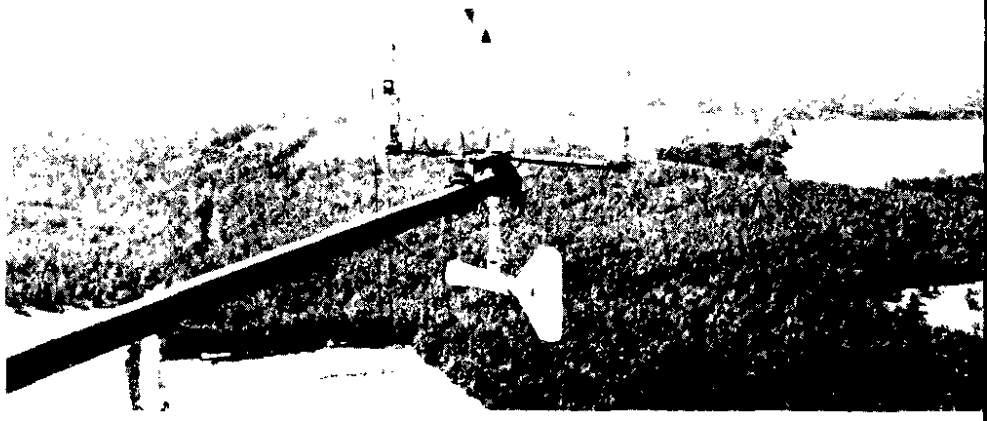
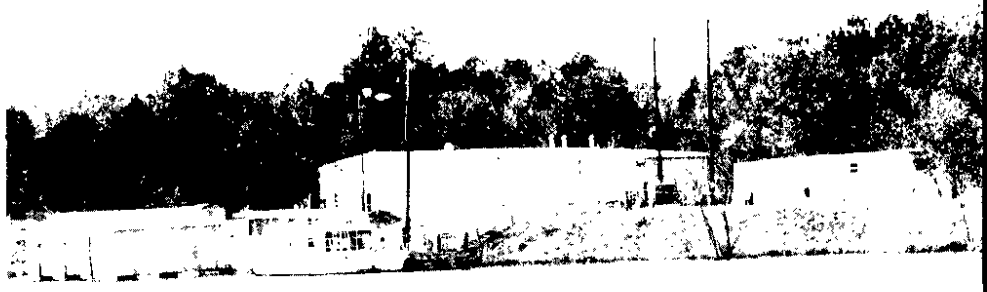
DP-1557

1979 REPORT

ENVIRONMENTAL TRANSPORT DIVISION





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ENVIRONMENTAL TRANSPORT DIVISION

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ABSTRACT

During 1979, the Environmental Transport Divison (ETD) of the Savannah River Laboratory conducted atmospheric, terrestrial, aquatic, and marine studies, which are described in a series of articles. Publications written about the 1979 research are listed at the end of the report if more details are desired about specific studies.

CONTENTS

INTRODUCTION

The environmental research at the Savannah River Laboratory (SRL) concerns the movement, cycling, and effects of pollutants released to the environment in the southeastern United States by Savannah River Plant (SRP) operations (Figure 1). The SRP site and operations are used in studies of the general environmental processes as well as to solve specific problems posed by SRP operations (Figure 2). Atmospheric processes, atmospheric exchanges with forest ecosystems, cycling in soil and plants, and environmental processes in SRP and nearby water systems are some of the studies conducted at SRL.

With increasing applied environmental research at SRL since the early 1970's, annual reports have been published to highlight accomplishments in the Environmental Transport Division (ETD). With this 1979 report, a marked change is taking place in style. The 1979 report summarizes the program in a more concise form than the collection of short research papers in previous reports. Key findings for the year are given. Details of ETD 1979 studies are found in references listed at the end of this report.

Special Events during 1979

At the request of Lawrence Livermore Laboratory (LLL), ETD meteorologists were sent to the Three Mile Island nuclear power plant shortly after the nuclear incident. They relieved other meteorologists stationed there to man the temporary Atmospheric Release Advisory Capability (ARAC) station at the Capital City Airport, Harrisburg, PA. ARAC is a meteorological system that is based at LLL and has satellite centers at several nuclear facilities to 1) predict plume concentrations, 2) perform dose assessments for population exposure, and 3) integrate measurements with plume predictions. This information was used by aircraft and ground sampling teams to collect air, vegetation, and milk samples in the area adjacent to the plant. ETD is presently evaluating the ARAC system concept, and ARAC can act as a backup to SRL emergency response capabilities.

The National Weather Service (NWS) of the National Oceanographic and Atmospheric Administration is phasing out its existing weather service information system in 1980. In order to receive NWS weather information, it will be necessary to have a system compatible with the new NWS system for Automation of Field

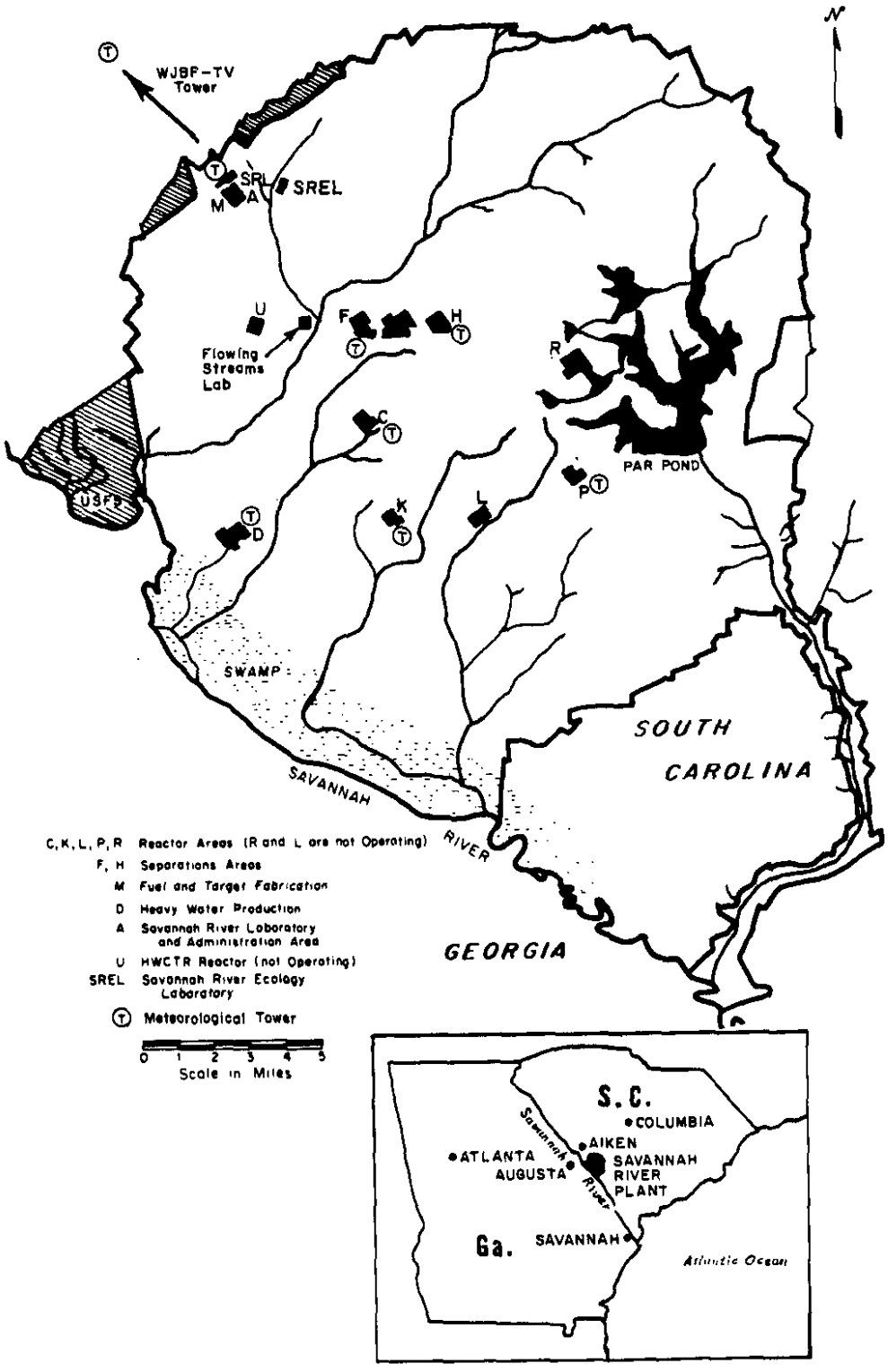

FIGURE 1. The Savannah River Plant Site. The inset shows SRP's regional location.

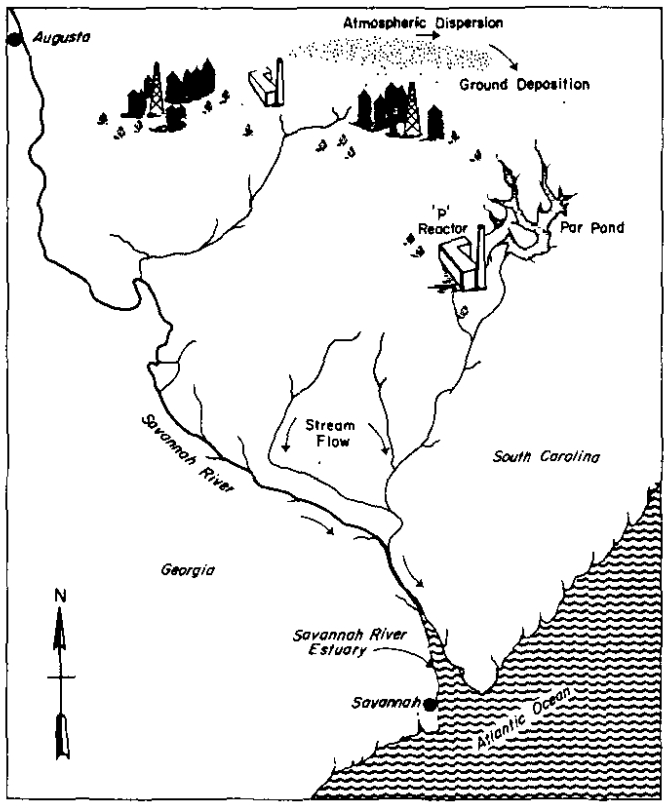

FIGURE 2. A non-scale drawing illustrating the relationship of SRP operations to the rest of the area's environment.

Operations and Service (AFOS). In 1979, an AFOS system was designed for installation at the SRL Weather Center Analysis Laboratory in October-November, 1980. NWS weather data will be transmitted on a Department of Energy (DOE) loop between the Nevada Test Site and SRP. The Nevada Test Site will act as a node in the NWS data loop and will forward this data to other participating DOE-AFOS centers. SRL will be the first DOE laboratory to use this system.

Terminals to the WIND minicomputer system were installed in major operating areas of the plant to handle meteorological data and perform calculations for accidental releases to the atmosphere. This permits operating personnel to have rapid access to the best available assessment methods.

In 1979, we completed the construction of a new Limnology Laboratory was completed alongside the Par Pond cooling reservoir. This contains four laboratories, two offices, and ample storage facilities. It replaces two trailers dating from the early construction days of SRP and an assortment of storage sheds, making good field laboratory facilities available for the aquatic ecology programs at Par Pond.

A sophisticated three-stage mass spectrometer was completed for use in environmental studies of transuranic elements. This versatile, sensitive instrument will also be used to study other elements.

ETD turned over to Skidaway Institute of Oceanography of the University of Georgia the operation of the meteorology and oceanography instrumentation installed on the Savannah Navigational Light Tower ten miles offshore from Savannah, GA. The division works with Skidaway in near-shore oceanography and estuary research, and all parties agreed, including the Department of Energy, that it would be best for the total program if Skidaway operated the instrumentation there.

The Environmental Transport Division

The Environmental Transport Division currently has 32 professionals in fields such as radiochemistry, meteorology, physics, fluid mechanics, oceanography, plant physiology, microbiology, engineering, soils, and biochemistry. Twenty-eight project assistants, technicians, and secretaries support the researchers. There are usually two graduate students in the division doing their thesis work, and four co-op students, with some additional students and visiting faculty members in the summer. Subcontractural arrangements for special studies with universities often add another three to five people to the division staff for months at a time. In 1979, the division lost four professionals and gained one by transfers, and hired seven well-qualified researchers.

The division obtained about one-third of its funding in 1979 from the Office of Health and Environmental Research under the Assistant Secretary for the Environment of the Department of Energy. An additional one-third of the division's funding came from the Assistant Secretary for Defense through the operating budget of SRP. The remainder of the division's budget came from miscellaneous sources; many of these were short-range studies requested by other SRL divisions or SRP departments. The work performed for the Office of Health and Environmental Research develops understanding of environmental processes of general applicability to the needs of the Department of Energy, by using the SRP site as a field laboratory. Specific SRP operational problems are answered using research funded by the Assistant Secretary of Defense programs. For instance, SRP environmental studies required by regulatory agencies and the operation of specialized monitoring are done with this funding (i.e., very low-level radionuclide monitoring at a few locations, and the operation of the meteorological tower network).

KEY RESULTS OF ETD STUDIES

Atmospheric Studies

- Several atmospheric transport and dispersion models were verified with krypton-85 emissions and meteorological data.

