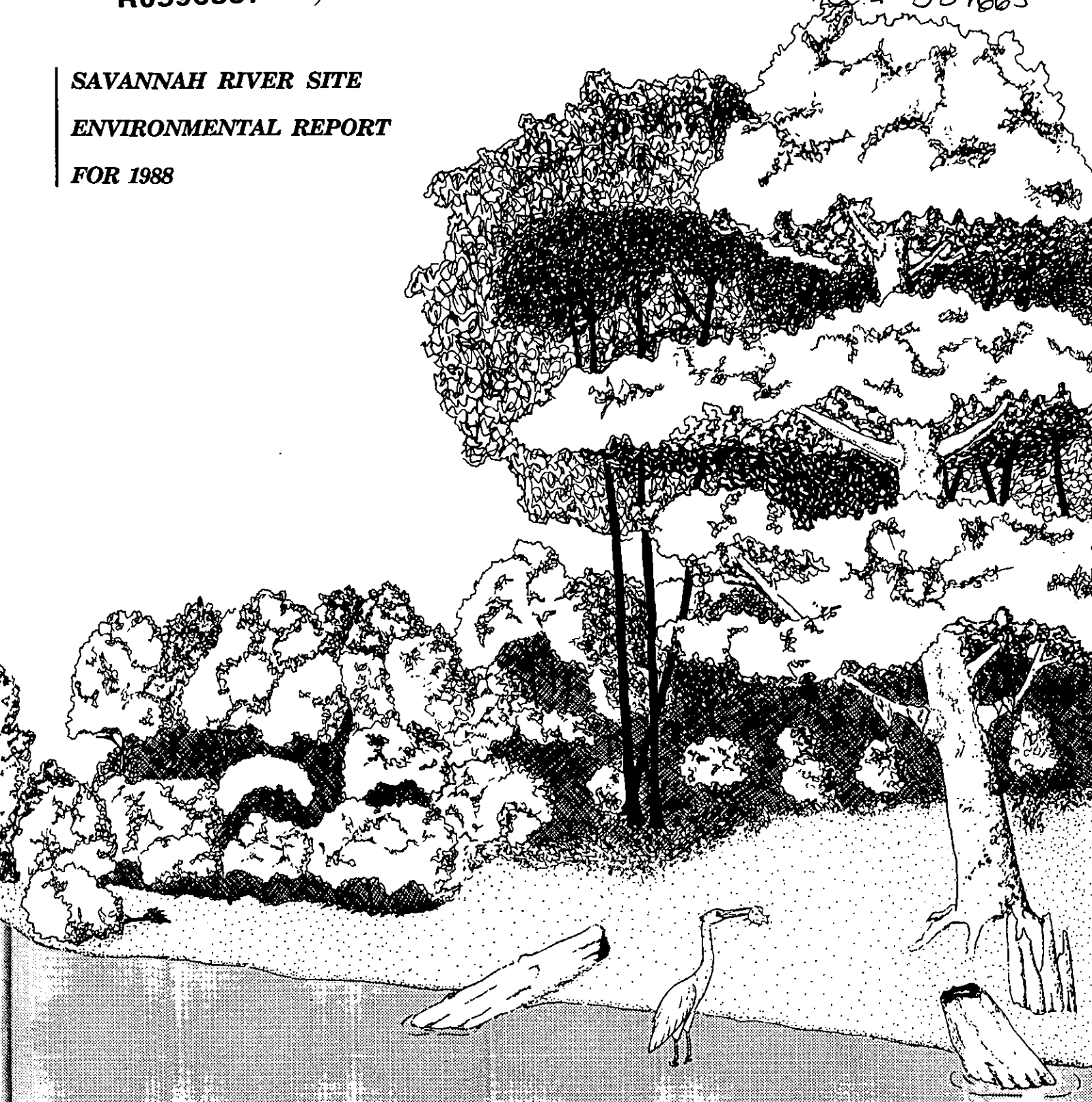
WSRC-RP-89-59-1
Volume I
Text

SAVANNAH RIVER SITE ENVIRONMENTAL REPORT FOR 1988



Westinghouse Savannah River Company
Savannah River Site
Aiken, SC 29808

SAFETY • RESPONSIBILITY • SECURITY
SRS
SAVANNAH RIVER SITE

PREPARED FOR THE U.S. DEPARTMENT OF ENERGY UNDER CONTROL CONTRACT NO. DE-AC09-88SR18035

FRACTIONS AND MULTIPLES OF UNITS

Multiple	Decimal Equivalent	Prefix	Symbol
10^{6}	1,000,000	mega-	M
10^{3}	1,000	kilo-	k
10^{2}	100	hecto-	h
10	10	deka-	da
10^{-1}	0.1	deci-	d
10^{-2}	0.01	centi-	c
10^{-3}	0.001	milli-	m
10^{-6}	0.000001	micro-	μ
10^{-9}	0.000000001	nano-	n
10^{-12}	0.000000000001	pico-	p
10^{-15}	0.000000000000001	femto-	f
10^{-18}	0.000000000000000001	atto-	a

CONVERSION TABLE

Multiply	By	To Obtain	Multiply	By	To Obtain
in.	2.54	cm	cm	0.394	in.
ft	0.305	m	m	3.28	ft
mi	1.61	km	km	0.621	mi
lb	0.4536	kg	kg	2.205	lb
liq qt - U.S.	0.946	L	L	1.057	liq qt - U.S.
ft^2	0.093	m^2	m^2	10.764	ft^2
mi^2	2.59	km^2	km^2	0.386	mi^2
ft^3	0.028	m^3	m^3	35.31	ft^3
mCi/mi^2	0.386	mCi/km^2 (nCi/m^2)	mCi/km^2	2.59	mCi/mi^2
d/m	0.450	pCi	pCi	2.22	d/m
nCi	1×10^{3}	pCi	pCi	1×10^{-3}	nCi
d/m/L	0.45×10^{-9}	μCi/cc	μCi/cc	2.22×10^{9}	d/m/L
$d/m/ft^2$	0.01256	mCi/mi^2	mCi/mi^2	79.6	$d/m/ft^2$
pCi/L (water)	10^{-9}	μCi/mL (water)	μCi/mL (water)	10^{9}	pCi/L (water)
pCi/m^3 (air)	10^{-12}	μCi/cc (air)	μCi/cc (air)	10^{12}	pCi/m^3 (air)
mCi/km^2	1	nCi/m^2	nCi/m^2	1	mCi/km^2

DISCLAIMER

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Savannah River Site

Environmental Report

for 1988 (U)

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Contents

PART I Environmental Monitoring Methods

Abbreviations and Acronyms

ACL	Alternative Concentration Limits
ACWS	Alternate Cooling Water System
AEC	Atomic Energy Commission
ALARA	As Low As Reasonably Achievable
ANSP	Academy of Natural Sciences of Philadelphia
APHA	American Public Health Association
ARAC	Atmospheric Release Advisory Capability
BDC	Beaver Dam Creek
BG	Burial Ground (Radioactive Waste Burial Ground)
BOD	biochemical oxygen demand
BP	biomass production
CAAC	Clean Air Act Code
CAI	computer-assisted instruction
CCWS	Comprehensive Cooling Water Study
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act (Superfund)
CF	continuous flooding
CL	confidence level
CLP	Contract Laboratory Program (EPA)
COD	chemical oxygen demand
CSRA	Central Savannah River Area
CSWE	Central Services Works Engineering (SRS)
CTS	Concentrate Transfer System
DCG	Derived Concentration Guide
DEL	deleted version
DM	Dry Monitoring (Wells)
DMR QA	Discharge Monitoring Report Quality Assurance (EPA)
DO	dissolved oxygen
DOE	U.S. Department of Energy
DOE-SR	U.S. Department of Energy—Savannah River Site
DOE-HQ	U.S Department of Energy—DOE Headquarters in Washington
DWPF	Defense Waste Processing Facility
EA	Environmental Assessment
ECS/Normandeau	Environmental and Chemical Services/Normandeau) Associates, Inc.
E & E	Environment and Energy Department (SRS)
EEI	Envirodyne Engineers, Inc.
EHP	Environmental and Health Protection Department
EID	Environmental Information Document
EIP	Environmental Implementation Plan
EIS	Environmental Impact Statement
EMS	Environmental Monitoring Section (SRS)
EMS-GW	Environmental Monitoring Section-Groundwater Monitoring Group
EML	Environmental Measurements Laboratory (DOE)
EMSL-LV	Environmental Monitoring Systems Laboratory /Las Vegas (EPA)
EOC	Emergency Operating Center
EPA	U.S. Environmental Protection Agency
EPS	Environmental Protection Section (formerly Environment & Energy Department)
ERA	Environmental Resource Associates
ESD	Environmental Sciences Division (SRL)
ETD	Environmental Technology Division
ETF	Effluent Treatment Facility
ETI	Environmental Testing, Inc.
ETP	Effluent Treatment Plant
FCM	flow cytometric
FDA	Food and Drug Administration
FEIS	Final Environmental Impact Statement
FMC	Four Mile Creek
FONSI	Finding of No Significant Impact
FRC	Federal Radiological Council
FY	Fiscal Year
GDNR	Georgia Department of Natural Resources
GIS	Geographic Information System
HAZMAT	hazardous materials
HDEHP	Di-2-ethylhexyl phosphoric acid in toulene
HDM	H-Area dry monitoring wells

HEP	Habitat Evaluation Procedures
HEPA	high efficiency particulate air filter
HP	Health Protection Department (SRS)
HPGe	high purity germanium detector
HT	Tritiated hydrogen
HWMW	Hazardous Waste/Mixed Waste Disposal Facilty
ICRP	International Commission on Radiological Protection
IDMS	isotope dilution mass spectrometry
IGB	Indian Grave Branch
IT	International Technology Corporation
ITAS	International Technology Analytical Services
IWT	Interim Waste Technology (SRL)
LANDSAT	Land Resources Observatory Satellite
LEPC	local emergency planning commission
LETF	Liquid Effluent Treatment Facility
LLD	lower limit of detection
LLNL	Lawrence Livermore National Laboratory
LSC	liquid scintillation counter
L3R	Lower Three Runs Creek
MCL	maximum contaminant level
MCS	multi-channel scaling
MDC	minimum detectable concentration
MSDS	Material Safety Data Sheet
MSS	multispectral scanner
MTF	Memorandum-to-File
NAAQS	National Ambient Air Quality Standards
NBS	National Bureau of Standards (now the National Institute of Standards and Technology)
NIST	National Institute of Standards and Technology (formerly National Bureau of Standards–NBS)
NCRP	National Council on Radiation Protection and Measurements
NEPA	National Environmental Policy Act
NERP	National Environmental Research Park
NESHAPS	National Emission Standards for Hazardous Air Polluants
NPDES	National Pollutants Discharge Elimination System
NRC	Nuclear Regulatory Commission
NRDC	Natural Resources Defense Council
PB	Pen Branch
PCB	polychlorinated biphenyl
PE	Performance Evaluation samples (EPA)
PF	periodic flooding
PHA	pulse height analysis
POC	point-of-compliance
QA	quality assurance
QAD	Quality Assurance Division (EPA)
QAP	Quality Assurance Program (DOE)
QC	quality control
RCRA	Resource Conservation and Recovery Act
REMS	Remote Environmental Monitoring System
RFI	RCRA Facility Investigation
ROD	Record of Decision
RTF	Replacement Tritium Facility
RWBG	Radioactive Waste Burial Ground (formerly the Solid Waste Storage Facility–Burial Ground)
RWHP	Raw Water Holding Pond
SARA	Superfund Amendments and Reauthorization Act
SBL	stable boundary layer
SCB	standing crop biomass
SCCP	South Carolina Coastal Plain
SCDHEC	South Carolina Department of Health and Environmental Control
SEFES	Southeastern Forest Experimental Station
SI	International System of Units
SMCC	Subsurface Microbiological Culture Collection

