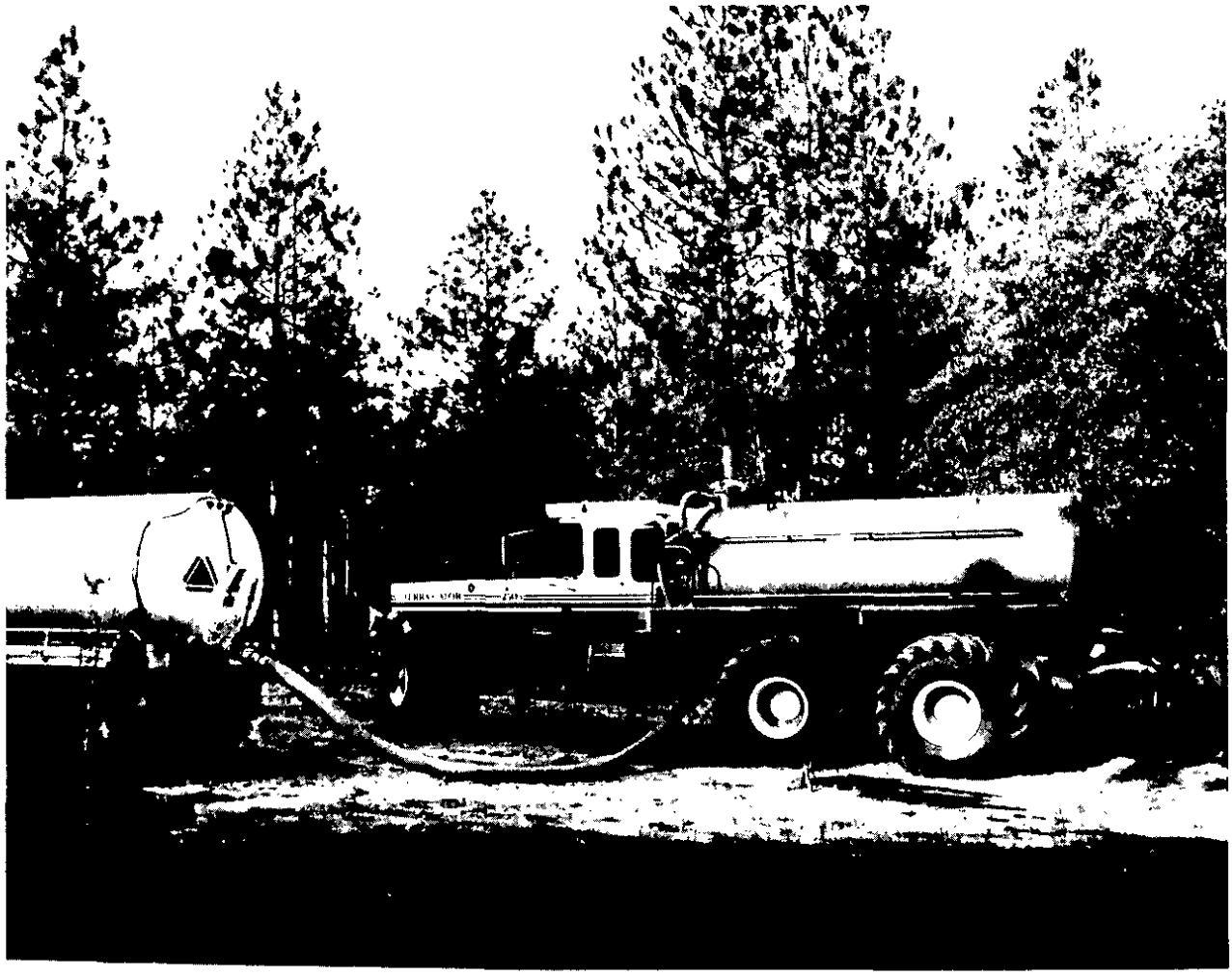

FIGURE 14. The sewage sludge is injected below the surface with a commercially available Terra-gator® (Registered Trademark of Ag-Chem).