- As little as 5×10^4 atoms/cm^3 of helium-3 were detected to help determine the lateral spread of pollutants at distances beyond 25 km.

- The JEREMIAH computer system was expanded to 1) calculate a mass consistant, three-dimensional wind field, 2) calculate three-dimensional pollutant transport and dispersion with second-moment and chapeau functions, 3) allow input of krypton-85 releases on an hourly basis to compare observed with calculated krypton-85 measurements 4) include a real-time precipitation atmospheric transport model from Pacific Northwest Laboratories and 5) include a modified AD-PLUM module to predict concentration frequency distribution with greater accuracy.

- A new forecast method which uses Model Output Statistics predicts plume transport better than subjective techniques or persistance for forecasts.

- Two models accurately predict the mixed layer depth for a daytime situation. One uses thermodynamic arguments, and the other is a turbulent-entrainment model.

Terrestrial Studies

- Tritium in the organic fraction of soil, separated as water by high temperature combustion, was 5-50 times higher in activity than water that was freeze-dried from the same samples.

- The 50-year dose commitment from ingestion of crops is not influenced significantly by the plutonium in the SRP environment. This plutonium is a result of more than 20 years of operating chemical separations facilities.

- Techniques were developed to detect as little as 0.02 pCi/m^2 of iodine-129 and 0.2 pg of technecium-99 in soil to evaluate SRP's environmental effects.

- A sensitive three-stage mass spectrometer was completed for use in environmental studies of transuranium elements.

Aquatic Studies

- Thermal stress to microorganisms can be measured by the production of dissolved organic matter by algal communities and the mineralization of glucose by heterotrophic populations.

- Mutagenic activity as measured by the Ames/Salmonella/microsome assay indicate that such activity does not occur in Par Pond, although limited mutagenic activity does occur in a nearby canal system due to chlorination of cooling water.

- Sodium hypochlorite, used as an algicide in the reactor fuel storage basins, caused increased pitting corrosion to reactor fuel targets. Five other compounds selected for testing proved to be superior to sodium hypochlorite.

- **Legionella pneumophila,** the pathogen which causes Legionnaire's disease, is a natural part of aquatic ecosystems. It occurs over a wide range of environments and is able to utilize nutrients provided by primary producers.

- Phytoplankton size classes of less than 3 μm (less than 5% of the total phytoplankton biomass) accounted for 15 to 40% of the total primary productivity in Par Pond, Pond C, and Clark Hill Reservoir.

- Three major biological data sets have been compiled and are available in the SRL computer system for analysis: 1) the SRP deer herd data, 2) 20 years of Par Pond data, and 3) 25 years of biological data on the Savannah River.

Marine Studies

- Nearly all plutonium in the Savannah River and its estuary resulted from nuclear weapons fallout. The plutonium concentration in the Savannah River is about one fourth the concentration in the Newport River which has no nuclear operations associated with it.

ATMOSPHERIC STUDIES

JEREMIAH System

The major objective of the meteorological programs at SRL is to developand validate atmospheric transport, diffusion, deposition, and resuspension models. These models are used to predict the consequences of both routine and accidental releases of major contaminants to the biosphere. Under this program, a data-based computational system (JEREMIAH) has been developed to assess the radioactive dose to man from routine and accidental releases of radionuclides to the atmosphere (Figure 3). This system calculates the transport, dispersion, and deposition 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. Codes which have been developed onsite and offsite have been incorporated into the system. During 1979, the JEREMIAH system was expanded by adding modules to 1) calculate a mass-consistent, three-dimensional wind field, 2) calculate three-dimensional transport and dispersion using second-moment and chapeau function methods of solution, and 3) allow input of Kr-85 releases on an hourly basis to permit comparisons of calculated Kr-85 levels with observed levels. Three-dimensional codes based on pseudospectral, finite element, and particle-in-cell methods of solution were developed and will be incorporated into the system. A unique atmospheric transport code was obtained from Pacific Northwest Laboratory. This code was an important addition because it contains a real-time precipitation model and was accompanied by a precipitation data base for the eastern U.S. for a one-year period.

ADPLUM is the two-dimensional, segmented Gaussian plume model used in the JEREMIAH system to simulate atmospheric transport and diffusion of radionuclides released routinely or accidentally. Recent improvements to ADPLUM include mathematical formulations describing the effects of time-varying mixing layers and reflective boundaries. Model verification has shown that the modified model produces a significant improvement over the earlier wind rose model and ADPLUM module. Moreover, the model demonstrates excellent predictive capability of concentration frequency distribution.

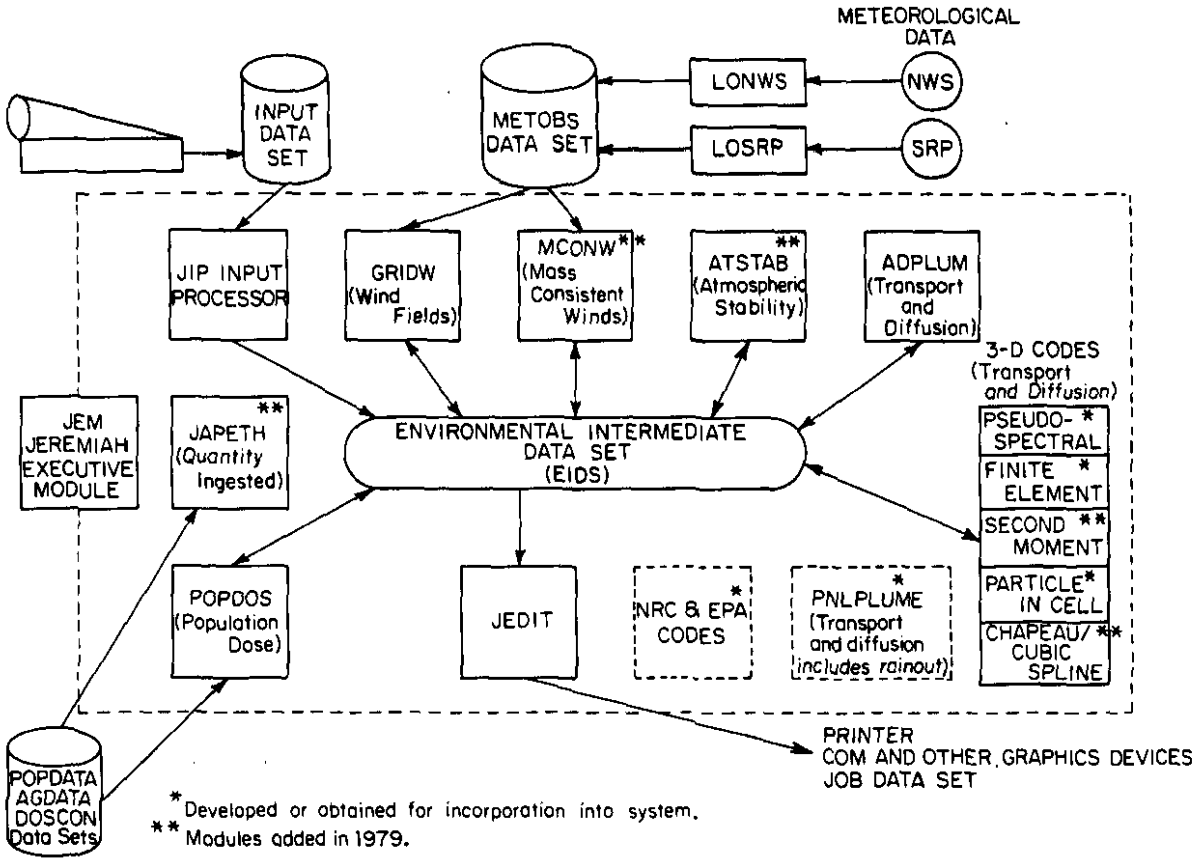

FIGURE 3. JEREMIAH atmospheric transport system used to calculate dose from meteorological observations, source data, and population data.

Automated Prediction of Winds for SRP

The Weather Information and Display (WIND) system at SRL collects meteorological data from eight towers and stores the data in a minicomputer. This information improves assessments of routine atmospheric releases from SRP and provides a valuable data base for atmospheric research. Until recently, the computer codes that calculate pollutant trajectories used the most recent wind information to predict the path of the pollutant. However, calculations based on the assumption that weather conditions in the future will be the same as the latest observations (persistance) can be considerably in error when wind conditions are changing.

Automatic forecasts of wind and turbulence for periods up to 30 hours were added to the WIND system in 1979. The wind forecasts originate at the National Weather Service in Suitland, MD, and are transmitted to SRP on teletype twice daily. These forecasts are based on Model Output Statistics (MOS), which is a new

forecast technique that statistically relates the output of numerical weather prediction models to the meteorology of a particular site. MOS was developed for SRP, under the direction of SRL, by the Techniques Development Laboratory of the National Oceanic and Atmospheric Administration using three years of data measured from the WJBF-TV tower near SRP. The MOS forecasts now provide wind direction, wind speed, and horizontal and vertical turbulence intensity at 10, 91, and 243 m above ground for the TV tower.

Validation studies indicate that the MOS forecasts offer a significant improvement over subjective forecasts and persistence. These validation studies have also shown that the error in the MOS forecasts increases in proportion to the duration of the forecast. Thus, to minimize the errors in predicting the path of an accidental release, the MOS forecasts are adjusted using a real-time validation technique. The present MOS forecasts are produced twice per day at 0100 and 1300 EST, so an assessment of an accident occurring at 1200 EST would be based upon a forecast that is 11 hours old; the real-time validation technique ensures that this 11 hour old forecast has been corrected with the latest weather observations (Figure 4).

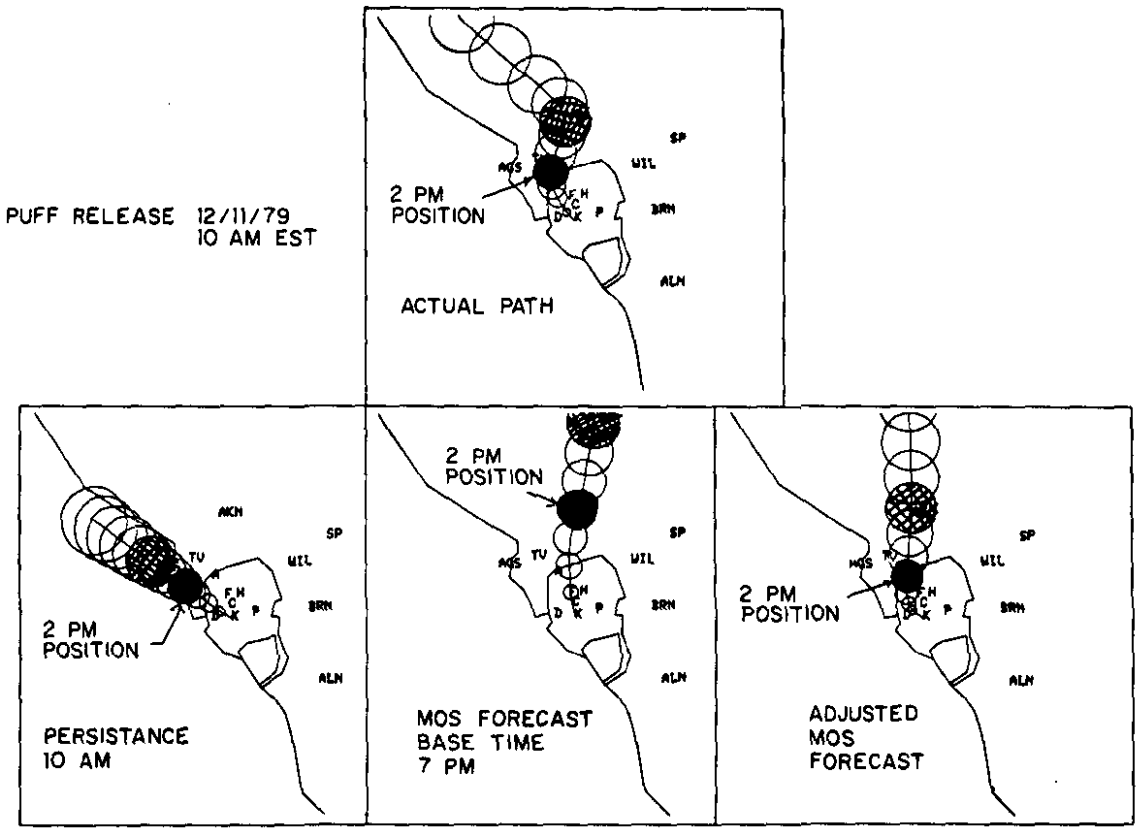

FIGURE 4. An example of the actual path of a Puff release and the path predicted by assuming wind direction persistance, or adjusting the NWS Model Output Statistics (MOS) for local conditions.

The twice-daily adjusted MOS forecasts obtained by this technique provide the best possible predictions irrespective of the time that the original MOS predictions were made. Plans for future research involve a similar real-time validation technique to improve other National Weather Service weather predictions for use at SRP in emergency response.

Real-Time Data Quality Control

One of the major problems associated with any nuclear accident is the ability to assess the consequence of an accident quickly and accurately. Modern computer systems have the computational power, speed, and reliability to provide such timely assessments, but only if accurate meteorological data are available.