SPOT	Satellite Pour l'Observation de la Terre (Earth Observation Satellite)
SREL	Savannah River Ecology Laboratory
SRFS	Savannah River Forest Station
SRL	Savannah River Laboratory
SRS	Savannah River Site
STABLE	Stable Atmospheric Boundary Layer Experiment
SWMU	solid waste management unit
TB	Tims Branch
TEDA	Triethyldiamine
TIMS	Thermal Ionization Mass Spectrometer
TIOA	Triisooctylamine
TKN	total kjeldahl nitrogen
TLD	thermoluminescent dosimeter
TOC	total organic carbon
TOH	total organic halogens
TRAC	Tracking Radioactive Atmosphere Contaminants
TSP	total suspended particulates
TSS	total suspended solids
TRU	transuranic
UCF	Underground Counting Facility
USF	Uranium Solidification Facility
USFS	U.S. Forest Service
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
U3R	Upper Three Runs Creek
VOC	volatile organic compound
WRMP	Water Resource Management Plan
WCAL	Weather Center Analysis Laboratory
WIND	Weather INformation and Display
WMin	waste minimization
WMT	Waste Management Technology
WP020	Water Pollution Study (EPA)
WSCTF	Waste Site Closure Task Force

Abstract

During 1988, as in previous years, Savannah River Site operations had no adverse impact on the general public or the environment. Based on the SRS site-specific code (see Chapter 2), the maximum radiation dose commitment to a hypothetical individual at the SRS boundary from 1988 SRS atmospheric releases of radioactive materials was 0.46 millirem (mrem) [0.0046 millisievert (mSv)]. To obtain the maximum dose, an individual would have had to reside on the SRS boundary at the location of highest dose for 24 hours per day, 365 days per year, consume a maximum amount of foliage and meat which originated from the general vicinity of the plant boundary, and drink a maximum amount of milk from cows grazing at the plant boundary. The average radiation dose commitment from atmospheric releases to the hypothetical individual on the SRS boundary in 1988 was 0.18 mrem (0.0018 mSv). This person, unlike the maximumly exposed individual, consumes an average amount of foliage, meat, and milk which originated from the foliage and animals living at the plant boundary.

The maximum radiation dose commitment to an individual downriver of SRS who consumed Savannah River water was 0.13 mrem (0.0013 mSv) at both the Cherokee Hill Water Treatment Plant at Port Wentworth, GA (near Savannah) and the Beaufort-Jasper Water Treatment Plant near Beaufort, SC. This assumes the individual drinks 2 L of water each day, 365 days per year.

These radiation doses from SRS operations are small when compared to the dose from natural radiation, which averages 295 mrem (2.95 mSv) per year [NCRP87]. The largest part of this natural dose is 200 mrem (2.00 mSv) from natural radon gas in homes. The maximum dose from SRS atmospheric releases of 0.46 mrem (0.0046 mSv) is only 0.46% of the DOE Revised Interim Radiation Dose Limit from extended exposure, and 0.16% of the average annual dose from natural radiation.

This 1988 report contains monitoring data from routine radiological and nonradiological environmental surveillance activities, summaries of environmental protection programs in progress, a summary of National Environmental Policy Act (NEPA) activities, and a listing of environmental permits issued by regulatory agencies and their status. The environmental surveillance activities at and in the vicinity of SRS comprise one of the most comprehensive and extensive environmental monitoring programs in the United States.

Preface

The purpose of this report is to provide information to the public about the impact of the Savannah River Site (SRS) operations on the public and the environment. This report, the U. S. Department of Energy *Savannah River Site Environmental Report for 1988*, describes environmental surveillance and monitoring activities conducted at and around SRS during the calendar year 1988. The SRS Environmental Report is published annually and is widely distributed to government officials, U. S. congressmen, universities, and other interested parties. Copies of the report are placed in public reading rooms. Preparation and publication of the report is mandated by Draft DOE Order 5400.xx, with a publication deadline of June 1 of the following year.

The objectives of this report are to:

- provide detailed information about the SRS and environmental monitoring activities
- report 1988 monitoring data for the SRS and surrounding environs
- provide radiation dose estimates for the surrounding populations and describe how the estimates were derived
- summarize all significant environmental activities at SRS in one report
- provide a historical document for reference and trending
- show trend analyses, when possible, to indicate increases and decreases in environmental concentrations and SRS discharges

Ensuring the safety of the public and the environment in the vicinity of SRS has been a foremost consideration in the design of the plant and has continued to be a primary objective during the 34 years of SRS operations. An extensive environmental surveillance program has been maintained continuously since 1951 (before SRS startup) to determine the concentrations of radionuclides in the environment of the plant. Data generated by the onsite surveillance program have been recorded in SRS documents since 1951. A public report, in which data from offsite environmental monitoring activities were published and issued to the public, was initiated in 1959. Dual reporting of SRS environmental monitoring activities continued until 1985 when data from both onsite and offsite surveillance programs were merged into a single publication. In 1985, the report expanded to two volumes, the first volume for text and the second for figures and data tables. A listing of past onsite and offsite reports is presented in Appendix A.

The scope of the environmental monitoring program at SRS has increased significantly during the years since plant startup. This change is reflected in the magnitude of annual reports. Prior to the mid-1970s, the reports contained primarily radiological monitoring data. Beginning in the mid-1970s, the reports included increased amounts of nonradiological monitoring data as those programs increased in size and scope. The nonradiological monitoring program is now as extensive as the radiological monitoring program.

This report consists of two volumes. Volume I summarizes environmental surveillance and monitoring activities at SRS, and includes key figures and summary tables. A brief summary is presented at the beginning of each chapter, and highlights of the chapter are presented at the end. Volume II contains figures (maps and diagrams) and detailed monitoring data tables.

Previous reports were categorized by radiological and nonradiological monitoring with subdivisions by media (air, water, etc.). The format of the 1988 report has been reversed; monitoring programs are presented first by type media and then subdivided by type of monitoring.

The *Savannah River Site Environmental Report for 1988* is written for a wide audience with a variety of environmental interests. Readers may selectively read different sections of the report according to their specific interests. The abstract gives an overall picture of what the report contains, while the executive summary provides a short digest of the pertinent information in the report. A brief summary is presented at the beginning of each chapter, and highlights appear at the end of the chapter. More detailed information is found in the chapters.

Executive Summary

The environmental surveillance activities at and in the vicinity of the Savannah River Site (SRS) [formerly the Savannah River Plant (SRP)] comprise one of the most comprehensive and extensive environmental monitoring programs in the United States. This 1988 report contains monitoring data from routine and nonroutine radiological and nonradiological environmental surveillance activities, summaries of environmental protection programs in progress, a summary of National Environmental Policy Act (NEPA) activities, and a listing of environmental permits issued by regulatory agencies and their status. The report consists of two volumes. Text, major figures, and summary data tables are presented in Volume I; Volume II is comprised of figures and comprehensive data tables. This report provides information to the public about the impact of SRS operations on the public and the environment.

The SRS occupies a large area of approximately 300 square miles along the Savannah River, principally in Aiken and Barnwell counties of South Carolina. SRS's primary function is the production of plutonium, tritium, and other special nuclear materials for national defense, for other governmental uses, and for some civilian purposes. From August 1950 to March 31, 1989, SRS was operated for the Department of Energy (DOE) by E. I. duPont de Nemours & Co. On April 1, 1989 the Westinghouse Savannah River Company assumed responsibility as the prime contractor for the Savannah River Site.

ASSESSMENT OF RADIOLOGICAL IMPACT OF SRS OPERATIONS ON THE PUBLIC

Radiation Dose Terms

As used in this report, the term *dose* normally means "effective dose equivalent." It is defined by the International Commission on Radiological Protection [ICRP77, ICRP79] as "the sum of the external dose equivalent plus the committed dose equivalents to specific organs of the body, times a weighting factor appropriate for each organ." The term *dose commitment*, as it is applied to an individual, means "committed effective dose equivalent," which is a measure of the amount of radiation dose received by the individual over a lifetime as a result of exposure to all radiation pathways during the year being considered. In this report, the individual's lifetime is assumed to extend 50 years beyond the time of exposure.

The terms *dose* and *dose commitment* are sometimes used interchangeably in this report. The dose commitment to an individual is usually expressed in units of millirem (abbreviated "mrem") or millisievert (abbreviated "mSv") (1 mrem = 1/1000 rem; 1 mSv = 1/1000 Sv; 1 mSv = 100 mrem).

Collective (population) dose commitment is the sum of individual dose commitments in a population group and is expressed in units of person-rem (person-sievert). For example, if each person in a population of 1,000 receives a dose commitment of 1 rem (0.01 Sv), the collective dose commitment would be 1,000 person-rem (10 person-Sv).

Applicable Dose Standards

The DOE radiation standards for the protection of the public in the vicinity of SRS are given in Draft DOE Order 5400.xx. These standards are based on recommendations of the International Commission on Radiological Protection (ICRP) and the National Council on Radiation Protection and Measurements (NCRP).

In 1985, a draft DOE order was issued that contained revised interim standards incorporating the recommendations and dose models contained in ICRP Publications 26 and 30 [ICRP77, ICRP79]. The previous standards had been based on ICRP Publications 2 and 10 [ICRP59, ICRP68]. The previous guides were based on a maximum annual dose of 500 mrem (5 mSv) to an offsite individual. The draft DOE order changed the maximum allowable offsite dose to 100 mrem (1 mSv). The

Table ES-1. DOE Revised Interim Radiation Dose Limits

All Pathways. The effective dose equivalent for any member of the public from all routine DOE operations[a] (excluding natural background and medical exposures) shall not exceed the values given below:

	Effective dose equivalent[b]	
	mrem/year	(mSv/year)
Occasional annual exposure	500	(5)
Prolonged period of exposure[c]	100	(1)

No individual organ shall receive a committed dose equivalent of 5 rem/year (50 mSv/year) or greater.

Air Pathway Only (Limits of 40 CFR 61, Subpart H)

	Dose equivalent	
	mrem/year	(mSv/year)
Whole body dose (effective dose equivalent)	25	(0.25)
Any organ	75	(0.75)

[a] "Routine DOE operations" means normal planned operations and does not include additional routine or nonroutine releases.
[b] Effective dose equivalent is expressed in rem (or mrem) with the corresponding value in Sv (or mSv) in parentheses.
[c] For the purpose of these standards, a prolonged exposure is one that lasts, or is predicted to last, longer than 5 years.

revised interim standards, which also include Environmental Protection Agency (EPA) limits for the atmospheric pathways contained in 40 CFR 61, Subpart H [EPA85], are given in Table ES-1.

EPA drinking water standards which apply at downriver water treatment plants are based on an annual whole body dose of 4 mrem (0.04 mSv) from the annual consumption of two liters of water per day [EPA75,EPA87]. Periodically in this report, radioactivity concentrations are compared with EPA drinking water standard concentrations. While this is a convenient reference, it should be noted that the current EPA standard concentrations for tritium (20,000 pCi/L) and ^{90}Sr (8 pCi/L) correspond to a whole body dose less than 4 mrem. EPA is considering a change to these concentrations to reflect the 4 mrem dose [EPA86].

Calculation Models

With few exceptions, most of the radioactive materials released from SRS are of such low concentrations that when dispersed in the environment they are not detectable by conventional monitoring procedures. Therefore, radiation doses to offsite populations are calculated with mathematical models that use known transport mechanisms for atmospheric and liquid releases and known major pathways of exposure to man. Environmental measurements of tritium oxide released in small quantities from production areas during routine operations are used to verify atmospheric dispersion in the transport models [Mar84].