INSTRUMENTATION DEVELOPMENTS

Surface Ionization Mass Spectrometer Research

Isotopic signatures of several elements, including plutonium, uranium, and technetium, help determine the physical and chemical transport of these elements in the environment. Construction of a three-stage mass spectrometer capable of analyzing these elements and others in environmental samples was completed in 1979. The spectrometer has since been tuned to meet or exceed goal specifications. ETD has also developed an efficient process to purify plutonium samples as small as 5 femtograms (3×10^{-16}Ci) for analysis.

The use of such small amounts of radionuclides allows many environmental phenomena (i.e., ocean currents, erosion, and meteorological particulate transport) to be followed by micro-tracer amounts of plutonium present in the environment. Additionally, the mass spectrometer can be used to measure plutonium isotopic signatures in leaves and soil to determine plutonium deposition rates and pathways, one of the ETD research goals.

Before samples are analyzed by mass spectrometry, they are typically electrodeposited on platinum counting disks to determine the total plutonium concentration. After alpha counting, the samples are removed from the disks and purified further before they are loaded into the mass spectrometer. Because the samples are small (about 10^{-15} g), the samples must be removed efficiently and with no contamination that would affect the isotopic analysis. A new process which uses a miniature ion exchange column process effectively prepares the samples for the mass spectrometer (>80% chemical yield).

Low-Level Tritium Analysis Techniques

Tritium is one of the major products at SRP and is therefore also an important contributor to human radiation dose in the event of a release, whether accidental or routine. To understand the behavior of tritium in the environment, highly sensitive techniques are required to measure tritium in the environment. Therefore, two new techniques of measuring tritium have been developed. One method uses a new highly sensitive gas mass spectrometer, and the other, a redesigned proportional counter.

Gas Mass Spectrometer

A highly sensitive gas mass spectrometer designed by ETD to measure tritium and helium-3 concentrations in environmental samples was constructed in 1980. This dual-collector, static-gas mass spectrometer has three distinct advantages over the proportional counting method for measuring tritium: (1) the sample is not destroyed by the analysis procedure, (2) hydrogen gas is not generated from the aqueous sample, and (3) the sample can be conserved for reanalysis. Because hydrogen gas generation is eliminated, there is less chance of sample contamination. The only limitations in the sensitivity are the integrity of the sample container, and background levels of helium in the container materials. Also, because the limit of sensitivity is for an absolute quantity of tritium, lower concentrations of tritium in aqueous samples can be measured by using larger samples.

The tritium is collected in the form of water by direct aquatic sampling, by atmospheric water vapor absorption on a molecular sieve, or by the direct oxidation of molecular hydrogen. The decay product of tritium, helium-3, can then be accumulated by storing the water in a sealed container for 2 to 10 weeks or longer depending on the sensitivity required.

Initial ion optic tests and tuning have begun on the spectrometer, which was constructed by the Nuclide Corporation. The sensitivity of the spectrometer results in about 5000 detected $^{3}He+$ ions in 1000 seconds for a sample containing as few as 50,000 atoms of helium-3. This sensitivity gives the capability of measuring 2.0 pCi (2×10^{-6} g) of tritium with 3% accuracy after a 4-week buildup of helium-3. The helium-3 mass spectrometer will be installed in ETD laboratories in 1981.

Low-Background Proportional Counter

Although the helium mass spectrometer measures the sample more accurately and is more sensitive, the researcher may have to wait for weeks for the decay product of tritium (helium-3) to build up in the sample container before it can be measured. The proportional counter can produce reliable, but not necessarily as sensitive analyses overnight, which can be important when determining pollutant transport. A proportional counter measures the number of radioactive decays from a sample within a gas-filled chamber between two electrodes, across which a voltage is applied. When the gas is ionized by the beta particle emitted during the decay of a tritium atom, the free electrons and ions move to the electrodes of the opposite sign, creating a small current pulse. The size of the current pulse is proportional to the number of ions.

The proportional counters were redesigned in 1980 to improve stability by allowing them to operate at a lower bias voltage and to decrease counter background. This was done through the use of counter shell modifications, improved pulse-shape discrimination, and increased shielding.