SRL's WIND minicomputer system allows quick and accurate assessment of an accidental release at SRP using data from eight meteorological towers. Since the accuracy of the assessment is largely determined by the accuracy of the meteorological data, quality control is quite important. In the past, the system averaged the measurements from the towers to minimize the influence of inaccurate data being used in calculations. But in 1979, real-time quality control of this data was developed to automatically identify inaccurate data and to replace it with reasonable values determined from the other towers. The real-time quality control code incorporates the many subjective judgments made by a meteorologist when he examines the data to detect instrument malfunctions in the data collection system.

Mixed Layer Research

Two methods to predict the atmospheric height to which pollutants will rapidly disperse have been shown in 1979 to be reasonably accurate. Atmospheric temperature usually decreases with height above the ground, causing pollutants to disperse upward. Above a certain level, temperature begins to increase with height. This condition inhibits pollutants from dispersing any higher. The distance from the ground to the highest level a pollutant can disperse is called the mixed layer depth. This depth ranges from 10 to 3000 m above the ground.

Mixed layer research is divided into two categories: 1) daytime and 2) nighttime or cloudy day. In the daytime case, turbulence is caused by solar heating, causing the mixed layer to be relatively deep. In the nighttime or cloudy day case, turbulence is caused by winds blowing over rough ground, and the mixed layer is relatively shallow. During 1979, ETD developed two prediction models for the daytime case which were tested against the

Wangara (Australia) and Great Plains (Nebraska) field data. One method is based on simple thermodynamic arguments, while the other is based on a turbulent-entrainment model, which allows more atmospheric physics to be included (Figure 5). The two models will continue to be tested with other high-quality data sets including atmospheric sounding data collected from stations near SRP. A method for predicting nighttime mixed layer depths is being investigated with acoustic sounder and WJBF-TV tower data.

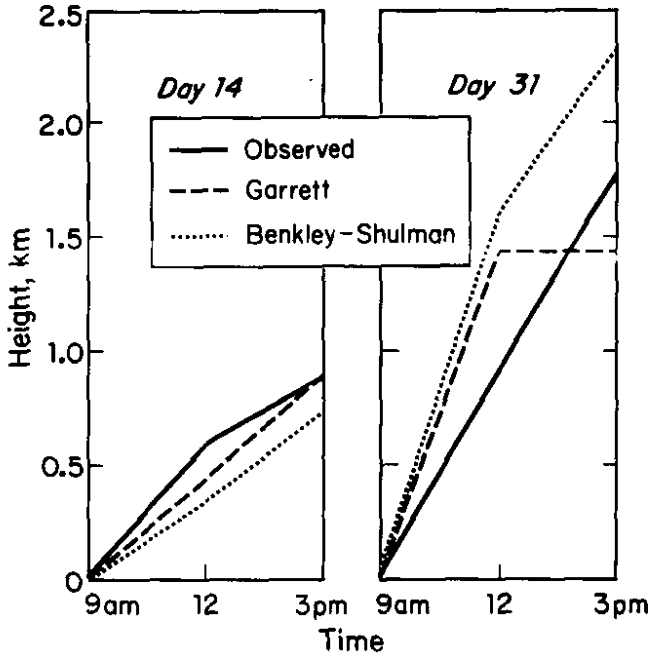

FIGURE 5. A sample of test days taken from the Wangara Data. Note the significant differences between predictions by Turbulent-Entrainment Model (Garrett) and the Thermodynamic Model (Benkley - Shulman) on day 31. Low clouds formed that day, which are included in the Garrett Model, but not in the Benkley - Shulman Model.

In 1979, a new doppler, bistatic acoustic sounder (echosonde) was temporarily located near a monostatic acoustic sounder to perform a comparison check of the backscatter data of the new echosonde. The echosonde was then moved to the WJBF-TV Tower site to compare the doppler wind speeds and direction with the wind speed and direction profiles obtained from the TV tower instruments. The new echosonde will extend the wind speed and direction profile to 620 meters, 320 meters above the TV tower.

The Beukers LO-CATE system at SRL is used for tracking constant pressure level (constant altitude) balloons called tetroons (Figure 6). During 1979, tests were performed on the system to validate the accuracy of the radio-telemetry (radiosonde) and computer software systems used in tracking the tetroon-radiosonde. The range stability was $\pm$ 10 meters, and the range offset was 100 meters. The system has also been used to determine the vertical profiles of temperature, relative humidity, wind speed, and direction to altitudes of over 20 km.

FIGURE 6. The tetroon (constant pressure height ballon) system will be used to tract the wind trajectory in atmospheric transport and diffusion experiments.

Modeling of Atmospheric Transport with Pseudospectral Methods

A new accurate technique is being used at SRL to calculate dispersion of pollutants released to the atmosphere under complex meteorological condition. A three-dimensional computer code, which uses a pseudospectral method, has been developed to solve the dispersion equation with Fourier transform expansions. This method yields accurate evaluations of the derivatives necessary in solving the transport equation. The periodicity involved in this method results in additional computer core requirements and computational time. However, this method is quite accurate. For physical problems having natural periodicity, the method is ideally applicable.

Chebyshev polynomial expansions were also investigated as a method for calculating derivatives. The inability of the Chebyshev method to adequately represent discontinuous spatial distributions precludes its use for the atmospheric transport problems that SRL is investigating. This method is also less accurate than the Fourier method. However, there are no periodicity requirements, and computer storage is less demanding.

ASCOT Program

SRL and other DOE-sponsored laboratories have recently begun studies to calculate atmospheric flow fields and dispersion patterns over irregular terrain in support of the DOE-funded Atmospheric Studies in Complex Terrain (ASCOT) program. Lawrence Livermore Laboratory (LLL) is the program manager of the ASCOT program.

Under ideal conditions, pollutant dispersion can be accurately predicted with analytical methods, such as Gaussian plume theory. The Pasquill-Gifford curves predict dispersion only for level, uniform terrain. However, ground-level concentrations are significantly influenced by interactions among atmospheric stability, surface irregularities, and wind fields. In such cases, the Pasquill-Gifford curves become unreliable.

SRL has concentrated on multidimensional, numerical algorithms for calculating atmospheric transport over mesoscale distances and for complex situations (Figure 7). Techniques currently under investigation are the finite element, chapeau, particle-in-cell, second moment, and pseudospectral methods. Each method has its own particular assets and limitations. By using appropriate coordinate transformations, the models have been restructured to account for surface irregularities, eliminating much of the site dependence attributed to conventional models. Wind fields, which are presently assumed, are readjusted through variational

techniques to account for the vertical motion due to topfraphical effects. Simple tests have been conducted to determine the accuracy of the numerical methods. The effect of topography on a continuous emission has also been examined under ideal conditions. More rigorous testing and validation are being conducted with krypton-85 dispersion data measured up to 140 km from SRP over a two and one-half year period.

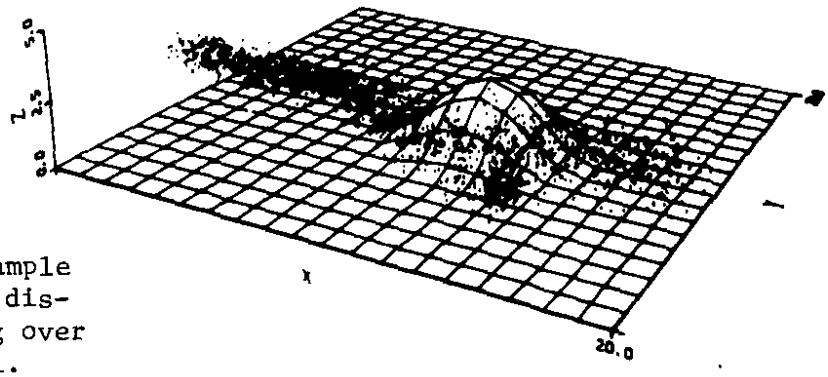

FIGURE 7. An example of air pollutant dispersion modelling over and around a hill.

At the request of LLL, in 1979, SRL investigated models currently available outside the DOE laboratories which predict drainage flows and wind fields over irregular terrain. Seven numerical models were found in a literature survey. All models could be used operationally, and three could be used for research as well. The models fall into four categories: (1) empirical model; (2) theoretical, one-dimensional, slab model that may have operational potential; (3) two-dimensional, diagnostic, slab models that use one or more of the fundamental conservation laws in simplified form; and (4) three-dimensional, hydrostatic, primitive equation models that include eddy diffusion, simplified radiative transfer, and surface energy budgets.

All of the empirical and slab models require some site-specific coefficients which must be found through observation and model readjustment. They also require surface temperature fields and other data. The three-dimensional models generate their own temperature fields, providing synoptic-scale pressure, wind, and temperature profiles are supplied as input.

Puff Release Studies with Aircraft

In order to support the testing of atmospheric dispersion models, a small, fixed-wing airplane was modified in 1979 to produce a simulated puff and to measure the puff dispersion in

real time using stable cesium as a tracer in the puff. Colorado State University was selected (Dr. P. C. Sinclair) to aid the SRL program. Smoke is generated to give a visible puff at the start of the test. Tests were performed during January 1980 under stable conditions and the initial puff was visible for approximately 10 minutes. The stable cesium tracer is used to measure the puff dispersion and also is used to locate the puff after the smoke is no longer visible because of dispersion.

Krypton-85 Tracers

Considerable attention is being directed at industrial air pollution and the need to determine atmospheric transport and dispersion of material for distances of a hundred kilometers or more from a pollutant source. Many different models have been developed to estimate pollutant concentrations for these distances but little data are available to verify these calculations beyond a few kilometers. The ETD and the Air Resources Laboratory (ARL) of the National Oceanic and Atmospheric Administration designed an air sampling program which used krypton-85 to verify models. Thirteen cryogenic air samplers monitored krypton-85 plumes produced by routine emissions from chemical separations facilities at SRP.

Air sampling was conducted weekly for two years and twice daily for four months at 13 locations surrounding SRP. Continuous sampling over this relatively long period has resulted in air concentration data measured over a wide range of meteorological conditions. The sampling also determined seasonal and annual average concentration patterns for distances ranging from 28 to 144 km from the source.

Because krypton-85 is an inert gas (radioactive half-life of 10.73 years), its use as a tracer enables atmospheric transport and dispersion parameters to be studied without the complications introduced by wet and dry deposition, and chemical transformations. In 1979, krypton-85 emissions data and meteorological data were compiled in a final report and data tapes. This information can be used as input for model calculations of hourly, daily, monthly, seasonal, and annual concentrations to be tested against the measured concentrations. This krypton-85 data base will be used in a Model Evaluation Workshop to be held by ETD in 1980 for nine DOE-funded laboratories.

Krypton-85 concentrations were measured hourly at ground level for over a year at six sites within 10 km of the SRP chemical reprocessing facilities. A krypton-85 monitor was developed by the Environmental Measurements Laboratory of DOE using a Geiger-Mueller counter array specially developed for

continuous operation. Sensitivity was about 100 times global background. Data analysis techniques were used which permit the detection of krypton-85 beta rays in the presence of interfering natural and artificial sources of radiation. The travel distances and averaging time of sampling complimented the tracer data from the ETD/ARL sample program.

In 1979, the results were compared to calculations made with the Gaussian plume model using meteorological and source term data for the same period. Annual average concentrations were predicted to within a factor of two, but were consistently overestimated. The frequency distributions of observed concentrations show a marked decrease in the geometric standard deviation as a function of downwind distance. The short-term average (10 hours to 2 days) concentrations were generally predicted to within about a factor of ten. In many cases, particularly in calm or stable conditions, measurable concentrations were predicted when none were observed. This may account for much of the excess in annual average concentrations predicted by Gaussian plume models.

Helium-3 Tracers

Helium-3 is a unique gas tracer that has been used by ETD for meteorological studies. Helium-3, like krypton-85, is nonreactive, easy to sample, easy to measure above global background, has few other sources, and has no biological significance to man. In 1979, ETD used helium-3 to determine the relative lateral spread of the pollutant at distances beyond 25 km, and to verify models for accidental releases of pollutants from nuclear facilities. New gas mass spectrometric techniques permit measurements of as little as 5×10^4 atoms of helium in a 1 cubic centimeter sample of air. This sample is small enough that large numbers of samples can be easily collected. The amount released in long-range meteorological studies can be very small compared to the global inventory of helium-3. (A release of 500 g can be detected at a distance of 1000 km.)

The sensitivity of the analysis procedure allows simple sampling and release methods. The amount of helium-3 in one standard milliliter of air is more than adequate to accurately measure (<1% error) the atmospheric concentrations of helium-3. Thus, whole air samples can be collected by opening small evacuated sample bottles, making manual, automatic, sequential, mobile, and time-integrated sampling possible.

Plutonium Particles

Small amounts of plutonium escape from the SRP facilities to the atmosphere by adhering to minute airborne particles in the exhaust systems of the facilities. Techniques have been developed with sufficient sensitivity to assay the very low levels of plutonium ($\sim 10^{-18}$ g) which may adhere to single airborne particles. The extensive exhaust filtration systems in the separation areas remove essentially all these particles. However, because of the sensitivity of the analysis techniques, the small number of particles which escape are detectable. During 1979, studies were conducted to determine the composition and amounts of these plutonium bearing particles so their distribution in the environment and hazard to man can be better understood.