Dose Commitment from Atmospheric Releases

The maximum radiation dose commitment to a hypothetical individual on the SRS boundary from 1988 SRS atmospheric releases of radioactive materials was 0.46 mrem (0.0046 mSv). The 0.46 mrem (0.0046 mSv) is 0.5% of the DOE guide of 100 mrem/yr (1 mSv) for a prolonged exposure to an individual in the public zone. The assumptions used in calculating the maximum public zone dose commitment are conservative; that is, they tend to overestimate the dose commitment. Therefore, it is very likely that the actual maximum individual dose commitment was less than 0.46 mrem (0.0046 mSv). This maximum individual dose commitment

from SRS operations was approximately 0.2% of the average dose of 295 mrem (2.95 mSv) per year received in the vicinity of SRS from natural radiation. The radiation dose commitment to the average individual at the plant perimeter was 0.2 mrem (0.002 mSv), which is 0.07% of the average dose of 295 mrem (2.95 mSv) from natural radiation sources.

The population dose commitment from SRS atmospheric releases to the 555,100 people who live within 50 miles (80 km) of the center of the site was 21 person-rem (0.21 person-Sv) with an average dose of 0.04 mrem (0.0004 mSv) per person. During 1988, this same population received an estimated annual radiation dose of 164,000 person-rem from natural radiation and an additional dose of 29,400 person-rem from medical procedures. Most of the natural radiation dose comes from radon in homes. The individual radiation dose from natural radioactivity, medical procedures, and consumer products averages 360 mrem per person, which is 7,200 times the dose from SRS operations (see the "Perspectives on Radiation" section).

Releases of tritium account for greater than 50% of the offsite population dose from SRS atmospheric releases. Tritium from SRS is released in two forms to the atmosphere. The HT or elemental gas form is not readily absorbed in the human body while the HTO or oxide form (tritiated water) is readily assimilated. The dose from the elemental form is therefore significantly less than from the oxide form; the dose per unit of intake of tritium oxide is 25,000 times that of elemental tritium.

Before 1985, all tritium released from SRS to the atmosphere was considered to be in the oxide form. Reliable continuous measurements could not be taken prior to that year because SRS did not have the methodology to distinguish between elemental and oxide forms. In 1985, SRS incorporated technical advances to distinguish and measure tritium oxide and elemental tritium. Measurements of the forms of tritium released in 1988 showed that approximately 62% of the tritium released to the atmosphere from SRS operations was in the oxide form.

Dose Commitment from Liquid Releases

Consumption of water from the two water treatment plants on the Savannah River below SRS also contributes to the offsite dose commitment. The Cherokee Hill water treatment plant at Port Wentworth, GA (near Savannah, GA) provides water for industrial and manufacturing purposes. The 20,000 consumers of this water are primarily adults working in industrial facilities. The Beaufort-Jasper Counties, SC, water treatment plant provides water to 50,000 consumers of all ages living in Beaufort and Jasper Counties, SC. Approximately 92% of the radiation dose at the water treatment plants from SRS operations is due to tritium.

The radiation dose commitment to an individual downriver of SRS who consumed Savannah River water at a maximum rate of two liters a day was 0.13 mrem (0.0013 mSv) at both the Cherokee Hill water treatment plant at Port Wentworth, GA, and the Beaufort-Jasper water treatment plant. The dose commitment for an individual consuming the water at an average rate of one liter per day was 0.07 mrem (0.0007 mSv) for Beaufort-Jasper and 0.06 mrem (0.0006 mSv) for Port Wentworth.

The dose commitment to a hypothetical individual who could receive the highest offsite doses from releases of radioactivity from SRS to the Savannah River was 0.79 mrem (0.0079 mSv). This *maximum individual* would consume an maximum amount of water and a maximum amount of fish from the river just downriver from SRS and would also spend many hours in shoreline activities, swimming, and boating. This dose commitment of 0.79 mrem is only 0.3% of the annual dose commitment of 295 mrem (2.95 mSv) received from natural radiation sources.

The collective dose commitment from liquid releases in 1988 was 6 person-rem (0.06 person-Sv). The dose commitments from the water consumption pathway (Beaufort-Jasper and Port Wentworth) occur to discrete population groups; however, the dose commitments from other exposure pathways (i.e., fish and shellfish consumption and recreational activities) occur to a diffuse population that cannot be described as being in a specific geographical location.

Perspective

The radiation doses from SRS operations are small when compared to the dose from natural radiation, which averages 295 mrem (2.95 mSv) per year [NCRP87a]. The largest part of this natural dose is 200 mrem (2.00 mSv) from natural radon gas in homes. The maximum dose from SRS atmospheric releases of 0.5 mrem (0.005 mSv) is only 0.2% of the average dose from natural radiation. Figure ES-1 graphically shows sources of an individual's radiation dose, the percentage each source contributes, and SRS's maximum atmospheric contribu-

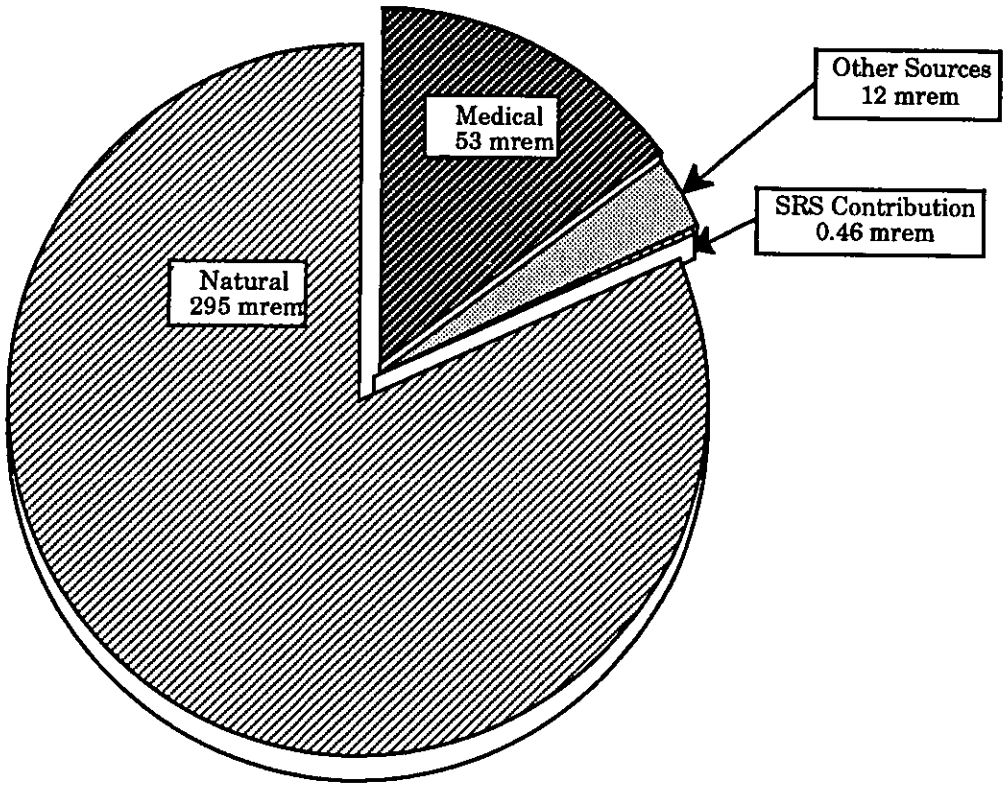


Figure ES-1. Sources of radiation dose versus SRS's contribution

tion from releases. Table ES-2 (Table ES-1, Vol. II) summarizes the individual and collective doses from SRS and other sources.

The collective dose commitment (person-rem) from SRS releases can be compared with the population doses from natural radioactivity (cosmic radiation, terrestrial radioactivity, internal radioactivity, and radon in homes) and medical radiation exposure. The 1988 population dose commitment from SRS releases (21 person-rem from atmospheric releases and 6 person-rem from liquid releases) is compared with annual population dose from natural and medical sources in Table ES-2. Even though the SRS contribution to population dose commitment is very small (0.02% of that from natural sources), SRS has a continuing program to improve operating techniques by integrating the principles of ALARA (As Low As Reasonably Achievable) and developing new technologies directed toward reducing releases of radioactive materials to the environment.

The radiation dose the public receives from nuclear operations at SRS can be viewed from several perspectives. In comparison to the EPA standard pertaining to atmospheric releases, the maximum individual dose at the SRS perimeter was 2.4% of the EPA limit. From the viewpoint of regulatory standards, the maximum radiation dose to consumers of water treated by the Port Wentworth and Beaufort-Jasper water treatment plants was 2.5% of the EPA standard. Compared to the exposure from natural radiation (295 mrem/year in the CSRA), the dose contributed by SRS operations is miniscule. Even the variation in the natural radiation dose in this area far exceeds the maximum offsite dose resulting from the Savannah River Site. In the context of the recommendations of the National Committee on Radiation Protection [NCRP 87b], any radiation dose less than 1 mrem (0.01 mSv) per year is so low that "further effort to reduce radiation exposure to the individual is unwarranted."

OVERVIEW OF 1988 MONITORING RESULTS

Magnitude of Program

The environmental monitoring program conducted at SRS is one of the largest and most comprehensive in the United States. A total of 211,500 analyses (113,500 radiological and 98,000 nonradiological) were performed in 1988. In addition, over 1.4 million nonradioactive measurements were made at ambient air quality monitoring stations and over 460,000 water quality readings were made in Beaver Dam Creek and Steel Creek.

Table ES-2. Individual and Collective (Population) Doses - 1988

Location/Source	Calculated Individual Dose, mrem[a]		Size	Calculated Collective Dose person-rem[a]
SRS Boundary	Average	Maximum		
SRS Atmospheric Releases	0.18	0.46[b]	-	-
SRS Liquid Releases	-	0.79[c]	-	-
Within 80 km of SRS				
Dose From Atmospheric Releases	0.04[d]	-	555,100	21.0
Water Treatment Plants Downstream of SRS				
Beaufort-Jasper plant	0.07	0.13	51,000	3.0
PortWentwort plant	0.06	0.12	20,000	1.3
River Fish and Recreation				
Consuming River Fish	-	-	555,100	1.9
Recreation	-	-	555,100	<0.1
SRS Releases Total				27.2

Other Sources[g]	Annual Dose,mrem		Collective Dose, person-rem
Natural Radioactivity[e]			
Cosmic Radiation	28		
External Terrestrial	28		
Internal	39		
Radon in Homes	200		
		555,100(within 80 km)	164,000
		71,000(water plants)	20,900
Subtotal (Natural)	295		185,000
Medical Radiation[e,f,g]	53		
		555,100(within 80 km)	29,400
		71,000(water plants)	3,800
Subtotal (Medical)	53		33,200
Consumer Products[g]	10		
		555,100 (within 80 km)	5,600
		71,000 (water plants)	700
Subtotal (Consumer Products)	10		6,300
Weapons Test Fallout	<1.0		
		555,100(within 80 km)	600
		71,000(water plants)	100
Subtotal (Weapons Tests)	<1.0		700
Other	<1.0		
		555,100 (within 80 km)	600
		71,000 (water plants)	100
Subtotal (Other)	<1.0		700
Other Sources Total	360		225,000

[a] Committed effective dose equivalent.
[b] Based on a hypothetical individual with maximum dietary habits located on the plant perimeter at locations of highest exposure. No such individual is known to exist.
[c] Based on a hypothetical individual with maximum dietary habits who lives on the shore of the Savannah River. No such individual is known to exist.
[d] Based on atmospheric dispersion of SRS releases as described in Table 2-2, Vol. II.
[e] Average values for the United States.
[f] Dose is prorated over the U. S. population. This is a means of arriving at an average dose, which when multiplied by the population size, produces an estimate of population exposure. It does not mean that every member of the population received radiation exposure from these sources.
[g] NCRP Report No. 93.
- Not applicable.

While the radiological monitoring program has continued to experience some growth from year to year, the most pronounced growth has occurred in the nonradiological program. This program began expanding in the mid-1970s and has continued to escalate so that it is now as large as the radiological program. The major growth has occurred in groundwater monitoring.