TRAC System

A mobile laboratory was designed in 1980 to enhance the SRP emergency response capabilities in case there is an atmospheric release of radionuclides from the Savannah River Plant (Figure 15). The TRAC (Tracking Radioactive Atmospheric Contaminants) system will improve SRP emergency response and the Radiological Assistance Program by identifying the radionuclide composition of the release, and by producing accurate real-time field measurements of radionuclide concentrations far below maximum permissible concentration limits.

The TRAC system will considerably reduce the time currently required for sample analyses, which are needed to make emergency response decisions. The TRAC system will also provide data to check the concentration calculations available from the Weather Information and Display (WIND) computer system at SRL. The WIND System collects meteorological data from around the plantsite and uses the data to predict the concentrations and pathways of any atmospheric releases resulting from SRP operations. Together, the two systems could determine accurate, timely, dose assessments at levels below those considered significant from a health standpoint, yet at levels where there is public concern.

Sensitive instruments being developed for the mobile laboratory include a cloud monitor to detect penetrating radiation; and Sensitive equipment to measure tritium (as HT or HTO) iodine, fission and activation products (beta-gamma particulates), transuranic products (alpha particulates), and noble gases in near real time.

The mobile laboratory will be used for environmental research to permit development of sensitive collection and measurement instrumentation, verification of measurements from the ring of remote gamma-ray monitors, measurements of normal release rates from routine SRP operations, verification of WIND system predictions, and experiments to improve atmospheric transport codes.

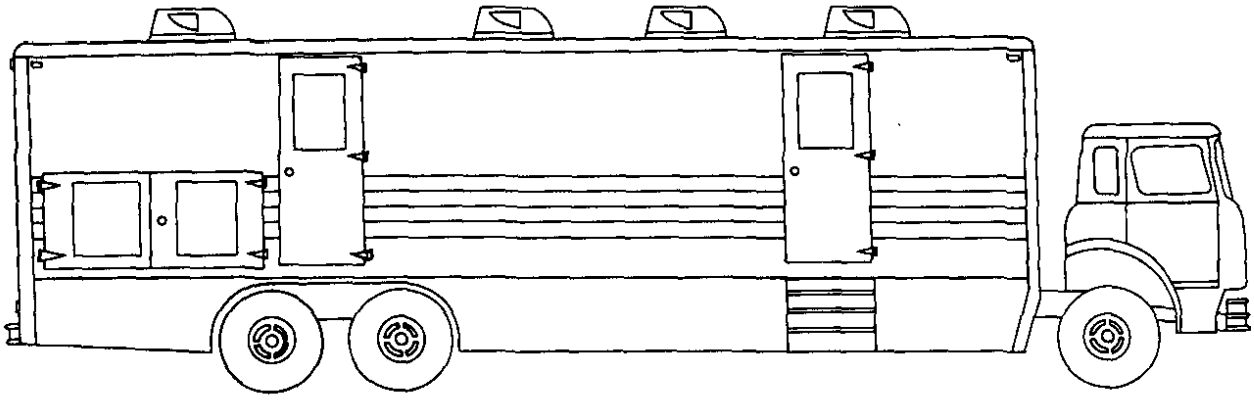

FIGURE 15. The TRAC mobile laboratory will improve SRL emergency response by identifying the radionuclide composition of a pollutant release.

Underground Low-Level Counting Facility

The ultra low-level counting facility for SRL was built in 1967 to provide shielding for detectors to analyze environmental and other low-activity samples. This facility consists of two counting vaults, each 10 x 10 x 8 ft with 12-inch-thick walls made of pre-World War II naval armor plate. The facility is currently operating at capacity, and the low-level sample load is expected to double during the next ten years. In addition, research and monitoring programs require even lower detector backgrounds to improve the sensitivity of nuclear counting techniques. Accordingly, a new counting facility was designed during 1980 to create additional shielded vault space with reduced background (Figure 16).