Another particle study was begun in 1979 in the plutonium fabrication facility where $^{238}PuO_2$ powder is received and, through various processes, compressed into pure plutonium oxide spheres for use as heat sources. Occasionally during these operations a small number of particles containing minute quantities of plutonium have been detected in the isolated service area of the facility. Individual particles isolated from large volumes of service area air were analyzed for size, shape, and elemental composition. The particles were found to be quite small (<0.7 μm) and were 89 to 99% plutonium dioxide. Traces of sodium, silicon, zirconium, molybdenum, thorium, and uranium were also found (Figure 8).

Large volumes of air from separations area exhaust systems were passed through filters to collect a small number of plutonium-bearing particles in 1979. The results of the analysis of these particles will be compared with results of analyses of similar particles collected from a prior ground-level collection program. The analyses will be completed in 1980.

Particle studies were also done to determine the uniformity of $^{239}Pu(NO_3)_4$ in ash from incinerated solid waste. Because the plutonium was found to be uniformly distributed in the ash, the hazard is a function of the size of the plutonium-bearing particles released to the environment. The particle size is dependent on 1) the physical treatment of the ash prior to and during a release, and 2) on the length of time the particles are airborne.

In order to determine the pathway of plutonium in the ecosystem adjacent to a nuclear facility, the properties of plutonium that would be entering the ecosystem must be known. The radioactive dose to man from inhaling plutonium is usually calculated assuming a particle size of 1 μm. But previous investigations of airborne plutonium-bearing particles at SRP have

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A cascade impactor that was 200 m from a stack was operated for two years to obtain data on particle size distributions. In 1979, data analysis showed that the largest percentage of entrapped particles containing Pu-238 and Pu-239,240 was in the size fraction less than 0.5 μm. When the actual particle size was substituted for the usual 1 μm size, the dose assessment of inhaled plutonium-bearing particles was calculated to be 30 to 70% higher, although still only about 1% of natural background dose values.

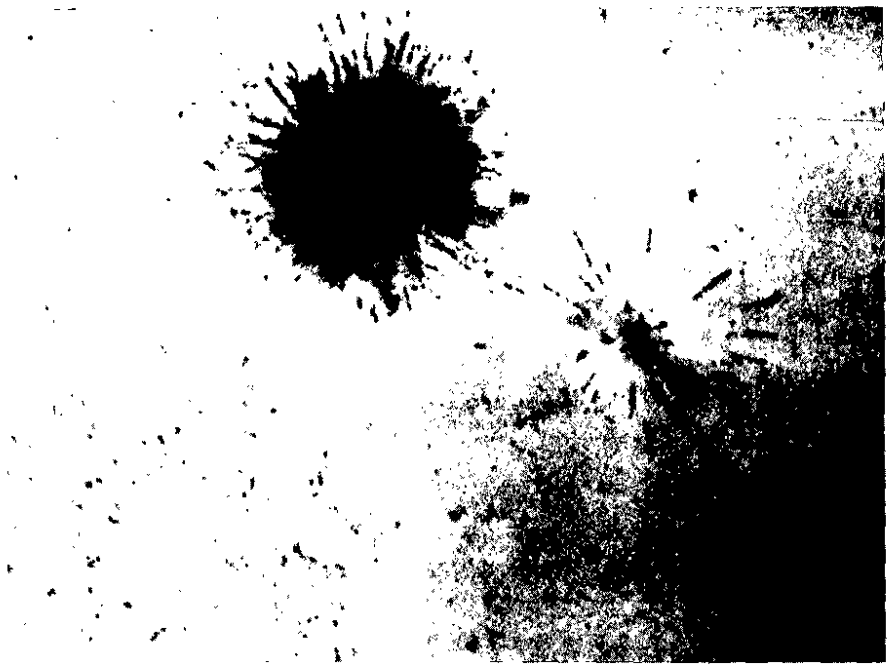

FIGURE 8. Photomicrograph of a uranium-bearing particle shows alpha tracks etched in it.

Tritium Deposition and Cycling

Most of the pollutants resulting from energy production are released to the atmosphere, which are in turn cycled to terrestrial ecosystems by wet and dry deposition. The fate of a pollutant is determined by its interaction with the ecosystem on which it is deposited. The pollutant may be destroyed or permanently detained, or it may be further transported through other paths such as food chain or hydrologic processes. The cycling research at SRL seeks to understand the deposition processes and develop models which can be used to estimate the rates of environmental exchange over a variety of conditions.

The deposition and cycling of tritium, in the forms of tritiated water and tritiated hydrogen, have been specifically studied. Energy and water balance studies in a pine plantation have provided information on how tritium is transported through the atmosphere and into the trees through the needle stomata (Figures 9 and 10). A model was developed that predicts the aerodynamic and stomatal transport coefficients from meteorological data. The stomatal transfer coefficient is described as a function of light, air temperature, and air vapor density.

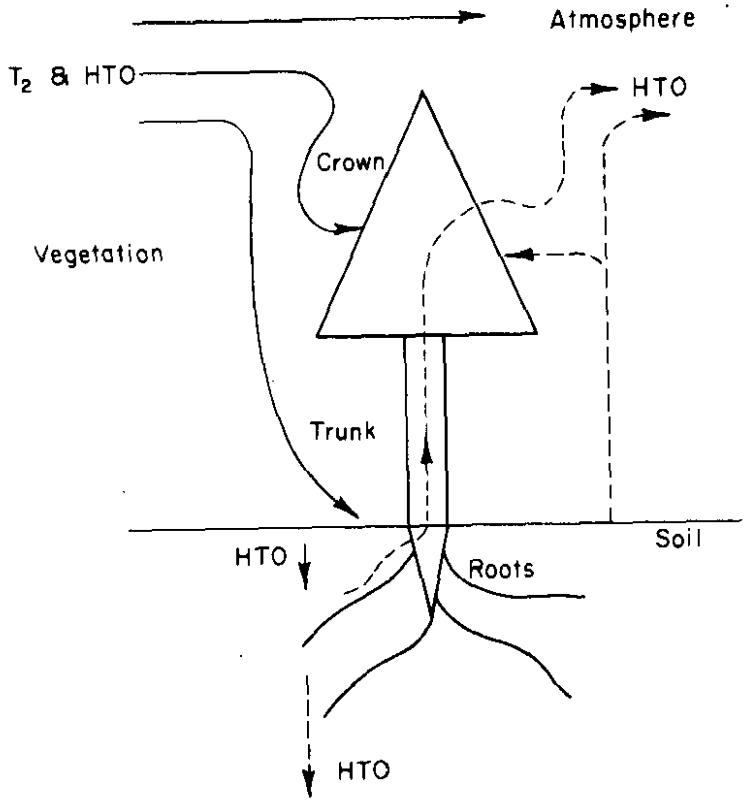

FIGURE 9. The path of molecular tritium and tritiated water movement after a release of tritium.

FIGURE 10. A forest meteorology tower for measuring deposition to a pine plantation. WJBF-TV tower in the background is instrumented for mesoscale meteorological measurements.

A model of annual deposition and cycling of tritiated hydrogen and tritiated water at SRP has been developed on the basis of several years' research. The model accurately predicts the relationship between the amount of tritiated hydrogen, as a percent of total tritium, in the pollutant release and the tritiated water found in the air and vegetation. Tritiated hydrogen is converted to tritiated water in the soil. When the atmosphere is high in tritiated hydrogen, conversion will lead to a source of tritiated water in the soil. The tritiated water is absorbed by the trees, leading to a higher tritiated water concentration in the vegetation than in the air.

In 1979, energy balance techniques (micrometeorology) were used to further refine the values of transfer coefficients between the atmosphere and the vegetation. The value of the transfer coefficients will also apply to the development of models for short tritium releases. The cycling of tritium into organic components of vegetation and soil (referred to as bound tritium) has also been investigated during 1979. Surveys of tritium concentrations in the organic fraction of vegetation indicate that the bound tritium is near or slightly above that of the water in the vegetation. The bound tritium in soil appears to be much greater than tritium in soil-water. The amounts of tritium released from samples by high-temperature combustion of soil are from 5 to 50 times greater than those in soil-water. We have no adequate explanation for these high values, but further experiments are planned.

Iodine-129 Deposition in Soils and Surface Litter

One of the fission products produced by SRP reactors is iodine-129. Some of the iodine-129 escapes to the environment through the exhaust stacks and is deposited on the soil. Because iodine and organic iodides are volatile, iodine can be deposited over large distances from its source.

In 1979, the radioiodine content in the soil was measured at sites 10, 20, 50, and 100 miles from SRP on five lines radiating from the plant, after having developed a sensitive analysis procedure. The sampling sites were selected on the basis of having been undisturbed since SRP began operations over 25 years ago. Surface litter and soil core samples at 1, 6, 12, and 24 inches were collected from ten spots at each site and composited.

Preliminary data indicate that the concentration of iodine in the litter depends strongly on the type of vegetation. Trends from the litter data will be difficult to distinguish. The depth profile of the iodine-129 shows that most of the iodine is in the top 1 inch of soil, and the concentration at 6 inches is less by a

factor of 6 to 10. The concentration reduces by the same factor over the next 6 inches of soil. In the top 1 inch of the soil, iodine-129 drops from 60 pCi/m^2 at 10 miles to 1 pCi/m^2 at 100 miles. At 24 inches, the iodine-129 content has been measured at 0.02 pCi/m^2 (the detection limit) up to 0.4 pCi/m^2. Further analyses are planned to evaluate SRP's contribution to the total iodine-129 in the environment around the plant.

Technetium-99

Another fission product from the nuclear reaction is technetium-99. This radioisotope is also water soluble and therefore susceptible to entering the food chain after it has been deposited on the soil from the stacks.

Isotope dilution mass spectrometry uses a technetium-97 spike to quantitatively determine technetium-99 in soil and litter samples. Procedures for analysis at environmental levels were developed during 1979. The surface litter of sites up to 100 miles from SRP contained from 100 to 500 pg/m^2 of technetium-99. The top 1 inch of soil contained technetium-99 ranging from 1,000 to 10,000 pg/m^2, depending on the distance from the source. Analyses will continue to more accurately determine SRP's contribution of technetium-99 to the environment.

Technetium must be separated completely from molybdenum and ruthenium to eliminate mass spectral interferences from molybdenum-97 and ruthenium-99. First, soil and vegetation are completely dissolved after carbonate-nitrate fusion. The technetium is separated from the molybdenum, ruthenium, and the bulk of other elements by cation and anion exchange, evaporation, and multiple solvent extractions. The final solution is evaporated to a small volume and the technetium loaded onto a resin bead by ion exchange (Figure 11). The resin beads are then shipped to Oak Ridge National Laboratory for isotope dilution mass spectrometric analysis, where the beads are mounted on the V-shaped spectrometer filament for ionization. The minimum detection limit is 0.2 pg of technetium-99. This value may be improved in the future if spectral interferences from the filament at masses 101 and 99 can be eliminated.

Transuranics in the Terrestrial Environment of SRP

The distribution of plutonium in terrestrial ecosystems has been a major environmental study on the SRP site. This information is used to calculate the radiation dose to man caused by releases from the chemical separation facilities (Figure 12). During these investigations, information has been obtained on plutonium present in air, soil, plants, and animals as a function of distance from the facility.

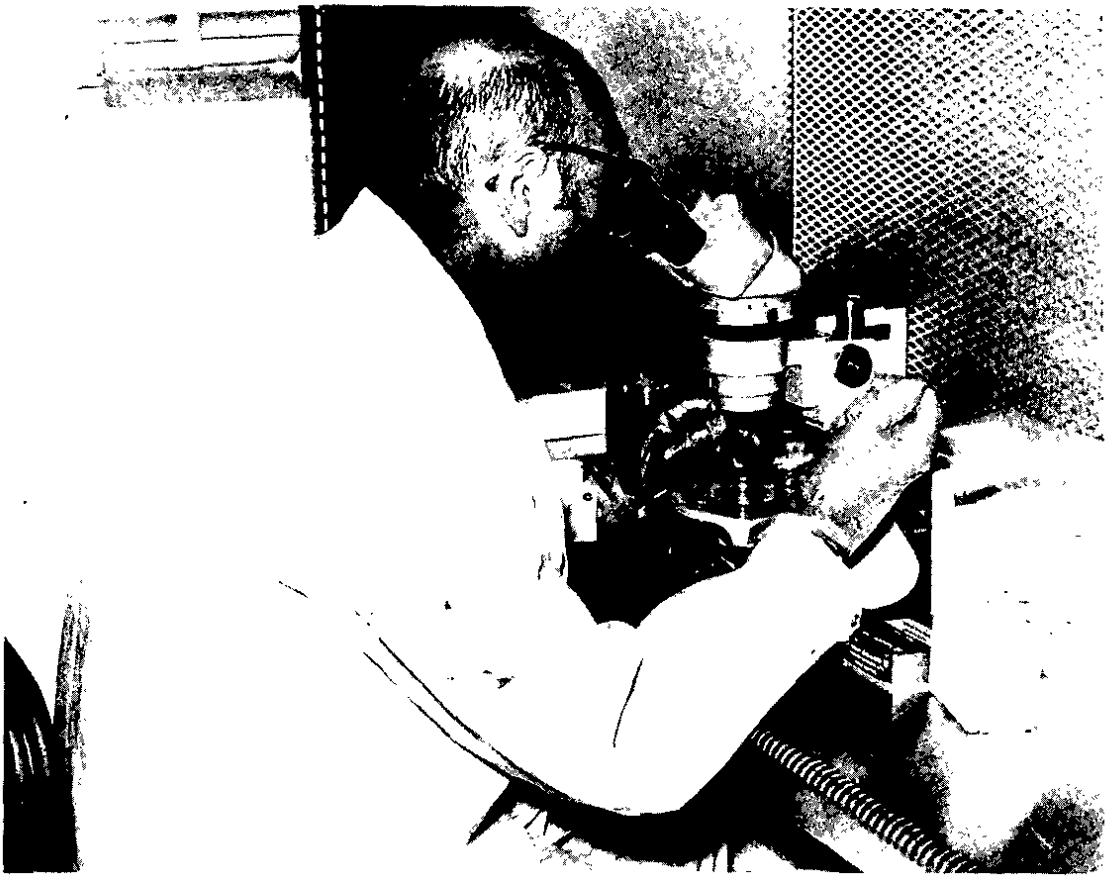

FIGURE 11. Loading of a resin bead with a technicium-99 sample for analysis by mass spectroscopy.