Presentation of Units

It is intended to use the most practical units of measure when presenting data in this report. Most data are presented in picocuries per liter (pCi/L) or picocuries per gram (pCi/g) [1 pCi = 10^{-12} Ci (curie)]. Fractions and multiples of units are shown on the inside front cover of Volume I of this report. In some cases, data are presented in femtocuries (fCi) [1 fCi = 10^{-15} Ci]. A few data are presented in attocuries (aCi) [1 aCi = 10^{-18} Ci]. Tritium concentrations are usually expressed in picocuries per milliliter (pCi/mL), but are sometimes shown in pCi/L [1pCi/mL = 1,000 pCi/L]. Statistical uncertainty is not presented with data shown in Volume I except when appropriate (e.g., wildlife monitoring, due to greater uncertainties), but is included in the comprehensive data tables in Volume II.

Air Monitoring

Extensive monitoring for radioactivity in air is performed at six onplant stations, 13 plant perimeter stations, 12 stations at the 25-mile radius of SRS, and four stations at the 100-mile radius. The small amount of particulate alpha and beta-gamma radioactivity released to the atmosphere from SRS facilities is generally obscured in the area surrounding SRS by worldwide fallout. Tritium, the only radionuclide of plant origin routinely detected in offsite air, showed a decreasing trend with distance from the site. The average tritium concentration at the plant perimeter was 54 pCi/m^3, compared to 17 pCi/m^3 at the 25-mile radius and 12 pCi/m^3 at the 100-mile radius. The average onsite tritium concentration was 840 pCi/m^3.

Continuous measurements of the intensity of gamma radiation levels at 452 locations at and around SRS were made with thermoluminescent dosimeters (TLDs). In the unlikely event of a significant unplanned release of radioactivity, these TLDs would provide a quick and reliable method to determine external gamma radiation doses to population groups within an 8,000-square-mile area in the vicinity of SRS. Significant variability in environmental radiation is seen from one location to the other because of variable radioactivity in soil, rocks, and building material. As observed in previous years, there were no differences in 1988 between measurements taken at the site boundary and those taken as far as 100 miles away from SRS.

Atmospheric emissions of sulfur dioxide, oxides of nitrogen, and total suspended particulates from the five onsite coal-fired power plants were within applicable standards in 1988. All SRS stacks met the 40% opacity standard at all times except for the 291-F stack, which occasionally exceeded the standard. A number of renovations are underway to ensure 100% compliance by the 291-F stack. The quality of air at SRS was monitored at several locations around the site that measure total suspended particulates, sulfur dioxide, oxides of nitrogen, and ozone. The states of South Carolina and Georgia performed additional ambient air monitoring. All SRS monitoring results were within state standards.

Surface Water Monitoring

The Savannah River and streams located on SRS, are continuously sampled to monitor radioactivity released in effluent water from SRS facilities. Radioactivity in the liquid effluents is diluted by stream water, reactor heat exchanger cooling water, and Savannah River water. In 1988, no measurable differences were detected between upriver and downriver alpha and nonvolatile beta concentrations in the Savannah River. The release of tritium accounted for greater than 99% of the total radioactivity introduced into the Savannah River from SRS activities during 1988. After dilution by SRS streams and the Savannah River, tritium concentrations averaged 3.1 pCi/mL in the river below SRS at Highway 301, compared to 3.3 pCi/mL in 1987. The only radionuclide other than tritium detected in river water by routine analytical techniques was ^{90}Sr in trace quantities.

Using a special low-level analysis technique, the Savannah River Laboratory (SRL) detected ^{137}Cs both upriver and downriver of SRS. In 1988,the average ^{137}Cs concentrations determined by this technique were 0.014 pCi/L upriver and 0.065 pCi/L downriver of SRS. The difference between the upriver and downriver concentrations is attributed to releases from SRS operations. The maximum ^{137}Cs concentration of 0.123 pCi/L detected downriver of SRS was 1,500 times less than the EPA drinking water standard of 200 pCi/L.

The Savannah River is continuously monitored by SRS

Pollutant Discharge Elimination System (NPDES). In 1988, 71 active, permitted outfalls were monitored. SRS had a 99.8% NPDES compliance rate in 1988, compared to a 99.7% compliance rate in 1987. Only 14 of the 6,250 analyses performed exceeded permit limits.

The Savannah River is extensively monitored for chemicals, physical properties, and metals. Chemical and biological quality standards for the Savannah River are specified in the requirements of the state of South Carolina for Class B streams. All indications are that SRS operations do not have a deleterious effect on the Savannah River aquatic environment.

Located approximately 20 miles from SRS, the Edisto River is minimally affected by SRS operations and is continuously sampled for radioactivity as a measure for comparison to concentrations in SRS streams. The maximum radioactivity concentrations detected in the Edisto River in 1988 were 1.9 pCi/L alpha, 3.4 pCi/L nonvolatile beta, and 750 pCi/L (0.75 pCi/mL) tritium.

The primary SRS stream with the highest concentration of radionuclides in 1988 was Four Mile Creek (FMC), which receives effluents from F- and H Areas, C-Reactor Area (although C Reactor was not operating in 1988) and migration from F- and H-Separations Areas seepage basins and the Radioactive Waste Burial Ground (RWBG). Alpha and nonvolatile beta concentrations in FMC were elevated with maximum activities of 6.5 pCi/L and 170 pCi/L, respectively. Tritium concentrations were also elevated with a maximum concentration of 2,900 pCi/mL.

A comparison of the amount of tritium released from SRS facilities in 1988 with the amount of tritium measured in transport in SRS streams and in the Savannah River continued to show relatively good agreement. Sources of tritium in liquid effluents include direct releases from site facilities (16% in 1988 compared with 20% in 1987) and migration of tritium from the Burial Ground, F-, H-, and P-Area seepage basins, and K-Area Containment Basin (84% in 1988 compared with 80% in 1987).

SRS liquid effluents are regulated by the South Carolina Department of Health and Environmental Control (SCDHEC) under the National

The Division of Environmental Research of the Academy of Natural Sciences of Philadelphia (ANSP) continued surveys of the aquatic environment and water quality of the Savannah River. Studies in 1988 included diatometer studies, aquatic insect surveys, and algal and aquatic macrophyte surveys. In addition, a comprehensive survey was conducted in the Savannah River in the vicinity of the Vogtle 1 Nuclear Power Plant.

Extensive monitoring of SRS streams indicates that, except for temperature in Pen Branch, the water quality is not adversely affected by SRS operations. Temperature profile surveys were conducted at the mouths and upriver of Beaver Dam Creek and Steel Creek as part of a comprehensive study of the thermal effects of SRS operations upon the waters of the state of South Carolina as stated in consent order 84-4-W between SCDHEC and DOE. During 1988, one temperature profile in both Beaver Dam Creek and Steel Creek was performed. All measurements were well within the consent order limits.

Groundwater Monitoring

SRS monitors groundwater quality to identify any contamination that may occur as a result of plant operations. Groundwater is monitored for the following purposes:

- to identify sources of contamination as soon as possible
- to measure concentrations of contaminants that may enter groundwater

- to provide data that can be used to design any needed cleanup projects

The SRS Environmental Monitoring Section, Environmental and Health Protection Department maintains the primary responsibility for installing monitoring wells, and for collecting and analyzing groundwater samples.

Monitoring of groundwater for radioactivity began in 1957. Monitoring groundwater for possible chemical or nonradioactive contaminants began in 1975.

Approximately 75 waste sites, operating facilities, and spill sites have monitoring wells. Nearly 900 wells were monitored in 1988and around 100 new monitoring wells are being added to the monitoring system each year. Many wells are being installed to comply with environmental regulations.

Concentrations of chemicals, metals, and organics were generally within applicable standards except for total iron, total manganese, turbidity, and color at a few locations. Twelve of the 16 samples had elevated total iron concentrations above the South Carolina drinking water standard of 0.3 mg/L. These elevated iron concentrations are attributed to natural sources.

No confirmed positive concentrations of tetrachloroethylene, trichloroethylene or 1,1,1-trichloroethane were detected in monthly analyses of drinking water from the A-Administration/M Areas in 1988. The new 112- and 113-G Wells have also shown no confirmed chlorocarbon concentrations. Semiannual analyses of other drinking water supplies at SRS showed no confirmed chlorocarbons. Occasional low levels of trichloroethylene and tetrachloroethylene continued to be detected at the well head of 31A. The maximum concentrations for 1988 were 6.20 μg/L of trichloroethylene measured at well 31A was reported by ECS/Normandeau, a subcontracted offsite laboratory. Duplicate analysis of the sample by the 320-M laboratory measured 4.33 μg/L. Previously an A-Administration backup domestic water well, well 31A was removed from the domestic water line in November 1988. Process water wells 20A and 53A continued to show elevated chlorocarbon concentrations. The maximum concentration was 178 μg/L of trichloroethylene detected in well 20A.

Environmental Monitoring of Other Media

Air and water are the principal dispersal media for SRS radioactive releases. However, the SRS environmental surveillance program also includes samples representing other segments of the environment that may be affected by these releases or that might provide pathways of radiation exposure to people.

Average concentrations of radioactivity routinely detected in milk, food, drinking water, wildlife, rainwater, soil, sediment, and vegetation in 1988 were generally within ranges observed during the last several years. Except for tritium, the concentrations observed were similar to those reported by other agencies in parts of the country not affected by SRS operations [EPA82,EPA83]. Therefore, the occasional trace amounts of radioactivity detected in these samples are attributed to worldwide fallout from atmospheric nuclear weapons tests. In most cases tritium, when present, is attributed to SRS operations.

Annual hunts are conducted at SRS to control the deer and hog populations and to reduce onsite animal-vehicle accidents. All animals are monitored for radioactivity before being released to the hunters. The 1988 hunts yielded 855 deer and 146 hogs, as compared with 606 deer and 123 hogs in 1987.

All deer and hog results were within ranges observed over the last several years and consumption of the meat from these animals presents no radiation hazard. The average ^{137}Cs concentration in SRS deer monitored in 1988 was 10.2 ± 11 pCi/g. The 50-year dose commitment to an individual who consumed one 8 oz. steak of deer meat with this concentration would be 0.11 mrem. This dose is 0.11% of the DOE Revised Interim Dose Limit from prolonged exposure.

The 50-year dose commitment received from consuming food with radioactive concentrations, is directly proportional to the amount of food consumed. For instance, if the same person were to eat one 8 oz. steak which contained a concentration of 10.2 pCi/g ^{137}Cs every day for one year, he would receive a 50-year dose commitment of 41 mrem. This dose is 41% of the DOE Revised Interim Dose Limit from prolonged exposure and 14% of the average CSRA resident's average annual dose from naturally occurring radioactivity. The deer with the highest concentration, 60 pCi/g, had edible meat which weighed approximately 13.6 kg and contained approximately 0.82 mCi of ^{137}Cs. An adult consuming all of this meat would receive a 50-year radiation dose commitment of 40 mrem (0.40 mSv) or 40% of the DOE Revised Interim Radiation Dose Limit from a prolonged

period of exposure. This dose would also be 13.6% of the average CSRA resident's annual dose from naturally occurring radioactivity. This deer to person exposure pathway has the greatest potential for the highest 50-year dose commitment; however the actual amount of ^{137}Cs in deer contributed by SRS operations compared to worldwide fallout is under investigation.

Special Surveys and Studies

Results of special comprehensive radiological surveys of Upper Three Runs Creek, Lower Three Runs creek, R Area, and R-Area Old and New Canal were reported in 1988. Environmental samples analyzed included soil, sediments, vegetation, timber, stream water, and fish as appropriate. Measurements of environmental gamma radiation were also made during these surveys. Details of these special surveys are included in Chapter 9.