The new facility will consist of a 10 x 20 x 8 ft vault made of 4-inch-thick pre-World War II naval armor plate completely surrounded by 4 feet of very low-activity iron ore (specular hematite). Additional shielding will be provided by locating the shielded vault 50 feet below ground. The approximately 40 feet of backfill above the vault should significantly reduce the cosmic background component, while the vault walls and hematite reduce the background component of the soil (natural uranium, thorium, and potassium). Access to the vault will be through a shielded maze from a small elevator and stairway attached to the end of the vault. At ground level, a 46 x 22 ft modular building will house a computer-electronic support laboratory with an air handling unit

providing a class 100 environment. All construction materials associated with the shielded facility will be assayed to eliminate materials with significant activity levels. Completion of the facility is anticipated in late 1981.

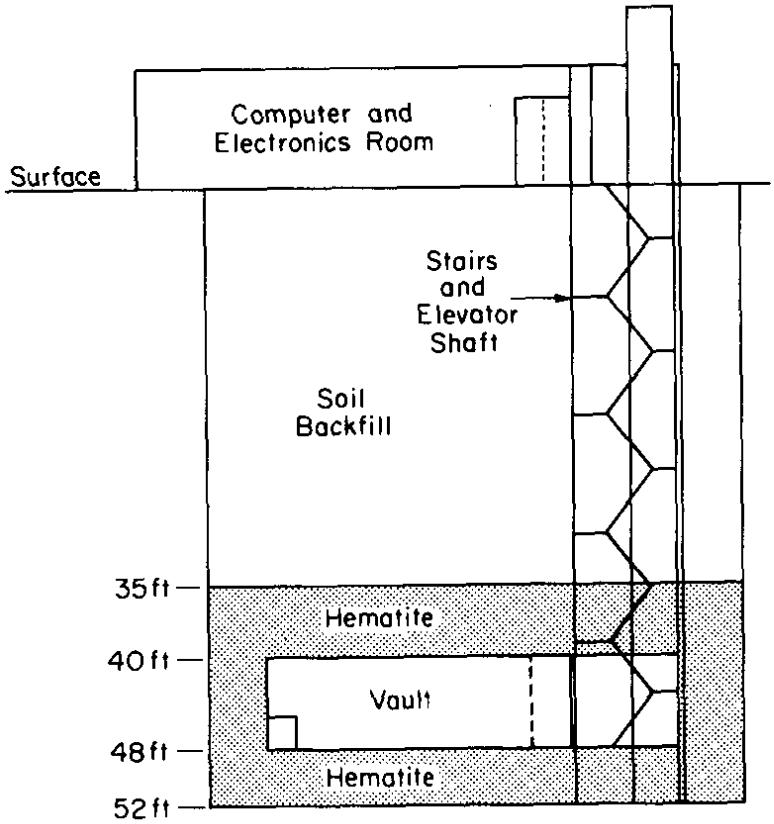

FIGURE 16. The underground low-level counting facility will accommodate the expected increase in demand for low-level analyses and provide even lower detector backgrounds to improve sensitivity of nuclear counting techniques.

REFERENCES

Publications

Aquatic Studies

Fallon, R. D., and C. B. Fliermans. "Formation of Nonvolatile Mutagens by Water Chlorination: Presistence and Relationship to Molecular Weight of Organic Material to Water." Chemosphere. 9, 385-391 (1980).

Fliermans, C. B., and T. C. Hazen. "Serological Specificity of Aeromonas hydrophila as Measured by Immunofluorescence Photometric Microscropy." Can. J. Microbiol. 26, 161-168 (1980).

Fliermans, C. B., W. B. Cherry, L. H. Orrison, S. J. Smith, D. L. Tison, and D. H. Pope. "Ecological Distribution of of Legionella pneumophila." Appl. and Env. Microbiol. 41, 9-16 (1981).

Gordon, R. W., and C. B. Fliermans. "Methanogenesis in Thermal Reactor Effluents." J. Therm. Biol. 5, 169-177 (1980).

Hayes, D. W., S. D. Harris, and R. S. Stoughton. "A Tidal Powered Water Sampler." Lim. and Oceanog. 25, 761-764 (1980).

Tison, D. L., D. H. Pope, C. B. Fliermans, and W. B. Cherry. "Growth of Legionella pneumophila (Legionnaire's Disease Bacterium) in Association with Blue-Green Algae." Appl. and Env. Microbiol. 39, 456-459 (1980).