The plutonium content in carrots, radishes, turnips, onions, white potatoes, red potatoes, and sweet potatoes were analyzed in 1979. Normal food preparation techniques affected the plutonium levels significantly. The plutonium content in the food was reduced by about a factor of 2 by scrubbing and to below detection (less than 0.0005 pCi/g dry weight) by peeling. Gamma analysis of these same crops indicated that the naturally occurring potassium-40 content was not affected by preparation techniques. Peeling the crop samples removed a lot of the plutonium-239, 240 which caused the radioactivity from the potassium-40 to be about 10^5 times more than the plutonium. When no preparation was practiced, the radioactivity from potassium-40 was still 10^3 times more than the plutonium in the same sample.

Assuming that 50 kg of each of the crops were ingested, the 50-year dose commitments to man of plutonium and potassium-40 were calculated from the data. The 50-year dose commitment from ingesting the naturally occurring potassium-40 is influenced only slightly by the plutonium accumulated in the crops from more than 20 years of chemical separations activities.

FIGURE 12. Crops are grown on fields where plutonium has been deposited to study the plutonium cycling in agronomic crops.

A new mass spectrometer was completed in 1979 that is capable of measuring the various plutonium isotopes, as well as other elements. This equipment will play a significant role in identifying plutonium sources and understanding transport methods associated with these sources (Figure 13).

Borrow Pit Studies

About 1000 acres on the SRP site have been severely denuded by construction. The organic matter and top soil have been removed in these areas preventing growth of any type of vegetation. As a result, there is considerable erosion of soil and sediment discharge into some SRP streams. Preliminary studies on a small portion of one borrow pit have shown that biomass response was five times greater for loblolly pine trees grown on soils amended with sewage sludge compared to those grown on soils amended with coal ash, tree bark, and commercial fertilizer (Figure 14). Plans were made in 1979 to determine the most cost-effective and environmentally safe procedures to restore these areas by applying sewage sludge to the land.

Soon, sewage sludge disposal by ocean dumping will be prohibited, and new major pollution problems associated with sewage sludge incineration have arisen, so the nation must evaluate new methods to dispose of sewage sludge. Plans were formulated in 1979 to study the survival and growth of trees grown on soils amend with sewage sludge. The SRP site is ideally suited for biomass response studies because of the diversity of soils and the variety of age and type of forest plantations representative of the coastal plain area. This program will evaluate how well sewage sludge will enhance timber productivity and its environmental consequences on coastal plain soils.

The sludge will be applied to controlled experimental plots that will be monitored for toxic organics, macronutrients, nitrates, and heavy metals in order to characterize cycling and transport of these materials in the soil and biomass. At a less intensive level 1) engineering aspects of sludge application will be compared, 2) monitoring of toxic material and organisms will be conducted at an adequate level to maintain environmentally safe conditions, and 3) demonstration plots of a range of application rates and frequencies will be established to obtain initial estimates of responses.

About 40 acres of borrow pits (denuded areas) have been cleared of any wood or stumps and will be subsoiled to 30 inches, dressed with two tons of lime per acre, and disked. About 30,000 hardwood and pine seedlings will be planted on the borrow pits in 1980.

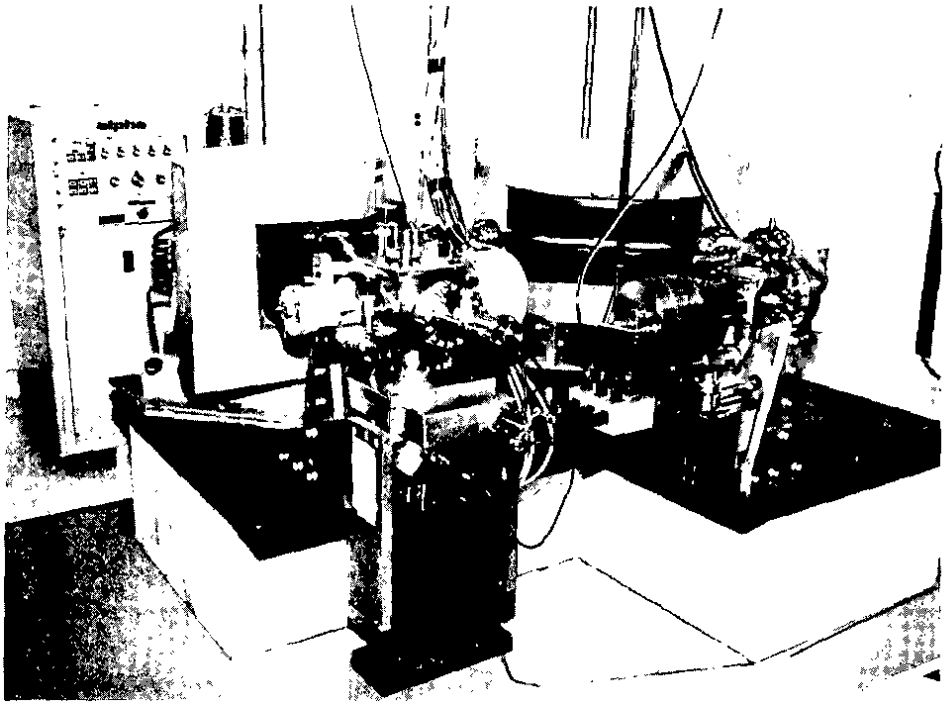

FIGURE 13. Part of the three-stage mass spectrometer developed for transuranic analysis.

FIGURE 14. Reclaimed barrow pit showing the effects of pine planting (foreground) and pine planting with sewage sludge amendments (background).

Deep water wells and a lysimeter network will be installed in the areas to monitor cycling and fate of heavy metals, toxic organics, pathogens, and nutrients. This monitoring system compiles with the South Carolina Department of Health and Environmental Control restrictions on land application of sewage sludge.

Deer Data Base

In 1965, SRP initiated and managed public deer hunts and kept records on the number of deer killed each year. The U.S. Forest Service and the Health Protection Department of SRP worked jointly from 1965 to 1978 to record pertinent information about the deer hunts and the deer. An SRP Deer Data Base, the largest of its kind known in the southeast, was created to store important information about the deer hunts and the physical traits of the deer killed, to answer questions on herds and hunt management, and to determine cesium-137 concentration levels. This data base is recorded on 9-track magnetic tape and has about 14,000 records. A new record format was designed to enter all information about a deer on one record. The data base was computerized for easy accessibility, and can be queried for general and specific information about the deer hunts and deer.

Burial Ground Survey

All solid radioactive wastes produced at SRP, as well as occasional special shipments from offsite, are stored in the burial ground. The original 76-acre burial ground was filled in 1972, and operations shifted to an adjacent 119-acre site where standard burial trenches of 20 x 20 feet were used to bury waste. Wells were installed throughout the burial ground to routinely monitor possible migration of radionuclides from their storage locations into the ground water table at a depth of 45 feet. One series of 67 wells used for the survey was installed on 200-foot centers. Each well had 4-inch-diameter casings. A high-resolution gamma-ray spectrometer, its ancillary equipment, and procedures were developed in ETD to identify and measure gamma activities as a function of depth in the soil surrounding these wells. During 1979, gamma-ray spectra were acquired at 6-inch intervals in 53 wells. The other 14 grid wells were too small to be measured by the spectrometer (Figure 15).

These data were recorded on magnetic tape and are currently under analysis. Typically, high-gamma fields were observed in wells passing through burial trenches, and no gamma activities (except for naturally occurring uranium, thorium, and potassium) were observed below the trench bottom (20 ft).

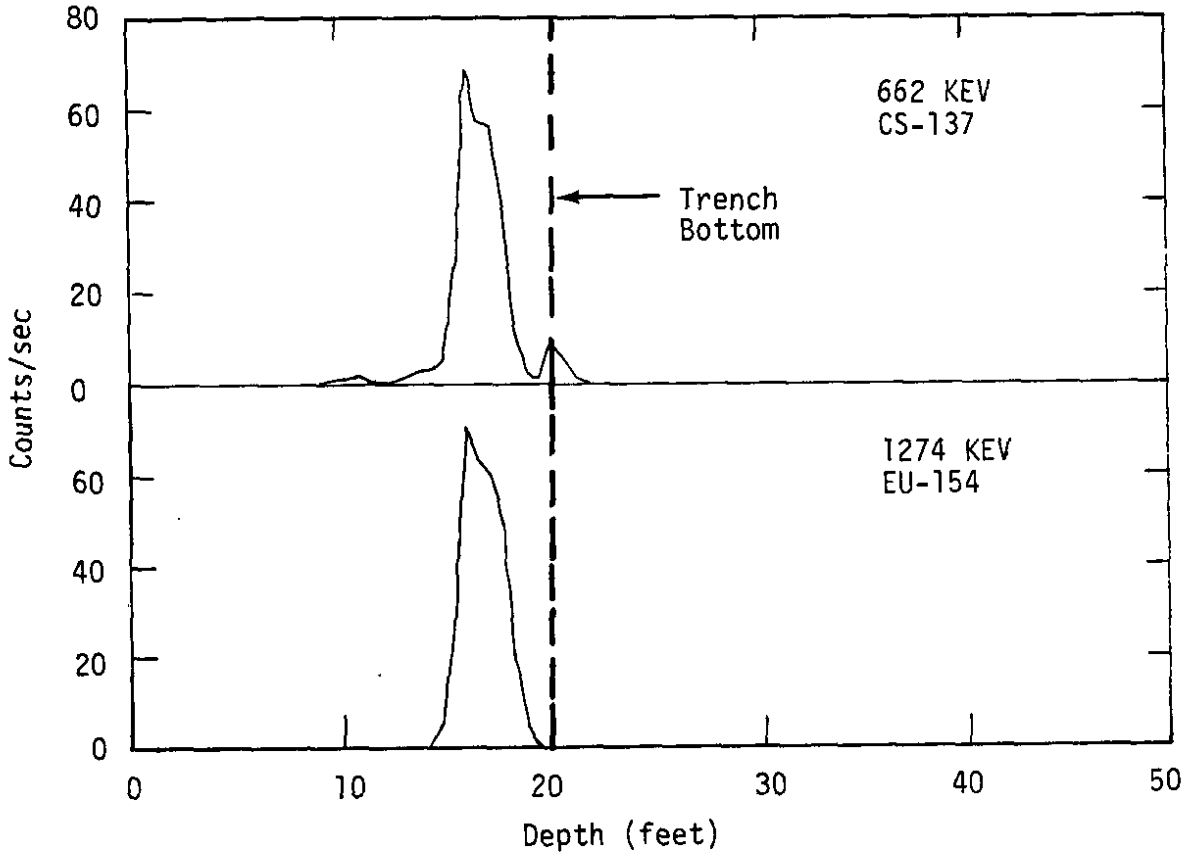

FIGURE 15. Cesium-137 and europium-154 activities were detected in buried nuclear waste with the bore hole probe.

AQUATIC STUDIES

SRP Stream Transport Studies

Pollutants can get into the aquatic systems from the air, the subsurface water, and by direct input from a facility. Being able to predict the transport of pollutants that might be discharged to onsite streams helps environmentalists understand SRP's effects on the environment. SRL has developed computer models, confirmed by field studies, that can predict the transport of specific pollutants (Figures 16 and 17). The model LODIPS has already been proven for transport of tritium, and adapted for hydrogen sulfide and cesium in SRP streams.

LODIPS is quick, easily implemented, and reliable in predicting travel time, concentration profiles, and durations of concentrations at a particular location. The code computes pollutant or tracer transport in a stream by solving a one-dimensional equation which takes into account both turbulent diffusion and transport. The variables needed to solve the equation were experimentally determined for SRP streams and the Savannah River. A pointer record in the LODIPS program assembles all the data needed to predict transport and diffusion in a particular SRP stream or the Savannah River.