Additionally special radiological surveys were conducted in the environment when short-term tritium releases occurred on eight occasions (four atmospheric and four liquid to streams) in 1988. The maximum calculated dose to an individual at the site boundary from the largest release was 0.2 mrem (0.002 mSv) when 3,500 Ci of tritium was released to the atmosphere on December 7, 1988. See Chapter 2 and Chapter 9 for more information.

Special surveys were also conducted on eight other occasions in 1988 when short-term radioactivity releases (five atmospheric and three liquid to streams) occurred. The maximum atmospheric activity release was 83 mCi of ^{238}Pu released in October 1988 from a laboratory facility. The contamination was confined to a 200 ft radius of the building exhaust stack and all site environmental samples were within normal activity levels. The maximum liquid to stream release was 27 mCi of ^{137}Cs on July 8, 1988 from the H-Area Retention Basin to Four Mile Creek. Elevated cesuim concentrations were measured in Four Mile Creek; however ^{137}Cs concentrations measured in the Savannah River remained within previously observed levels both during and after the release. More details on these special surveys are included in Chapter 9.

Savannah River Swamp Survey. Monitoring of five square miles of swamp bordering the Savannah River below the SRS boundary continued to indicate radioactivity (previously identified as ^{60}Co and ^{137}Cs) above natural background levels. The offsite swamp area is uninhabited and inaccessible except for possible occasional hunting or fishing. A comprehensive survey along 10 sampling trails that traverse the swamp was conducted in 1985 before the startup of L Reactor. Cursory surveys performed in 1986 and 1988 indicated the following radiological conditions:

- Gamma radiation measurements were within ranges observed in previous years. The maximum radiation measurement was 0.88 mR/day.
- Radionuclide concentrations in soil and vegetation samples were within ranges observed in previous years.
- Concentrations of ^{137}Cs in fish collected from two lakes near the swamp trails were within ranges observed in previous years.

Spills. A site-wide procedure requires prompt reporting of oil and chemical spills to a spill coordinator who ensures spills are reported to the Department of Energy (DOE), Environmental Protection Agency (EPA), and South Carolina Department of Health and Environmental Control (SCDHEC) as appropriate to satisfy regulatory requirements. In 1988, there were 155 minor spills reported to the spill coordinator. Most of these were minor spills of petroleum products. None of the spills were reportable under the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA). SRS has not had a CERCLA reportable spill in over two years.

ENVIRONMENTAL MANAGEMENT AND RESEARCH PROGRAMS

A wide variety of environmental management and research programs are conducted at the SRS each year by the Savannah River Site (SRS), Savannah River Laboratory (SRL), Savannah River Ecology Laboratory (SREL), and the Savannah River Forest Station (SRFS). Summaries of programs conducted during 1988 are included in Chapters 11, 12, 13, 14, 15 of this report. Highlights of a few of the programs are discussed in the following paragraphs.

SAVANNAH RIVER SITE ENVIRONMENTAL MANAGEMENT PROGRAM

Environmental Implementation Plan

The Savannah River Site (SRS) has developed a comprehensive Environmental Implementation Plan (EIP) that sets specific site environmental policies, objectives, and implementation strategies

for the next five years. The EIP provides an integrated approach to SRS environmental programs. The plan outlines specific programs to maintain air quality, prevent surface water and groundwater contamination, manage waste handling and disposal, and protect wildlife. The site's environmental program manpower and budget requirements are also established by the EIP.

NESHAP Issues

The Savannah River Site reviewed and prepared comments on the Environmental Protection Agency (EPA) proposed rule-making for benzene under Section 112 of the Clean Air Act. Benzene was the first chemical proposed for National Emissions Standards for Hazardous Pollutants (NESHAP) regulation in which EPA must weigh health effects above cost in setting air standards. The rule was expected to have major implications for subsequent NESHAPs standards, most notably for radionuclides.

A NESHAP Radionuclide Compliance Manual was drafted during 1988. The purpose of this manual is to provide guidance to SRS operations on regulation requirements, administrative procedures that will enhance regulatory compliance, and technical guidance in preparing applications for EPA approval. The manual is scheduled to be issued in 1989.

Because of NESHAP regulation requirements for new facilities that have radioactive emissions, several new facilities at SRS were required to have a permit for construction and operation. SRS applied to EPA for approval to construct and operate these new facilities. SRS received the construction and operation NESHAP approval for the F- and H-Area Effluent Treatment Facility (ETF) in March 1988. EPA issued the construction and operation NESHAP approvals for the Defense Waste Processing Facility (DWPF) and Replacement Tritium Facility (RTF) in April and May 1988, respectively. Conditional approval was received from EPA in September 1988 for the construction and operation permit for the Uranium Solidification Facility (USF). A NESHAP application was prepared and given to DOE in September 1988 for the proposed Consolidated Incineration Facility.

Waste Site Closure

Fourteen nonhazardous waste management units were closed prior to 1989 as required by SCDHEC. During 1988, seven nonhazardous waste sites were closed and plans for closing 12 nonhazardous sites were approved.

Completion of the M-Area Settling Basin and Lost Lake closure is scheduled for 1989. Closure plans for the F- and H-Area Hazardous Waste Management Facilities were submitted to SCDHEC and are awaiting approval.

The Postclosure Care Permit Application for the F- and H-Area Hazardous Waste Management Facilities is being developed. Closure plans are being written for the Metallurgical Laboratory Basin, the F-, H-, K-, and P-Area Acid/Caustic Basins, the new TNX Seepage Basin, and four Savannah River Laboratory Seepage Basins.

A Memorandum-to-file (MTF) for the Mixed Waste Management Facility Closure was issued in November 1988. The MTF satisfies the NEPA documentation requirements by including closure details not covered in the EIS, "Waste Management Activities for Groundwater Protection at SRS." The MTF will serve as the example for completing NEPA requirements in other waste site closures.

SAVANNAH RIVER LABORATORY, SAVANNAH RIVER SITE ENVIRONMENTAL MANAGEMENT AND RESEARCH PROGRAMS

1988 Radiometric Analyses of SRS and Plant Vogtle Effluents in the Savannah River

Trace radionuclide concentrations in the Savannah River are continually studied to distinguish between the effluent contaminants from SRS and the Georgia Power Company Plant Vogtle nuclear reactor. During 1988, radionuclide concentrations of these effluents were well below DOE guide values. The largest gamma component in the Vogtle effluent was ^{58}Co and its maximum concentration was 15.5 pCi/L, far below the DOE guide of 40,000 pCi/L. The maximum radionuclide concentrations in the SRS effluents were 3,000 pCi/L tritium and 0.4 pCi/L ^{137}Cs, also well below the DOE guide levels of 2,000,000 pCi/L tritium and 3,000 pCi/L ^{137}Cs. These low-level radiometric studies continue to provide early detection to avoid potential hazards.

The radionuclide concentrations in the river are appraised using several methods. Previously the most sensitive method was to collect samples on resins for about two weeks and then count them

overnight on High Purity Germanium (HPGe) and Sodium Iodide [NaI(Tl)] detectors in the ETD Underground Counting Facility (UCF). Periodic sediment samples were also counted in this fashion. A more real-time sampling mode has involved consecutive one-day counts with an underwater NaI(Tl) detector located on the ETD monitoring platform at Highway 301 bridge; the activities measured by this underwater detector are in good agreement with those from the resin samples. Tritium concentrations were measured with a low-level liquid scintillation counter.

The results indicate that Plant Vogtle effluents primarily contain only neutron activation products (^{51}Cr, ^{54}Mn, ^{57}Co, ^{58}Co, ^{59}Fe, ^{60}Co, ^{95}Zr, and ^{95}Nb). The SRS effluents primarily contain a small amount of tritium and a single fission product, ^{137}Cs.

Geographical Information System

United States Geological Survey (USGS) map data bases are being installed for use with the new Geographic Information System (GIS). The GIS will link these map data with output from the emergency response codes. Coupling of the data will provide and display information on population distribution and dose, road networks, routing and location of emergency response vehicles, land use, topography, and maps of the impact regions.

Microbial Life in the Terrestrial Subsurface of Southeastern Coastal Plain Sediments

The distribution and function of microorganisms are vital issues in microbial ecology. A DOE program, "Microbiology of the Deep Subsurface," concentrates on establishing fundamental scientific information about organisms at depth. This investigation was initiated at SRS with the drilling of three microbiological boreholes in 1986. A fourth borehole was drilled in cooperation with the SCWRC south of the site in 1988. This boring extended the depth of investigation to greater than 1,700 ft. The findings of this program have direct implications for a variety of subsurface activities, including bioremediation.

Approximately 2,000 new and different species (principally bacteria) have been isolated as deep as 800 ft beneath the soil's surface. SRS plans to make these organisms available to U.S. industry for possible new product development under technology transfer.

The diversity of the microbiological communities in deep terrestrial sediments is one of the most striking discoveries of this study. A wide and diverse variety of metabolically active microorganisms capable of transforming a spectrum of organic and inorganic compounds were present. These sediments contained many types of aerobic chemoheterotrophic bacteria, as well as a wide assemblage of other forms.

The diversity of platable forms decreased sharply with depth in shallow aquifers, but this was not the case in the deeper sediments studied at SRS. Such differences are surprising for a presumably nutrient-limited environment, and contrary to the traditional thinking in soil microbiology. In this study, the diversity was not limited by depth, however, such limitation was observed where the concentration of clays was greater than 20%. Such zones may not be drastically different, but because they contain fewer microorganisms than the more transmissive sand zones, they were not readily evaluated for diversity.

Additionally, this investigation has isolated an extensive number of bacteria which may be new to the scientific community and may provide investigators with a new source of genetic material from organisms adapted to living and metabolizing hundreds of meters below the earth's surface.

The "Microbiology of the Deep Subsurface" program is an initiative that has demonstrated the presence of numerous, active, and diverse microorganisms associated with the sediments of the terrestrial deep subsurface. The understanding of the microbiology of the deep terrestrial environment is not only an important advance for the sciences of microbial ecology, geomicrobiology, and geology, but has great applicability to a variety of industrial and governmental concerns, (e.g., fossil fuel recovery and storage, deep waste repositories, groundwater storage and retrieval, biologically produced products and transformations, as well as transport and fate of groundwater contaminants). This investigation opens new avenues for research and fundamental investigations into the interaction between the biosphere and the geosphere.

Sitewide Seismic Survey

All data acquisition using the Conoco seismic crew is complete with data processing and analysis complete. The faults previously identified on only one seismic line were also located on the recent data, so their locations have been defined. Three exploratory borings, along with a complete suite of electric logs, were completed into the basement

rock. The cores from these borings were geologically logged in detail. These are the first borings cored into bedrock at SRS since the early 1960s. In-situ stress measurements were made in two of the three new borings and in DRB 8, one of the deep borings from the 1960s. Results indicate horizontal stresses are higher than vertical stresses. The estimated magnitude and direction of stress appears consistent with other measurements made in the state.

The Seismic Advisory Committee was finalized and the committee met once in the fall of 1988. The committee was established to provide additional independent overview and guidance to management on seismic issues relevant to SRS and its operations. On August 5, 1988, a small earthquake (local magnitude 2.0) occurred south and east of the location of the 1985 earthquake. Earthquakes of this magnitude and intensity are usually not felt and are detected only by instruments. Within the southeastern U.S., approximately 40 earthquakes per year of this magnitude are recorded by seismographic networks. About 10 events of this size are recorded in South Carolina each year. This event was not felt on site and the seismic alarms in site facilities were not triggered.

NATIONAL ENVIRONMENTAL RESEARCH PARK PROGRAM

The National Environmental Research Park (NERP) program was established in 1972 to use the SRS as an outdoor laboratory for studies of the environmental impact of human activities. During 1988, approximately 10 NERP program research projects were conducted, with baseline studies providing information on wetland bacteria of Okefenokee Swamp, GA, wading birds' feeding behavior, and the cesium-binding capacity of the Savannah River Site.