Hayes, D. W. and J. H. Horton. "Plutonium and Americium behavior in the Savannah River Marine Environment." Transuranic Elements in the Environment, USDOE Report DOE/TIC-22800, W. C. Hanson, Ed., U. S. Department of Energy, Washington, DC, 602-611 (1980).

Terrestrial Studies

Adriano, D. C., J. C. Corey, and R. C. Dahlman. "Plutonium Contents of Field Crops in the Southeastern United States." Transuranic Elements in the Environment, USDOE Report DOE/TIC-22800, W. C. Hanson, Ed., U. S. Department of Energy, Washington, DC, 381-402 (1980).

Buckner, J. T., M. R. Buckner, W. S. Durant, W. E. Prout, and J. R. Watts. Methodology Development for Risk Assessment of Fuel Reprocessing. NRC Report NUREG/CR-1604, U.S. Nuclear Regulatory Commission, Washington, DC (1980).

Corey, J. C., G. J. Hollod, D. M. Stone, C. G. Wells, W. H. McKee, and S. M. Bartell. "Environmental Effects of Utilization of Sewage Sludge for Biomass Production." Utilization of Municipal Waste Water and Sludge for Land Reclamation and Biomass Production. U.S. Environmental Protection Agency, Washington, DC (in press).

Hollod, G. J., J. C. Corey, and E. F. Dyer. The Environmental Effects of Producing Biomass in Pine and Hardwood Plantations for Renewable Energy Resources. USDOE Report CONF, U.S. Department of Energy, Washington, DC (1981).

Horton, J. H., D. C. Adriano, J. E. Pinder, III, and J. C. Corey. "Distribution of Surface-Deposited Plutonium in Soil After Cultivation." Health Physics. 38, 697-699 (1980).

McLeod, K. W., D. C. Adriano, A. L. Boni, J. C. Corey, J. H. Horton, D. Paine, and J. E. Pinder, III. "Influence of a Nuclear Fuel Chemical Separations Facility on the Plutonium Contents of a Wheat Crop." J. Env. Qual. 9, 306-215 (1980).

McKee, W. H., G. J. Hollod, and C. G. Wells. "Influence of Sewage Sludge on Growth and Nutrition of 2-Year-Old Loblolly Pine on Well-Drained Sandy and Clayey Soils." Study Plan. USDA Report FS-SE-1103-138(2), U.S. Department of Agriculture, Washington, DC (1980).

McKee, W. H., G. J. Hollod, and C. G. Wells. "Influence of Sewage Sludge on Growth and Nutrition of 27-Year-Old Loblolly Pine on Well-Drained Sandy and Clayey Soils." Study Plan. USDA Report FS-SE-1103-139(2), U.S. Department of Agriculture, Washington, DC (1980).

Murphy, C. E., Jr., J. F. Schubert, and A. H. Dexter. "Parameter Estimation for Prediction of the Dry Removal of Bases by Ecosystems." American Institute of Chemical Engineers Symposium Series 196, 16, 210-217 (1980).

Murphy, C. E., Jr., and J. Ares. "The Use of Forests as Filters for Air Pollutants." Second Joint Conference on Applications of Air Pollution Meteorology, American Meteorological Society, Boston, MA, 253-257 (1980).

Sanders, S. M., and A. L. Boni. "The Detection and Study of Plutonium Particles Following the Reprocessing of Reactor Fuel." Transuranic Elements in the Environment, USDOE Report DOE/TIC-22800, W. C. Hanson, Ed., U.S. Department of Energy, Washington, DC, 107-144 (1980).

Shields, J. D., N. D. Woody, A. S. Dicks, G. J. Hollod, J. Schalles, and G. J. Leversee. Locations and Areas of Ponds and Carolina Bays at the Savannah River Plant. USDOE Report DP-1525, U.S. Department of Energy, Savannah River Laboratory, Aiken, SC (1980).

Instrumentation Developments

Carlson, D. C., and W. L. Clarke. "Nondestructive Measurement of Sensitization of Stainless Steel: Relation to High Temperature Stress Corrosion Behavior." Materials Performance, 19 (3), (1980).