Field studies were begun in 1979 on the transport of transuranics in a small onsite stream. This stream is adjacent to the fuel processing areas and has received low levels of transuranics for 25 years. Analyses were recently completed on a set of samples from this stream, and the only transplutonium isotopes detected were americium-241 and curium-244. The americium-241 concentration was 3.4 fCi/L, and the curium-244 concentration was 7.5 fCi/L, which are considerably less than the drinking water guidelines. For comparison, the concentration of americium-241 in ocean surface water is about 0.2 fCi/L, and curium-244 is usually not detected. The samples were obtained in the upper portion of the creek. The americium and curium concentrations downstream in the Savannah River would be significantly less because the river has a flow volume of about 40 times the stream.

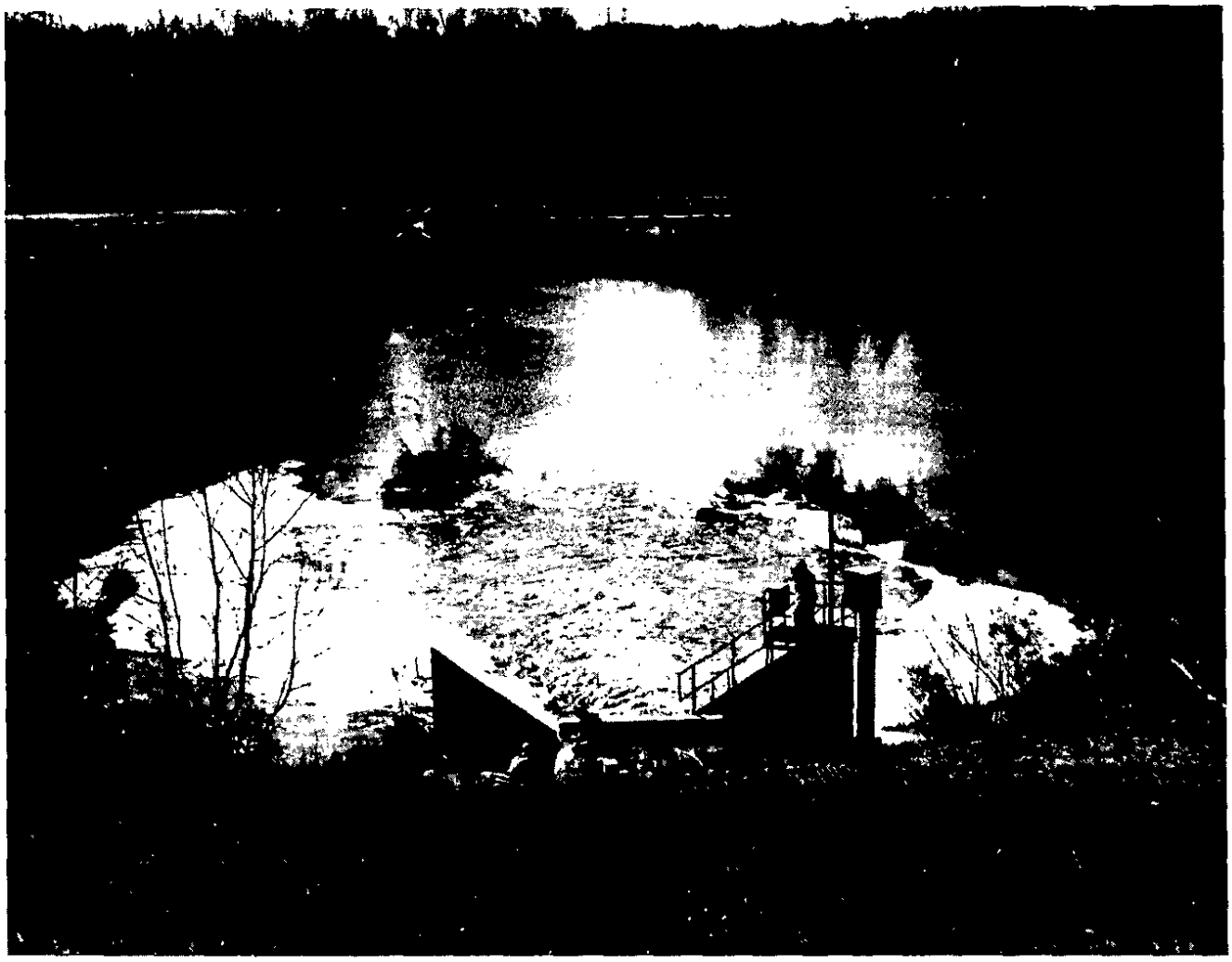

FIGURE 16. Stream transport and dispersion experiment using rhodimine dye.

FIGURE 17. Sequential stream sampler developed at SRL for automatic sampling during stream dispersion experiments.

Thermal Effluent Effects on Algal-Bacterial Communities

Cooling water for one of the SRP production nuclear reactors (P Reactor) comes from a "closed-loop" system made of ponds connected by canals. Unlike natural thermal areas, such as the geyser basins of Yellowstone National Park where thermal gradients are constant, the thermal portions of the SRP cooling system are periodically exposed to ambient temperatures when reactor operations are temporarily halted for removal of products or refueling. The large thermal gradient and the periodic exposure to ambient temperatures create a unique situation. Algal-bacterial mat communities growing in 35 to 50°C effluent cooling waters were studied to determine the effect of the large temperature fluctuations on the primary and secondary production of these communities (Figure 18).

Primary productivity was greater during reactor operations when thermal effluents were heating the cooling water system than during ambient water temperatures. Primary productivity was measured by incorporating radioactively tagged $^{14}CO_2$ into the cellular material of the algae and bacteria, and monitoring the $^{14}CO_2$ released extracellularly. Primary productivity remained the greatest during reactor operations even after the water temperatures had oscillated between ambient and above ambient several times. This indicates that the primary producers were best adapted to the thermal conditions, but could survive at ambient temperatures.

Secondary productivity was greatest near 40°C when thermal conditions were increasing after a short (5-day) exposure to ambient temperatures. The thermophilic communities were not optimally adapted to thermal conditions, but were able to grow over a broad temperature range. The secondary productivity was measured by incorporating ^{14}C-labeled glucose into cellular material which was respired as $^{14}CO_2$. The increase in the ^{14}C-labeled CO_2 and glucose released during changing thermal conditions may be an effective metabolic indicator of thermal stress by these algal-bacterial communities.

Mutagenic Activity in the P-Reactor Cooling System

Mutagens have been previously detected in the cooling canal from P Reactor. The canal water is chlorinated to prevent slime from decreasing the efficiency of the reactor heat exchangers, and chlorination is known to result in mutagen formation. A possibility that Par Pond might contain some form of mutagen existed, so studies were begun in 1979 to analyze organic materials in Par Pond for their mutagenic activity.

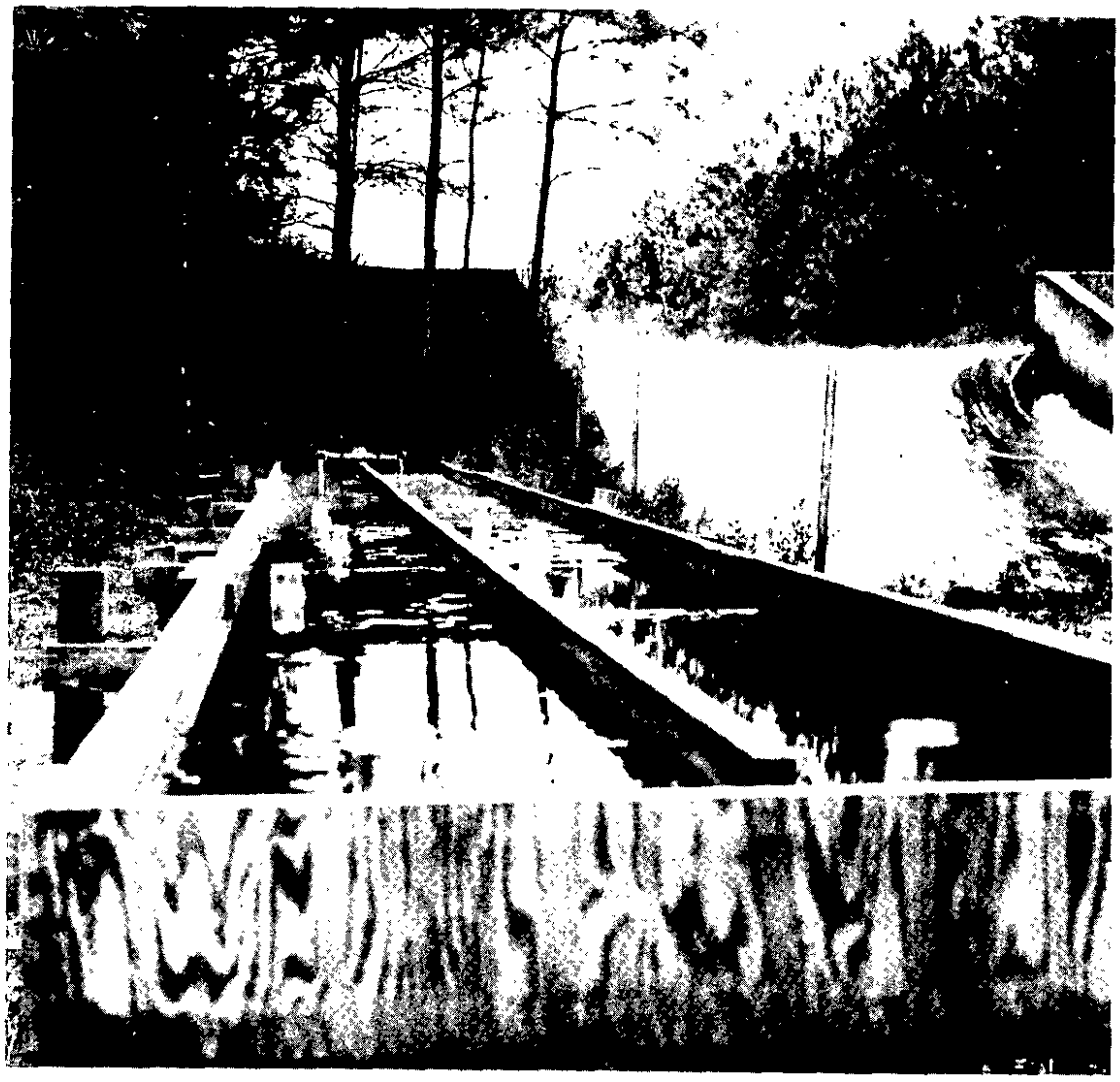

FIGURE 18. Hot water trough next to P-Canal where studies of thermophilic and thermotolerant microorganisms are conducted.

Using the Ames/Salmonella/microsome assay, sampling showed that while the P canal contained mutagens during chlorination, Par Pond had none. P Reactor is chlorinated daily for one hour to a level of 1.5 ppm of chlorine (total residual). Samples taken from P canal at times other than during chlorination and samples taken during a five-month period from Par Pond failed to show any mutagenic activity. The level of mutagenic activity detected in P canal was below that considered to be significant.

Because mutagenic activity was detected in the canal system during chlorination, the question arose as to why activity was never detected in Par Pond. Experiments showed that the mutagenic activity resulting from chlorination decayed rapidly with a half-life of five to ten days. This rapid decay plus the large size of Par Pond caused dilution of the daily mutagen load from the canal and prevented the accumulation of mutagenic activity there.

Algicides in Reactor Fuel Storage Basins

Increased chloride levels from the use of sodium hypochlorite (NaOCl) to kill algae in the reactor fuel storage basins have resulted in increased pitting corrosion to the reactor fuel targets stored there. This corrosion allowed water to leak into the core of the targets, resulting in a tritium-hydrogen exchange. The basins became contaminated with tritiated water, and the water trapped within the targets caused production difficulties in the tritium recovery process. In response to a request for technical assistance from the plant, ETD and the SRL Hydrogen Technology Division collaborated in an effort to solve the problem.

In 1979, five relatively noncorrosive compounds were compared with NaOCl as potential algicides in water systems containing aluminum alloys. All five compounds selected for testing proved to be substantially superior to sodium hypochlorite. They were all more toxic to algae and demonstrated considerably less potential for causing corrosion of aluminum.

Potassium permanganate ($KMnO_4$) is the most suitable compound when corrosion prevention is of prime concern. This algicide ranked fourth in terms of algicidal effectiveness, but was the only compound for which no pitting corrosion or surface damage of any type was observed in the most sensitive corrosion test (potentiostatic anodic polarization). Polyrad® (Hercules Co.) 1110A and hydrogen peroxide (H_2O_2) ranked third and fifth in toxicity tests and showed slight corrosion potential. These compounds would be used when some slight corrosion could be tolerated. Polyrad® 1110A is a corrosion inhibitor when used in systems containing stainless steel, but its effectiveness as an

algicide had not previously been reported. The herbicide diuron (DCMU) and Amine D® (Hercules Co.) acetate were the two most effective compounds for killing algae. Corrosion testing, however, indicated that some pitting of aluminum could be expected from repeated use.

Legionnaire's Disease Bacteria and Naegleria fowleri

Since the bacterium that causes Legionnaire's disease was detected in a plantsite aquatic system, a research program was conducted by ETD to understand the distribution of **Legionella pneumophila** in aquatic habitats on and offsite. Thermally altered habitats were also studied to determine if they enhanced **L. pneumophila** densities and to determine the effects of seasonality on the bacterium.