SAVANNAH RIVER ECOLOGY LABORATORY PROGRAMS

Genetic Survey of the Endangered Red-Cockaded Woodpecker

A small population of the endangered red-cockaded woodpecker exists on the SRS. This population has declined steadily since monitoring began in 1977, and reached a low of four individuals in 1985. Research was initiated at that time to investigate the factors responsible for the population's decline and to determine the steps necessary to restore a viable population of red-cockaded woodpeckers at the SRS. A genetic survey was conducted from 1985 to 1987 to:

- compare levels of genetic variability of the red-cockaded woodpecker on the SRS to those of populations elsewhere in the south
- investigate the relationship between population size, genetic variability, and physical fitness
- develop guidelines for translocation of red-cockaded woodpeckers onto the SRS based on genetic structure of populations in the south

Results of this survey indicate that, relative to other populations, the red-cockaded woodpeckers on the SRS exhibit normal levels of heterozygosity, but slightly lower percent polymorphic loci and mean number of alleles per locus (measurements indicative of genetic variability). This slight decrease likely reflects the recent decline in the number of individuals present in the population. There is no indication of reduced fitness level in the SRS population. Finally, the wide scale genetic survey indicates that red-cockaded woodpecker populations exhibit a greater degree of genetic variability among populations than other birds which have been studied. This suggests that caution must be used in moving birds among populations, so as not to disrupt locally adapted populations. Thus, birds chosen for introduction onto the SRS are best chosen from populations occupying similar habitats in close geographic proximity to the SRS.

U. S. FOREST SERVICE SAVANNAH RIVER FOREST STATION PROGRAMS

During 1988, the federal government received nearly $2 million for 22.9 million board feet of cut timber from the SRS. Pine seedlings were planted on nearly 2,700 acres during the same period. Nearly nine miles of secondary roads used for the timber harvest were upgraded to handle large trucks used for hauling tree-length sawtimber and pulpwood. Routine road maintenance was performed on 120 miles of roads.

Southern bald eagles nested at SRS for the third consecutive year; three young were fledged successfully during 1988. Selected trees within six Eagle Management Key Areas were shaped and modified to provide perching and nesting sites. To protect forests, roads, and research sites, 326 wild hogs were trapped and removed from locations where they were causing damage. During 1988, 48 field studies involving over 20,000 trees of longleaf pine, loblolly pine, sweetgum, and black walnut were active at the SRS.

Introduction and Program Overview

DESCRIPTION OF THE SAVANNAH RIVER SITE AND FACILITIES

The Savannah River Site (SRS) occupies an area of approximately 300 square miles along the Savannah River, principally in Aiken and Barnwell Counties of South Carolina. Most of the plant's environs are rural. Average population density in the counties surrounding SRS ranges from 23 to 560 people per square mile with the largest concentration in the Augusta, GA metropolitan area, which has a population greater than 250,000. The countryside is predominantly forested. Farming is diversified; the main crops are cotton, soybeans, corn, and small grains. Production of beef cattle continues to expand.

The climate is mild, with an average frost-free season of approximately 246 days. The annual average rainfall at SRS is about 48 inches, and is fairly evenly distributed throughout the year. The SRS and surrounding area are described in more detail in "The Savannah River Site Environment" [Du84].

SRS Primary Operation Description

SRS's primary function is the production of plutonium, tritium, and other special nuclear materials for national defense, for other governmental uses, and for some civilian purposes. Major site facilities include five nuclear reactors, a fuel and target fabrication plant, a naval fuel materials facility, two chemical separations plants, the Defense Waste Processing Facility, and the Savannah River Laboratory (SRL), a process development laboratory which supports production operations. Many other facilities necessary to support operations are located on the SRS . The heavy water production plant, which began operation in 1953, was shut down in 1981. Three reactors operated in 1988. K Reactor operated from January 1, 1988 to April 10, 1988. P Reactor operated from January to April, and 10 days in August. L Reactor operated from January 1, 1988 to late June 1988. A fourth reactor, C Reactor, operated until 1986, when it was shut down for repairs. The fifth reactor, R Reactor, was permanently shut down in 1964. Reactors and separations plants are located near the center of the site; other facilities are located near the perimeter.

Nuclear fuels and targets, together with other reactor components, are manufactured in the fuel and target fabrication facility. The reactors at SRS are fueled with uranium, moderated and cooled by heavy water circulated in a closed system through heat exchangers. Water from the Savannah River and Par Pond, a man-made cooling water impoundment covering 2,640 acres, is used as a coolant in the heat exchangers.

Because heat exchanger cooling water does not pass directly through the reactors, it is not subject to direct neutron activation. The heat exchanger cooling water from P Reactor is returned to Par Pond, some of which overflows to Lower Three Runs Creek. L and K Reactors use Savannah River water as a heat exchanger coolant. The water is discharged via different waterways. L Reactor heat exchanger cooling water is discharged to L Lake, which overflows to Steel Creek. K Reactor heat exchanger cooling water is discharged to Pen Branch.

Reactor-produced products are recovered in the chemical separations areas. Plutonium-238, ^{239}Pu, and uranium are separated from each other and from fission products by complex chemical processes. These areas also have facilities for purification and packaging of tritium and for storage of fission product wastes. SRS production areas and effluent streams are shown in Figure IP-1.

Other Major Site Facilities

The Naval Reactor Fuel Materials Facility, located in F Area, produces uranium fuel for the U. S. Navy. Approximately 40% of the Navy's major combat fleet is nuclear powered. The Naval Reactor Fuel Materials Facility converts a special

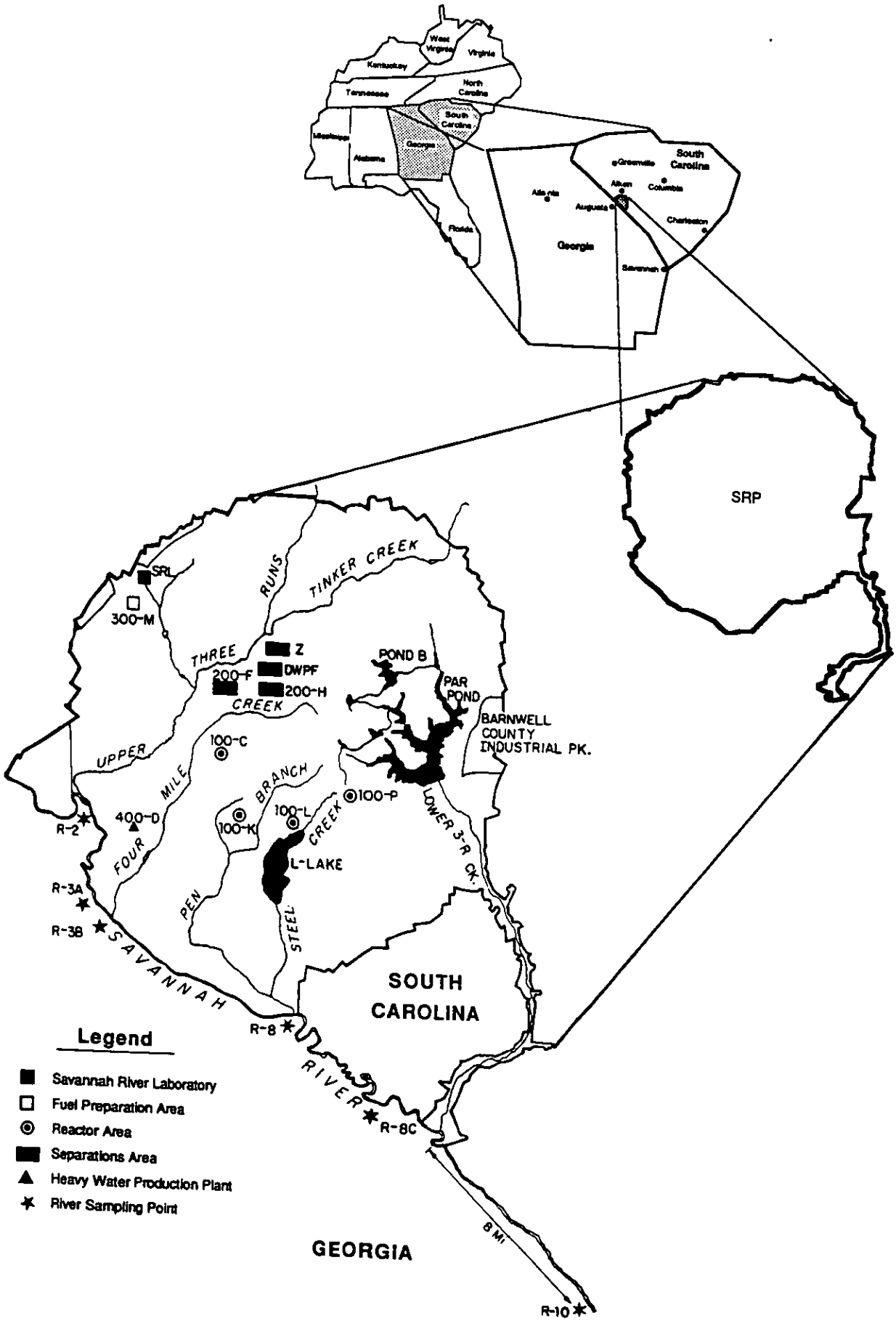
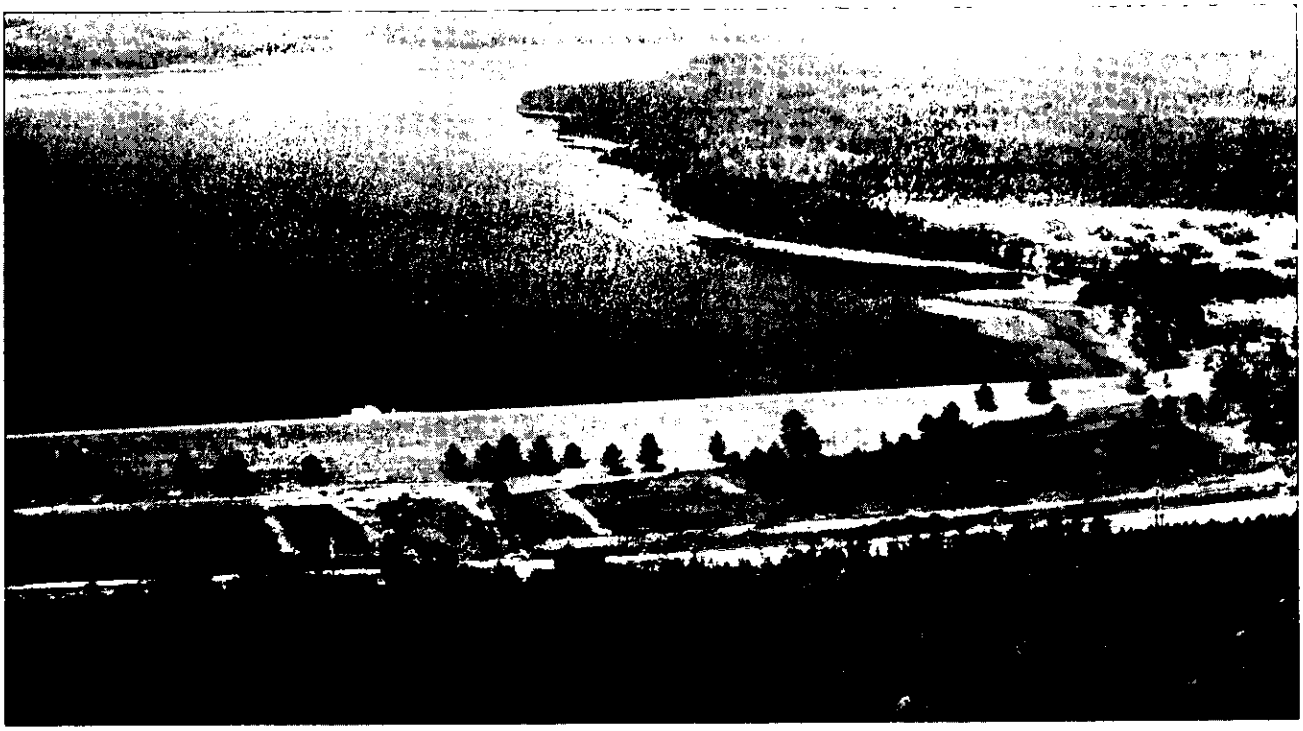


Figure IP-1. The SRS and its facilities in relation to the southeastern United States



Par Pond is a 2,640 acre man-made lake on the SRS

enriched uranium into a material that can be used to manufacture special reactor cores to power the nuclear fleet. Construction of the facility was completed in 1986. From 1986 to 1988, the facility underwent startup tests. In late 1988, production of the naval fuel material began.