Submitted Manuscripts

Aquatic Studies

Fliermans, C. B., G. E. Bettinger, and A. W. Fynsk. "Treatment of Cooling Systems Containing High Levels of Legionnella pneumophila." Submitted to Water Research.

Fliermans, C. B., R. J. Soracco, and D. H. Pope. "Measure of Legionella pneumophila Activity in situ." Submitted to Current Microbiology.

Holloway, R. W. and D. W. Hayes. " The Mean Residence Time of Plutonium in the Troposphere." Submitted to Environmental Science and Technology.

Orrison, L. H., W. B. Cherry, C. B. Fliermans, S. B. Kees, L. K. McDougal, and D. J. Dodd. "Characteristics of Environmental Isolates of Legionnella pneumophila." Submitted to Current Microbiology.

Pope, D. H., P. L. Tison, E. B. Braun, and C. B. Fliermans. "The Effect of a Thermal Regime on the Heterotrophic Activity of Algal-Bacterial Mat Communities." Submitted to Applied and Environmental Microbiology.

Tison, D. L., and E. W. Wilde. "Primary Production and Biovolume of various Phototropic Plantation Size Fractions in Three Southeastern U.S. Reservoirs." Submitted to Applied and Environmental Microbiology.

Wilde, E. W., and L. J. Tilly. "Structural Characteristics of Algal Communities in Thermally Altered Artificial Streams." Submitted to Hydrobiologia.

Wilde, E. W., and B. D. McLaughlin. "Selecting an Algicide for Use with Aluminum Alloys." Submitted to Water Research.

Atmospheric Studies

Garrett, A. J. "Comparison of Observed Mixed-Layer Depths to Model Estimates Using Observed Temperatures and Winds, and MOS Forecasts." Submitted to Journal of Applied Meteorology.

Pendergast, M. M. "The Effect of Spatial Variability of Meteorological Data on Annual Average Air Concentrations Predicted by a Wind Rose Model." Submitted to Atmospheric Environment.

Pepper, D. W., and R. E. Cooper. "An Investigation of Multidimensional Numerical Modeling for Calculating Pollutant Transport." Submitted to Atmospheric Environment.

Schubert, J. F., R. E. Cooper, J. R. Watts, and C. E. Bailey. "Population Dose from Light Water Reactor Fuel Reprocessing. Submitted to Nuclear Technology.

Terrestrial Studies

Beasley, T. M., A. L. Ball, J. E. Andrews, III, J. E. Halverson. "Hanford-Derived Plutonium in Columbia River Sediments." Submitted to Science.

Corey, J. C., J. G. Pinder, J. R. Watts, D. C. Adriano, A. L. Boni, and K. W. McLeod. "Stack-Released Plutonium in the Terrestrial Environment of a Chemical Separations Facility." Submitted to Nuclear Safety.

Halverson, J. E. "A Three-Stage Mass Spectrometer for Isotopic Analysis of Environmental Radionuclides." Submitted to the International Journal of Mass Spectrometry and Ion Physics.

Kantello, M. V., B. Tiffany, and T. J. Anderson. "Iodine-129 Distribution in the Terrestrial Environment Surrounding a Nuclear Fuel Reprocessing Plant After 25 Years of Operation." Submitted for presentation at the International Symposium on Migration in the Terrestrial Environment of Long-Live Radionuclides from the Nuclear Fuel Cycle to be held in Knoxville, TN on July 27-31, 1981.

Murphy, C. E., Jr. "Water Vapor and Carbon Dioxide Exchange in a Young Loblolly Pine Plantation." Submitted for presentation at the 15th Conference on Agricultural and Forest Meteorology to be held in Anaheim, CA on April 1-3, 1981.

Murphy, C. E., Jr., and J. Ares. "The Uptake of Hydrogen Fluoride by a Forest." Submitted to Ecological Modeling.

Murphy, C. E., Jr., J. F. Schubert, and A. H. Dexter. "The Energy and Mass Exchange Characteristics of a Loblolly Pine Plantation." Submitted to the Journal of Applied Ecology.

Sweet, C. W., and C. E. Murphy, Jr. "Oxidation of Molecular Tritium by Intact Soils." Submitted to Environmental Science and Technology.