ETD studies led to the development of quantitative techniques for isolating the bacterium from aquatic habitats and for assessing serogroup distributions. To try to determine the effects of heated waters on the bacteria, both ambient and thermally altered habitats were studied.

L. pneumophila was found to be a natural part of the aquatic ecosystem. It occurs in a wide variety of environmental parameters and is able to use nutrients provided by primary procedures. More than 90% of 67 lakes and rivers observed in Alabama, Florida, Georgia, Indiana, Illinois, North and South Carolina contained **L. pneumophila**. Over 1000 samples were taken from these aquatic systems, which represent a wide diversity of habitats. The systems which had the bacterium exhibited:

- temperatures ranging from 5.7 to 63.0°C,
- pH values of 5.4 to 8.8,
- conductivities ranging from 18 to 104 μmho/cm,
- dissolved O_2 levels of 0.3 to 9.2 ppm,
- and chlorophyll *a* amounts ranging from 0.2 to 10 mg/m^3 (indicating a wide range of primary productivity).

In the thermal aquatic systems at SRP, an association predominates between the blue-green alga **Fischerella** sp. and **L. pneumophila**. The bacterium placed in a 45°C medium with **Fischerella** sp. increased the pH of the medium from 6.9 to 8.1 after 10 hours and had a doubling time of 2.7 hours, greater than previously observed in the laboratory. This growth indicates that **L. pneumophila** can exist on substrates such as those with algal extracellular products and that its temperature and pH ranges are greater than previously expected.

SRL's intensive studies on the distribution of L. **pneumophila** within the Par Pond system involved Hartley breed guinea pigs to measure the virulence of the bacterium. Each guinea pig was injected with a normalized sample, so all animals received the same number of bacteria. During the summer months, 75% of the pigs became ill while less than 10% of the animals contracted legionellosis during November and December. Control samples from ambient temperature habitats showed only 10% infectivity during the summer months (Figure 19). It is not known whether this increase in infection is due to a change in virulence or a change in activity of the bacterium.

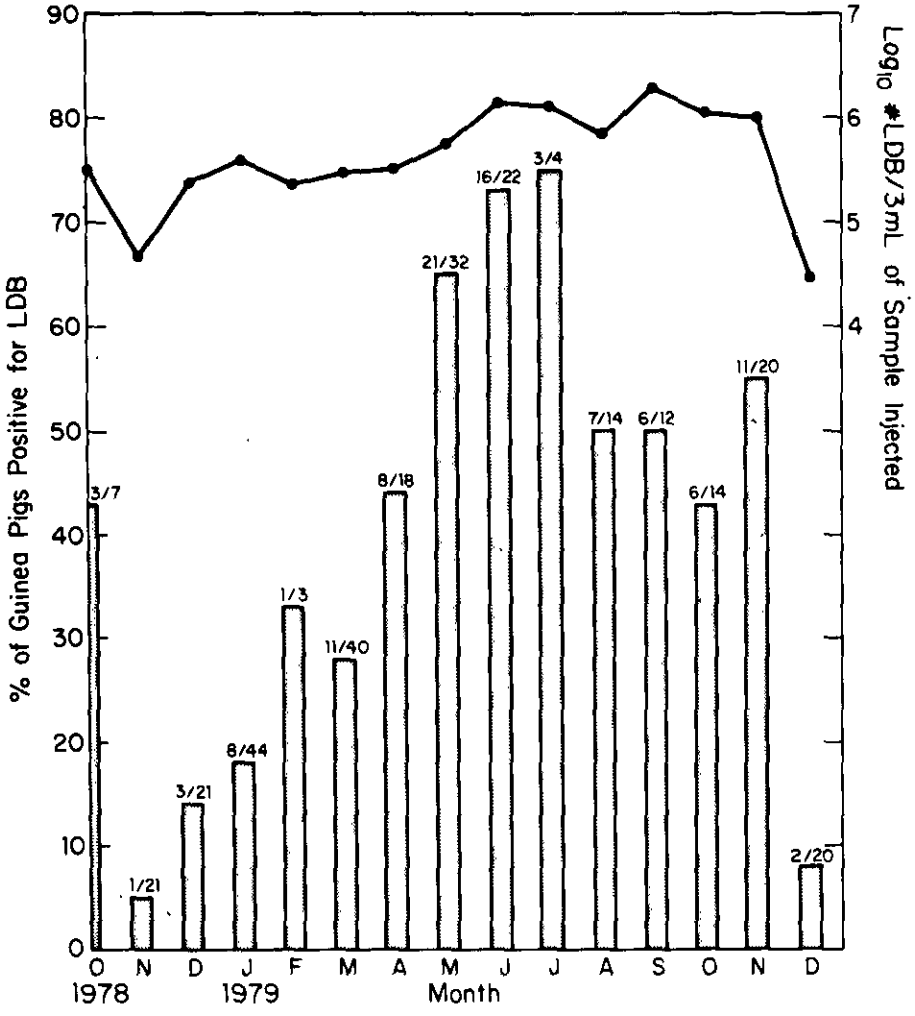

FIGURE 19. Annual variation in incidence of positive Legionnaire's Disease in injected guinea pigs and annual variation of the number of Legionnaire's Disease organisms in each sample injected.

The protozoan **Naegleria fowleri** was also observed in both thermally and nonthermally altered habitats. The studies demonstrated that **N. fowleri** had a 2% frequency of isolation in ambient temperature. Habitats which had temperatures between 35 and 55°C had a frequency of isolation of nearly 40%. The data indicate that thermophilic protozoa are more readily isolated from the hotter habitats than from cooler ones, as would be expected. However, the data have shown that two forms of **N. fowleri** are present in the natural habitat. The highly pathogenic strain dominates in the cooler waters, while the less virulent strain dominates the higher-temperature habitats. The reason for the switch in pathogenicity and the temperature ranges in which each of the strains exists has not yet been determined.

Thermal and Post-Thermal Studies at the Flowing Streams Laboratory

The Flowing Streams Laboratory, adjacent to Three Runs Creek, was used to predict some of the effects of water temperature increases from cooling systems on algae and bacteria. For three years, 4 of 6 artificial streams were continuously heated to temperatures of 2.5, 5.0, 7.5, and 12.5°C above ambient. The thermal conditions were terminated in February 1979.

The post-thermal recovery of the algae and bacteria have been studied since February 1979, but the results are incomplete. The results should be useful in predicting the recovery rates of aquatic systems after they have been exposed to prolonged heat stress.

Some of the key findings of the thermal studies were as follows:

- Significant thermally related differences in algal structure and function occurred only in the stream heated to 12.5°C above ambient.
- As temperature increased, respiration rates were greater than the photosynthesis rates.
- Significant changes in temperature did not affect the rate of methanogenesis.
- The nitrification process was most efficient in the stream heated 7.5°C above ambient because the temperature is optimal for the algae responsible for nitrification.

- The algae responsible for nitrification survived best in the stream heated 7.5°C above ambient, which caused the nitrification process to be most efficient in that stream.

Algal "Competitive Exclusion" Experiments

"Competitive exclusion" is an ecological principle which predicts that no two species can occupy the same ecological niche at the same time and place. The vast diversity of algae observed in many aquatic ecosystems presents an apparent contradiction to this principle. In 1979, experiments were performed to determine the influence of varying temperatures and nutrients on a specially prepared 12-species algal community. Seventy identical algal samples were kept in three constant light- and temperature-controlled environmental chambers for three months. The chambers were set for 10, 20, and 30°C. Light was kept constant at 100 ft-candles. Half of the samples received nutrients at the rate of 10% new media per week, and the other half received 50% new media per week. Seven temperature regimes were included by maintaining samples at each of the three constant temperatures and then shifting the samples from one temperature to another every two days.

Results showed that diversity and biomass were significantly higher in samples receiving the low level of nutrients under all but one of the temperature conditions. Temperature regimes greatly influenced which species were dominant, but only the samples maintained at a constant low temperature (10°C) or high temperature (30°C) demonstrated complete (>95%) domination by a single species.

Aquatic Insects of Upper Three Runs Creek

The study of Upper Three Runs Creek and its tributaries during 1979 has shown that this stream has an unusually diverse community of aquatic insects (321 species other than **Diptera**). This community includes a large number of species that are rarely found elsewhere. Several species which are considered more characteristic of northern and mountanious streams were found to coexist in this stream system with southern, lowland species.

Certain important questions remain unanswered from this study: 1) is the study repeatable, 2) how many species were missed because only adults caught in light traps were counted, 3) how does the fauna of Upper Three Runs Creek differ from other nearby streams, and 4) can some of the species caught in light traps be identified in their immature stages as captured in stream netting? Subsequent studies will be designed to help answer these questions.

Phytoplankton Studies in Par Pond

The entire biological community of a lake or pond is largely dependent upon phytoplankton, which constitute a major portion of the photosynthetic production in the aquatic ecosystem. Until 1978, almost no studies were conducted at Par Pond to determine the diversity and composition of the phytoplankton communities. Therefore, in 1979, Par Pond phytoplankton studies were conducted to 1) assess spatial and temporal abundance and species composition, 2) compare Par Pond communities with those of surrounding lakes and ponds, both on and offplant, and 3) measure primary production rates in relation to biomass for various phytoplankton size fractions.

Despite varying water temperatures caused by reactor cooling water effluent, phytoplankton communities in various locations of Par Pond were found to be relatively similar on any given day. The phytoplankton community in Par Pond is larger and more diverse than those of the other cooling ponds on the SRP site. The composition is similar to that of Clark Hill probably because of a strong influence from the Savannah River, which furnishes water to both.

Phytoplankton size classes of <3 μm (<5% of the total phytoplankton biomass) accounted for 15 to 40% of the total primary productivity in Par Pond, Pond C, and Clark Hill. Fluorescence microscopic analyses and laboratory culturing experiments showed that unicellular blue-green algae were primarily responsible for the relatively high primary production rates by the <3 μm component of the phytoplankton. Unicellular blue-green algae have been virtually ignored in previous phytoplankton studies based on microscopical examinations.

Par Pond Data Base

Ecological data have been collected from the Par Pond cooling reservoir as part of normal power department operations since 1958. In 1964, a formal limnology program was begun to answer questions on effects of the cooling reservoir system on the environment. The data that was collected over the years was compiled into a computer data base to help determine the environmental effects of Par Pond. Currently, two reports are being prepared which describe the data base and estimate the environmental effects of 20 years of cooling system operations (Figure 20).

Several generalizations have been derived from this data base:

- The ecosystem of Par Pond strongly resembles that of the Savannah River. The Savannah River supplies the makeup water for Par Pond.
- More than 80% of the dominant periphytic diatoms in Par Pond are found in the Savannah River.
- Contrary to earlier beliefs, water surface temperatures in Par Pond that are away from the heated effluents fluctuate in phase with reactor operations.
- The relatively constant water level in Par Pond, dictated by reactor operations, results in a better-established shoreline community than for most water supply reservoirs in the region.
- In the reservoir as a whole, translocating water is probably the major factor in the cooling system operations that affects the environment. However, dramatic shifts in the biotic structure and function in the canal system can be tied primarily to temperature fluctuations.

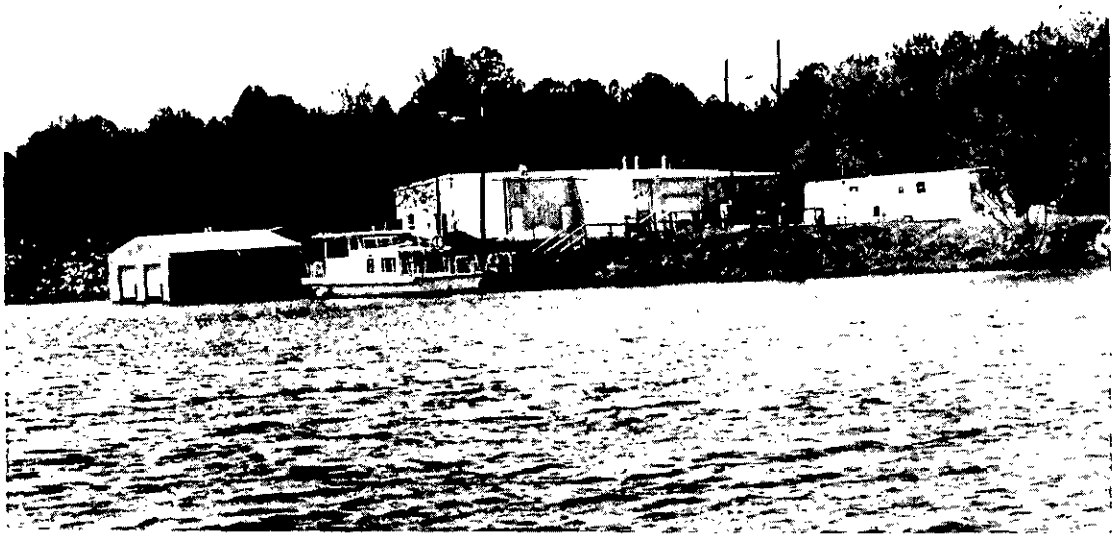

FIGURE 20. The new laboratory facility for limnological studies in Par Pond.