The Defense Waste Processing Facility (DWPF) is a major construction effort currently underway at SRS. The facility will be the nation's first high-level radioactive waste glassification plant. The DWPF will accept high-level radioactive waste currently stored in waste tanks in F and H Area, mix it with glass, heat the mixture until it is molten and then pour the material into stainless steel containers. As the mixture cools, it becomes a solid inert glass form that is suitable for storage into an offsite geologic repository. The DWPF glass form and the geologic repository will effectively isolate the nuclear waste from the environment. The scheduled date for operation of the DWPF is 1992.

The Effluent Treatment Facility (ETF), located on the south side of H Area, began operation in 1988. The purpose of this facility is to collect and treat routine process wastewater, nonroutine radioactivity contaminated canyon facility cooling water, and tank farm storm water, which had previously been discharged to the F- and H-Area seepage basins and lined retention basins. The radioactive and nonradioactive hazardous materials, which had been discharged to the F- and H-Area seepage basins, have adversely impacted the quality of groundwater in the vicinity of the basins. The F/H ETF now reduces both the radioactive and nonradioactive materials in the process effluents to allow discharge directly to Upper Three Runs Creek (U3R), eliminating the use and future problems associated with the F- and H-Area seepage basins. The only contaminant which remains in the ETF effluent is tritium.

OVERVIEW OF ENVIRONMENTAL PROGRAMS

Environmental Monitoring and Regulatory Compliance

The environmental monitoring program at SRS is one of the largest and most comprehensive in the United States. Extensive programs are conducted in both radioactive and nonradioactive monitoring. Each year, extensive radioactive monitoring is performed in a 2,000-square-mile area in the immediate vicinity of SRS, and representative

samples are collected from an additional 30,000-square-mile area. In this 30,000-square-mile area, many different types of samples are collected routinely and analyzed for radioactivity. The radiological monitoring program generated approximately 25,000 samples and 113,500 analyses in 1988. Approximately 529,000 samples and 1,972,500 analyses have been generated since the program began in 1951. Types of samples collected and analyzed for radioactivity are presented in Table IP-1.

Table IP-1. Types of Samples Analyzed in the Radiological Monitoring Program

Air
Thermoluminescent Dosimeters
Surface Water
- rivers
- streams
- seepage basins

Groundwater
Milk
Food
- (i.e., eggs, chickens, meats, fruits, grains,

Wildlife
- fish
- crabs and oysters
- deer and hogs
- furbearers (i.e., opossums, foxes, raccoons)
- turtles
- ducks

Rainwater
Soil
Sediment

The nonradiological ambient air monitoring program is coordinated by the Environmental Monitoring Section (EMS), and routine operation of the program is contracted to an offsite company. Onsite stations house instruments which monitor for sulfur dioxide, oxides of nitrogen, ozone, and total suspended particulates. Table IP-2 list the types of samples analyzed in the nonradiological monitoring program.

Table IP-2. Samples Analyzed in the Nonradiological Program

Air
Surface Water
- rivers
- streams
- seepage basins

Groundwater
Drinking Water
Sediment
- rivers
- streams

In 1988 a total of 211,500 analyses (113,500 radiological and 98,000 nonradiological) were performed on 31,700 samples (25,000 radiological and 6,700 nonradiological). In addition, over 1.4 million nonradioactive measurements were made at ambient air quality monitoring stations and over 460,000 water quality readings were taken from monitor locations in Beaver Dam Creek and Steel Creek.

Monitoring programs are coordinated by the EMS of the Environmental and Health Protection (EHP) Department at SRS. Regulatory compliance is coordinated by the Environmental Protection Section (EPS) at SRS. Research programs are conducted by the Savannah River Laboratory (SRL), the Savannah River Ecology Laboratory (SREL), and the Savannah River Forest Station (SRFS). The various organizations involved with SRS environmental surveillance programs are shown in Table IP-3.

The Environmental Monitoring Section (EMS) performs most radiological and nonregulatory water quality analyses. Environmental Monitoring Section (EMS) facilities include sample receiving areas, radiochemical preparation laboratories, nonradiochemical analytical laboratories, and radioanalytical counting rooms. Nearly 30 laboratory analysts and technicians collect, prepare, and analyze environmental samples. In addition to the laboratory supervisors who supervise sample collection, preparation, and analysis, a staff of over 20 professionals in biology, chemistry, geology, health physics, computer science, and statistics provides technical support to the monitoring program. A large portion of the regulatory monitoring programs is contracted to commercial laboratories.

The Environmental Protection Section (EPS) of the Environmental and Health Protection (EHP) Department is responsible for the oversight and coordination of site programs to protect the environment and ensure regulatory compliance. A staff

Table IP-3. Monitoring Programs at SRS and Departments Involved[a]

Radiological Programs	Organizations Involved
Environmental Monitoring (Air, Surface Water, Groundwater, Food, Drinking Water, Wildlife, Rainwater, Soil, Vegetation, Sediment)	Environmental Monitoring Section
Nonradiological Programs	**Organizations Involved**
Air Monitoring	Environmental Monitoring Section Environmental Protection Section Operating Departments
Water Quality Monitoring	Environmental Monitoring Section Laboratories Environmental Protection Section
Drinking Water	Environmental Monitoring Section Power Technology Environmental Protection Section
Surface Water Monitoring (NPDES)	Environmental Monitoring Section Environmental Protection Section Operating Departments
Groundwater Monitoring (Nonregulatory & Regulatory)	Environmental Monitoring Section Environmental Protection Section Operating Departments SRL Interim Waste Technology

[a] On April 1, 1989, Westinghouse Savannah River Company assumed responsibility as the prime contractor of the Savannah River Site. Environmental Monitoring (Health Protection Department) and Environment and Energy Department were included as sections in the Environmental and Health Protection (EHP) Department. Environmental Monitoring (Health Protection) became the Environmental Monitoring Section of the EHP Department. The Environment and Energy Department became the Environmental Protection Section (EPS) of the EHP Department. In this report, the sections, groups, and departments are referenced using both designations.

of over 30 professionals in engineering, chemistry, geology, biology, toxicology, and health physics provides support to the site environmental programs.

SRS has monitored site stream wastewater discharges and their effects on Savannah River water quality since the early 1960s. The in-house nonregulatory water quality program, conducted by the Environmental Monitoring Section, monitors site streams and the Savannah River for chemicals, metals, and organics. Each year, approximately 200 samples are collected and 5,500 analyses performed. Six to 30 constituents are analyzed at each sample location. The SRS Laboratories Department performs coliform bacteria analyses for this program. In addition, water quality parameters are measured in Steel Creek and Beaver Dam Creek to comply with consent order 84-4-W between the South Carolina Department of Health and Environmental Control (SCDHEC) and the DOE. Temperature and dissolved oxygen measurements are taken

daily in Steel Creek, and readings for temperature, conductivity, pH, oxidation/reduction potential, and dissolved oxygen are made every 5 minutes in Beaver Dam Creek. In 1988, nearly 500,000 measurements were made.

Analyses for the regulatory National Pollutant Discharge Elimination System (NPDES) liquid effluent monitoring program coordinated by EMS are contracted to commercial laboratories certified by SCDHEC. EMS handles sample collection and administration of analytical contracts. EPS reviews and reports data to SCDHEC via DOE. Approximately 6,250 routine analyses were performed on 71 active outfalls in 1988. An additional 10,000 analyses were performed for NPDES permit renewal.

Sample collection, laboratory analysis, and data handling for the groundwater monitoring program (nonregulatory and regulatory) are contracted to offsite companies. Contracts are administered by EMS. EPS reviews and reports groundwater data to SCDHEC to fulfill regulatory requirements. Approximately 85,500 analyses were performed on 5,500 groundwater samples collected in 1988.

Drinking water analyses for a variety of chemicals are subcontracted to offsite laboratories by the Power Technology. Total coliform analysis of drinking water is performed onsite by the Laboratories Department. Chlorocarbon analyses are performed on duplicate drinking water samples by both the Laboratories Department and an offsite laboratory. EPS reviews and reports the regulatory required data to SCDHEC via DOE.

River and stream water and sediment are analyzed for pesticides, herbicides, and polychlorinated biphenyls (PCBs) by an offsite laboratory. In addition, mercury analyses in fish are normally conducted each year. In 1988, 221 fish were collected and 354 analyses were performed.

SRS ENVIRONMENTAL RESEARCH AND SERVICE

In 1972 the SRS was designated as the first National Environmental Research Park. Scientists from universities and other organizations are encouraged to use the site as an outdoor laboratory, focusing on the impact of man's activities on the environment. In addition to routine environmental research programs funded by the Department of Energy (DOE), approximately 10 research projects were conducted at the SRS under the National Environmental Research Park program in 1988.

Environmental research, in addition to the National Environmental Research Park programs, is conducted each year at SRS. Many of these activities are described in Chapters 11, 12, 13, 14, and 15 of this report. Groups involved in these efforts include the following:

- Savannah River Laboratory, SRS
  - Environmental Sciences
  - Environmental Technology
  - Interim Waste Technology
- Savannah River Ecology Laboratory (University of Georgia)
- Savannah River Forest Station

In a continuing effort to maintain and develop the 300-square-mile site, the U.S. Forest Service has planted 102 million pine seedlings on nearly 94,000 acres of the plant since 1952. Significant quantities of pine, hardwood saw timber, and pulpwood harvested during this same period have contributed millions of dollars in revenue to the U. S. government. Many of the U. S. Forest Service sitewide programs play significant rolls in protecting endangered species, providing quality habitats for native wildlife, protecting soil and watershed quality, and providing a healthy forest for environmental research.

A committee composed of four consultants meets quarterly to review SRS environmental programs and make recommendations. The committee members are nationally-recognized experts in their respective fields of biology, ecology, hydrogeology, and health physics.

Rationale for Environmental Monitoring

OBJECTIVES AND RATIONALE FOR THE SAVANNAH RIVER SITE ENVIRONMENTAL MONITORING PROGRAM

Objectives of the Savannah River Site Environmental Monitoring Program

The objectives of the Savannah River Site Environmental Monitoring Program are described below.

Primary Objectives for Environmental Surveillance

- To assess actual or potential exposures to critical groups and populations from the presence of radioactive and non-radioactive materials from normal operations or accidents;
- To provide credible, authoritative, accurate information in an expedient manner to local, state, and Federal agencies, and to the public for evaluating the maintenance of environmental quality and public safety;
- To demonstrate compliance with authorized limits and legal requirements;
- To check the operation of the facility by verifying the adequacy of the facility containment of effluent radioactivity and the effectiveness of effluent control;
- To assist in providing a warning of unusual or unforeseen conditions and, where appropriate, activate a special environmental monitoring program;
- To effectively communicate the results of the monitoring program to the public.