Watts, J. R., E. W. Rabon, and A. S. Dicks. "Radiation Dose and Content of Cs-137 in Deer: Savannah River Plant vs. Southeastern Coastal Plain Herds." Submitted to Health Physics.

Watts, J. R., J. C. Corey, and K. W. McLeod. "Land Application Studies of Industrial Waste Oils and Solvents." Submitted to Environmental Pollution.

Instrumentation Developments

Bowman, W. W., and M. B. Hughes. "Proportional Counting Techniques for Routine Analyses at Environmental Levels." Submitted for presentation at the International Symposium on Methods of Low-Level Counting and Spectrometry to be held in West Berlin, Germany on April 6-10, 1981.

Halverson, J. E., and L. F. Herzog, Jr. "A Static Gas Mass Spectrometer for Low-Level Tritium Concentration Measurements." Submitted for presentation at the International Symposium on Methods of Low-Level Counting and Spectrometry to be held in West Berlin, Germany on April 6-10, 1981.

SPECIAL DISTRIBUTION FOR THIS REPORT:

No of Copies	
1	N. D. Pewitt Acting Director Office of Energy Research ER-2, FORSTL U.S. Department of Energy Washington, DC 20585
1	C. W. Edington Acting Director DOE-OHER EP-30, Germantown Washington, DC 20545
1	D. H. Slade DOE-OHER EP-36, Germantown Washington, DC 20545
1	R. L. Watters DOE-OHER EP-34, Germantown Washington, DC 20545
1	R. W. Wood DOE-OHER EP-35, Germantown Washington, DC 20545
1	D. H. Hamilton DOE-OHER EP-34, Germantown Washington, DC 20545
1	D. S. Ballantine DOE-OHER EP-35, Germantown Washington, DC 20545
1	Helen McCammon DOE-OHER EP-34, Germantown Washington, DC 20545
1	Janet Dorigan DOE-OHER EP-34, Germantown Washington, DC 20545

1 George Sherwood
DOE-Nuclear Reactor Programs
NE-524, Germantown
Washington, DC 20545

1 E. Markee
Nuclear Regulatory Commission
Silver Springs, MD

1 R. Abby
Nuclear Regulatory Commission
Silver Springs, MD

1 Dr. Joseph B. Knox (G-Division)
University of California
Lawrence Livermore National Laboratory
P. O. Box 808
Livermore, CA 94550

1 Dr. M. L. Mendelsohn, (V-Division)
University of California
Lawrence Livermore National Laboratory
P. O. Box 808
Livermore, CA 94550

1 Dr. Ruth Patrick
Academy of Natural Sciences
19th and Race Streets
Philadelphia, PA 19103

1 Dr. L. E. Neimeyer
Meterorology Division
Environmental Protection Agency
Research Triangel Park, NC 27711

1 Dr. L. J. Tilly
Center for Energy and Environmental Research
University of Puerto Rico
College Station
Mayaquez, Puerto Rico 00708

1 Asst. Administrator
Office of Research and Development
Environmental Protection Agency
Washington DC 20460

1 Glen Hilst
Electric Power Research Institute
P. O. Box 10412
Palo Alto, CA 93404

1 Jared J. Davis
Office of Nuclear Regulatory Research
Nuclear Regulatory Commission
Washington, DC 20555

1 Dr. Lester Machta
Air Resources Laboratory
ESSA, P. O. Box 2108
Idaho Falls, ID 83101

1 DIRECTOR
NOAA Air Resource Atmospheric Turbulence
and Diffusion Laboratory
P. O. Box E
Oak Ridge, TN 37830

1 Mr. Ray Dickson
Air Resources Field Research Office
ESSA, P. O. Box 2108
Idaho Falls, ID 83101

1 The Institute of Ecology
University of Georgia
Athens, GA 30601

1 Skidaway Institute of Oceanography
P. O. Box 13687
Savannah, GA 31406

1 Savannah River Ecology Laboratory
University of Georgia
Aiken, SC 29801

1 U. S. Forest Service
Savannah River Plant
Aiken, SC 29801

1 National Fisheries (NOAA)
Beaufort, NC 28616