Carolina Bays and Ponds at the Savannah River Plant

SRP has many wetland areas on its 192,000-acre site. An executive order was issued in 1977 which required that each Federal agency minimize the destruction, loss, or degradation of wetlands. In 1979, a study to locate and categorize the wetland areas on the SRP site was begun, and the data have been compiled on the SRL computer. The SRP site has numerous shallow, undrained, or poorly drained depressions classified as ponds or Carolina Bays. Most are relatively small, ranging in diameter from 100 to 1000 feet. Ponds are defined as impoundments caused by the blockage or obstruction of the natural drainage of streams. Carolina Bays are defined as either upland or lowland depressions with no apparent inlets or outlets. The well-defined bays are oval or elliptical in shape and aligned in a northwest-southwest direction.

This study showed that there are 28 ponds and 189 Carolina Bays on the SRP site (Figure 21). The mean pond area is 17.6 acres when Par Pond is not included, with a range of 0.4 to 202.8 acres. Par Pond is the largest pond, with an area of 2500 acres. The mean Carolina Bay area is 6.6 acres, with a range of <0.3 to 124.0 acres.

The ponds and Carolina Bays do not all hold water, but the variations in aquatic vegetation, such as marsh grass and cattails, indicate higher soil moisture content than the surrounding forest or grassland areas. The water depth in any one pond or Carolina Bay is dependent on the seasonal variations in precipitation.

25-Year Savannah River Data Base

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 ETD to generate a 25-year Savannah River Data Base. This Savannah River Data Base is the longest, continuously monitored biological data base ever assembled in the U.S. It includes over 200,000 environmental entries.

This data base contains important water-quality parameters and biological data, including taxonomic names and numerical counts for species of protozoans, fish, diatoms, other algae, insects, and macro-invertebrates. Sixteen surveys were completed between 1951 and 1976 for all species (except diatoms, which had 95 surveys) at upstream, midplant, and downstream locations. The data base lists 2157 species that were present at least once in the river during the 25-year study.

During 1979, compilation of the majority of the data base was completed and during 1980 analysis of this unique data set was begun. Questions are being investigated such as: do biological measurements reflect changes in water quality in a relatively healthy river, what are the specific organisms that are most useful in identifying, significant water quality changes, and how did the structure of the Savannah River's biological community change over 25 years?

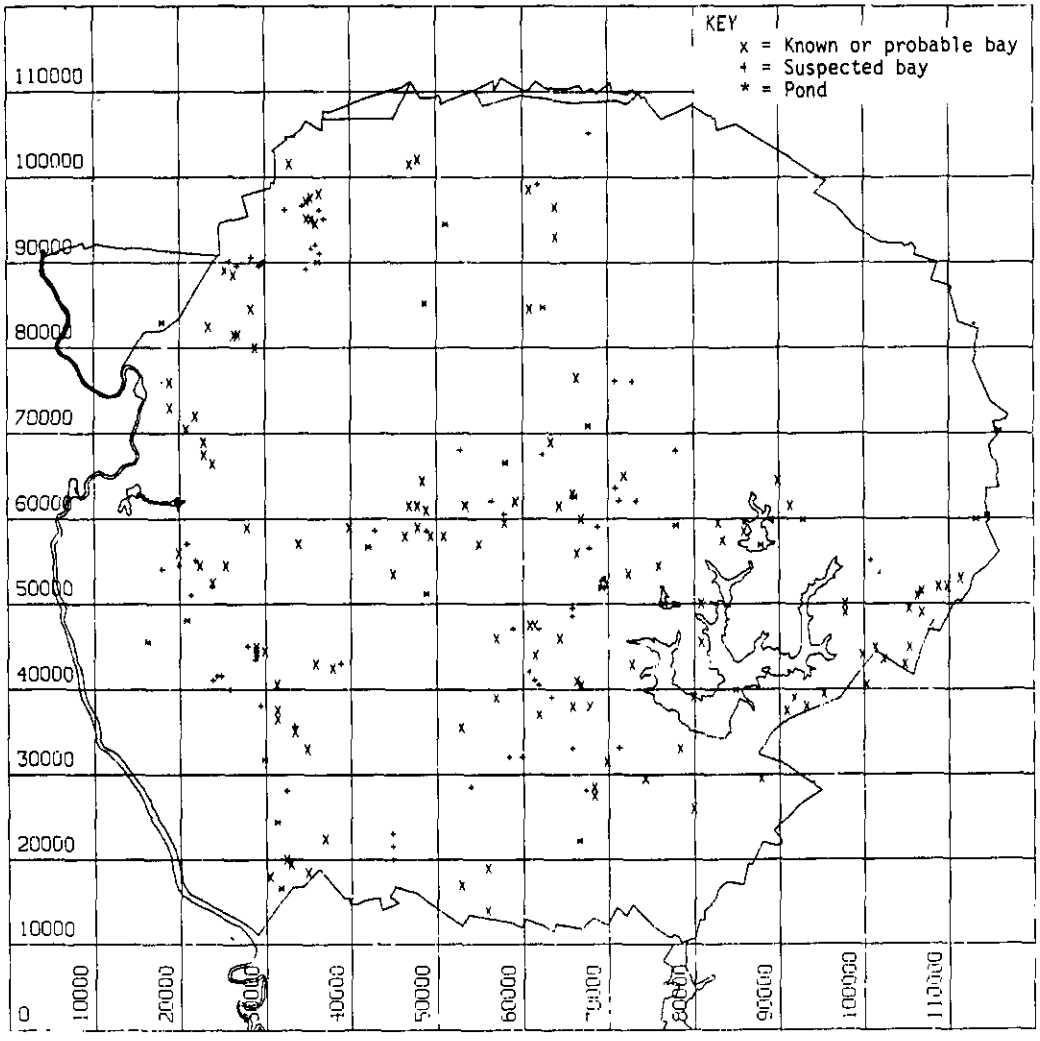

FIGURE 21. Map showing the location of wetlands on SRP. Wetlands include farm ponds and carolina bays.

MARINE STUDIES

Savannah River Marine Waters

Some radionuclides are detectable in the Savannah River estuary which might be a result of the numerous reactor operations conducted throughout South Carolina. The focal point of the nuclear component though is SRP, which is located adjacent to the Savannah River 200 river miles above the estuary. A two-year study by SRL determined that the plant's impact on plutonium concentrations in the Savannah River is minimal.

During the two-year study, plutonium transport was monitored monthly in the Savannah River and Newport River (North Carolina). There were no differences in transport above and below SRP, and concentration in the Savannah River was a fourth that of the Newport River. Also, the plutonium concentrations at three locations in the lower part of the Savannah River were essentially the same, indicating that the river was at equilibrium with regard to plutonium transport. Nearly all plutonium in transport in the Savannah River resulted from nuclear weapons fallout. The plutonium alpha activity in the river is about 1/1000 the natural activity present.

Plutonium may be more mobile in small Coastal Plain rivers. The plutonium concentration in the Newport River (1.4 fCi/L) was two to four times greater than other southeastern U.S. rivers. These rivers are usually small with heavy loads of organic matter and drain sandy soils when compared to piedmont rivers. The plutonium concentrations in the Newport River estuary biota were about the same as in other aquatic systems.

One nearshore experiment showed that once pollutants reached the nearshore zone, their transport from sound to sound was strongly influenced by residual circulation patterns, caused by asymmetrical tidal flow and the irregular coastline (Figure 22). Hydrodynamic models for our nearshore zone will therefore have to take these influences into account.

In the nearshore experiment, Savannah River water did not have the southerly component expected. In fact, Savannah River water represented only about 20% of the freshwater over the two-day experiment. This concentration of 20% was relatively constant, which implies, at least for the region south of the Savannah River, that a uniform concentration of Savannah River water is expected in the spring season.

FIGURE 22. The Savannah River Navigational Light Tower, the site of cooperative oceanographic measurements for SRL and Skidaway Oceanographic Institute.

Monthly Wind Fields for the South Atlantic Bight

Oceanographers are concerned with the transport and dispersion of passive contaminants possibly released into the atmosphere or ocean of the South Atlantic Bight (the nearshore waters between Florida and North Carolina). The winds are the driving force for pollutant transport in the ocean and in the atmosphere. Earlier, 30 years of weather observations taken aboard ships passing through the South Atlantic Bight were analyzed to provide average wind fields for the region. In 1980, the analysis was extended to include the Sargasso Sea (Figure 23).

The original data set consisted of about 400,000 observations covering the 30 years. The data set was divided into monthly segments using computer codes and the data-handling capabilities of the JOSHUA system on the SRL computer. Mean vector winds were computed in 1979 for each 1/4° latitude by 1/4° longitude cell in a grid extending from Cape Hatteras, NC, to Miami, FL. Three spatially coherent patterns of wind vectors were recognized.

- The winter (November, December, January, and February) pattern consists of N-NW winds which extend from the shore to the eastern side of the Gulf Stream.

- The summer (June and July) pattern is composed of south and southwest winds produced by the Azores high-pressure system. The summer pattern extends beyond the Gulf Stream region into the Sargasso Sea.

- The late fall (September and October) pattern consists of northeasterly flow over the nearshore and Gulf Stream regions, with a light easterly flow for the bulk of the Sargasso Sea.

Only two transitional seasons can be resolved in the monthly analysis of winds, one between summer and late fall patterns, and the other between winter and summer. The transition between late fall and winter is too rapid to be detected on a monthly basis. The South Atlantic Bight winds are not always related to the Sargasso Sea winds, indicating that the Gulf Stream may be a demarcation line between the two.

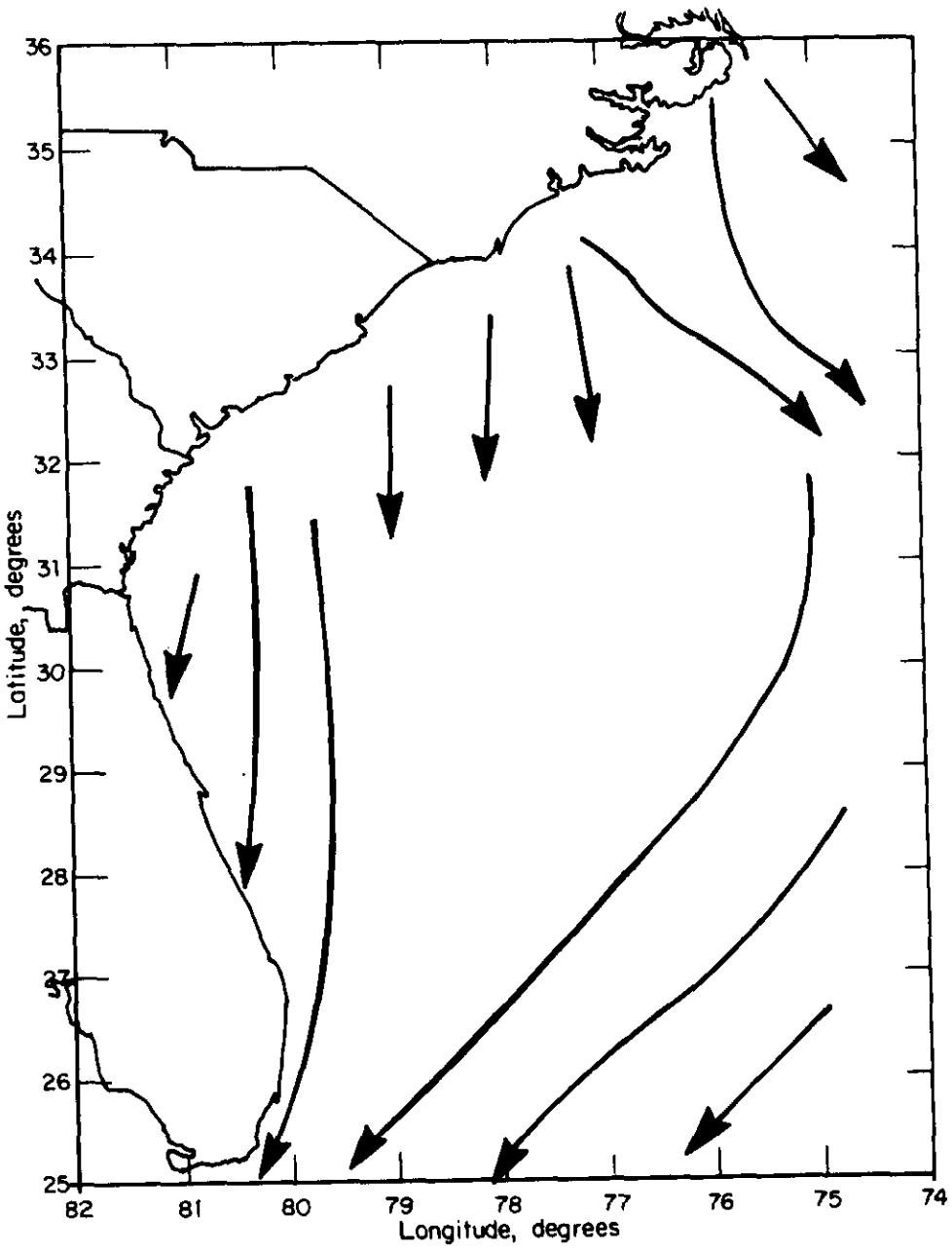

FIGURE 23. Example of a mean monthly wind field derived from historical records of winds in the South Atlantic Bight.

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