Secondary Objectives for Environmental Surveillance

- To provide, where feasible, methods of monitoring and appropriate instrumentation to the public so that they can participate in the monitoring program in a meaningful way;
- To maintain a continuing record of the effect of the Savannah River Site on preexisting environmental conditions;
- To obtain data on the concentration of radioactive and non-radioactive substances in the atmosphere, surface water, groundwater, organisms, soils, or sediments to assess the immediate and long term consequences of normal or accidental releases;
- To distinguish the contribution from the operation of the Savannah River Site from contributions from other sources;
- To identify changes in the relative importance of transfer pathways and mechanisms, including the emergence of new pathways, enabling the environmental monitoring program to be revised in the light of experience and in response to changing conditions;
- To provide site-specific data to verify or refine the predictions of risk estimates to humans and reduce uncertainties in the parameters and predictions of these estimates;
- To provide data that continuously record the extent of effects of plant operations; and,
- To conduct more general scientific studies aimed at improving knowledge of the transfer of radioactive and non-radioactive substances in the environment.

The chapters that follow describe how these objectives are being met through implementation of a comprehensive environmental monitoring program.

Rationale for Monitoring

Environmental monitoring of radioactive and non-radioactive substances released to the environment from the the Savannah River Site is based on fundamental principles of measurement, dispersion, accumulation, and potential risk to humans and the environment once the substances have been released. Therefore, there are deliberate reasons supporting the frequency, location, and types of samples that are collected and the specific analyses that are performed as part of the program. Collectively, this is called the "rationale for monitoring." Examples of factors which form the basis for this rationale are listed below.

Measurement. The program relies heavily on continuous measurement of radioactive and non-radioactive substances at the source. Measurement of releases at the source is always the most efficient and defensible type of monitoring. When providing measurements at the source of the effluent and beyond, the Savannah River Site environmental monitoring program is supported by laboratory and field instrumentation that permit sensitive detection of most radioactive and non-radioactive substances in environmental media. The levels of sensitivity and specific detection capabilities of these instruments play a major role in design of the program.

Dispersion. Predicted dispersion of releases from the Savannah River Site to air, surface water, and ground water is important to the design of the program. For example, spacing between thermoluminescent dosimeters around the perimeter of the plant was determined using predicted dispersion of radioactive material following release on site. This rationale for placement assures that external exposure could be reconstructed for a plume carrying an inadvertent release of airborne radioactive contamination.

Accumulation. Many radioactive and non-radioactive substances accumulate in the environment at specific points. The monitoring program takes advantage of this bioconcentration, using these points as indicators of contamination that might not otherwise be possible due to extremely low concentrations in the environment. One example of accumulation as a basis for design of the monitoring program is the monitoring of algae which tends to accumulate certain radioactive and non-radioactive materials to concentrations that are many thousands of times greater than the concentration in surrounding water.

Potential Risk. Substances that could pose a significant hazard to humans or the environment are given high priority for monitoring. The degree of hazard is determined by considering the quantity of material that is released, its environmental transport properties, and the potential risk following exposure. Examples of radioactive substances included in the program because of potential risk are ^{137}Cs and ^{239}Pu. Some radioactive materials are included because, although they do not constitute a major risk from exposure, they are important from the standpoint of public concern. Examples are ^{99}Tc and ^{14}C which have very long radioactive half lives but have very low potential to contribute to dose to humans once inhaled or ingested.

The type, frequency, and location of environmental measurements is reviewed routinely to determine if there continues to be a need for monitoring. If a clear rationale no longer exists for a measurement to be made, it is deleted from the program. Likewise, as new methods for environmental monitoring evolve, the environmental monitoring program is expanded to maintain its state-of-the-art design. In the chapters that follow, many of the underlying principles are described that form the rationale for monitoring at the Savannah River Site.

Perspectives on Radiation

People are exposed to sources of ionizing radiation in their everyday lives. Exposure from these sources varies depending on an individual's location and lifestyle. The following summary provides facts and information on exposures to ionizing radiation from non-occupational sources to members of the general public not involved in work associated with ionizing radiation.

NATURAL RADIATION

The major source of radiation exposure to the public is attributed to natural radiation and naturally occurring radioactive materials in the environment. Exposure to this radiation may be from natural sources external or internal to the body.

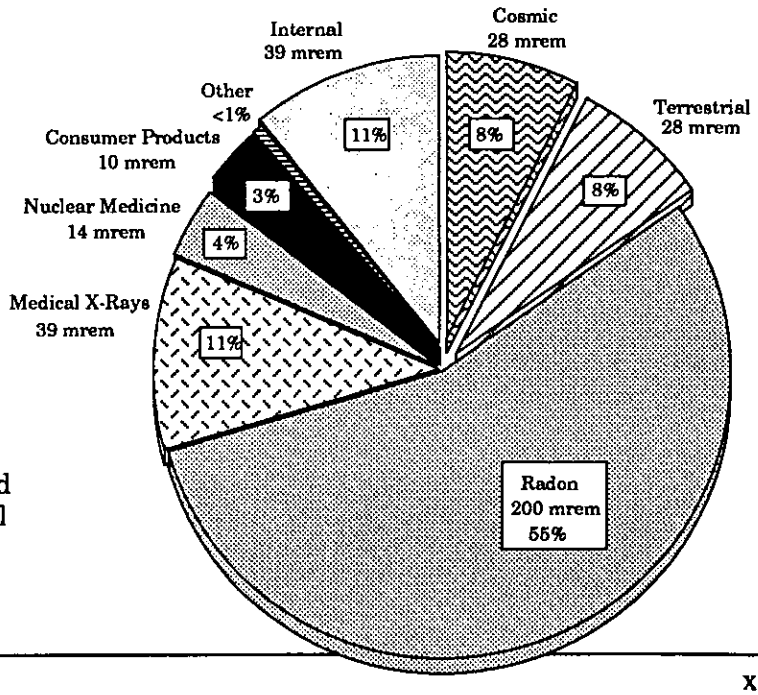
Types of Natural Radiation

Cosmic radiation results from energetic charged particles from outer space hitting the earth's atmosphere. These particles and the secondary particles and photons they create are ionizing radiation. Cosmic radiation is more intense at greater altitudes. The average cosmic-ray annual dose equivalent is approximately 26 mrem at sea level. This value increases with altitude. In fact, an airline passenger flying at an altitude of 39,000 feet would receive a dose of 0.5 mrem in one hour due to the increase in cosmic radiation at that altitude.

Terrestrial radiation is primarily from ^{40}K, thorium, and uranium in the earth's rocks and soil. The average annual gamma-ray effective dose equivalent is approximately 28 mrem. In the U.S., this annual dose varies geographically from about 16 mrem at the Atlantic and Gulf coastal plains to 63 mrem for the eastern slopes of the Rockies Mountains.

Contribution of Various Sources of Radiation to the Total Average Effective Dose Equivalent

U. S. Population



Natural radionuclides in the environment may enter the body by ingestion of food, milk, and water, or by inhalation. These radionuclides follow the same metabolism path as nonradioactive isotopes of the same element. Natural radionuclides in the body include isotopes of uranium, thorium, radium, radon, polonium, bismuth, and lead in the ^{238}U and ^{232}Th series, as well as ^{40}K, ^{87}Rb, and ^{14}C. The major contributors to the annual dose equiva-

Table PR-1. Estimated Total Average Annual Effective Dose Equivalents for a Member of the U.S. Population from Natural Sources of Radiation

Source	mrem/year
Cosmic	28
Terrestrial	28
Internal	39
Inhaled radon	200
Total	295

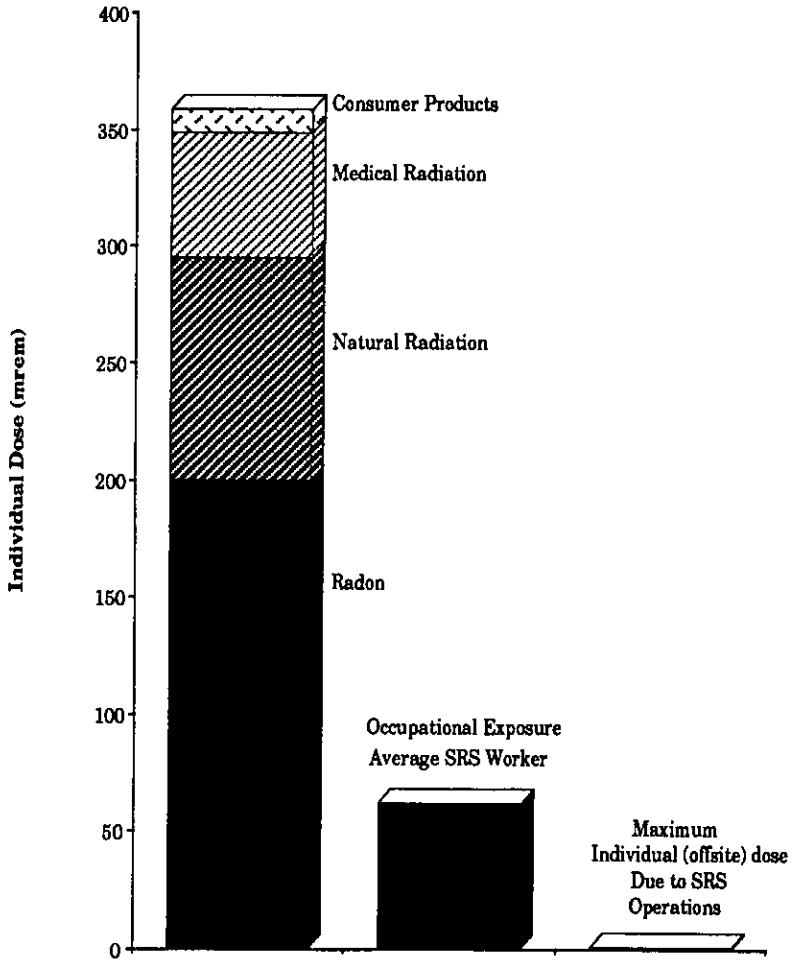
lents for the various inhaled radionuclides are the short-lived decay products of radon which contribute about 200 mrem per year. The dose from other radionuclides in the body is dominated by ^{40}K and is estimated to contribute 39 mrem to the effective dose equivalent from natural sources of radiation.

CONSUMER PRODUCTS

There is a wide range of consumer products which are sources of ionizing radiation. In many of these products, the emission is essential to the performance of the device. For example, smoke detectors and airport x-ray baggage inspection systems fall into this category. In other cases, the radiation is incidental to the performance of the device, as in television receivers or tobacco products. The average annual effective dose equivalent to an individual ranges from 6 to 12 mrem.

MEDICAL DIAGNOSIS AND THERAPY

Radiation is one of the principal tools of diagnostic medicine and of cancer treatment. Exposure to patients is deliberate, and the purpose of medical and dental use is for the direct benefit of the patients exposed. In general, medical exposures from diagnostic or therapeutic x-rays result from radiation beams directed to specific areas of the body. All body organs are not normally irradiated uniformly, and many are not even in the field of radiation. In nuclear medicine examinations, the distribution of internally administered radionuclides is not uniform throughout the body. The concept of effective dose equivalent, which relates exposure of organs or parts of the body to one effective whole body dose, is quite useful in making comparisons. The average annual dose equivalent in the U.S. from all medical examinations is 53 mrem [39 mrem for diagnostic x-rays (1980) and 14 mrem for nuclear medicine procedures (1982)]. Much higher individual doses are encountered in radiation therapy procedures.



Part I

Environmental Monitoring Methods

1
Sample Collection, Analytical Procedures, and Data Analysis

SUMMARY—Procedures for the collection, preparation, and analysis of environmental samples for both radioactive and nonradioactive constituents are described in detail. The instruments and detector types for determining radionuclide concentrations in environmental samples, as well as the routine counting geometries for gamma spectrometry, are outlined.

Thermoluminescent dosimeters are used to measure external radiation. Air, streams, the Savannah River, the seepage basins, groundwater, milk, drinking water, food, rainwater, wildlife, soils, sediments, and vegetation are sampled for radiological analysis, in clearly outlined procedures.

For nonradiological analysis, five ambient air monitoring stations on the site measure sulfur dioxide, oxides of nitrogen, ozone, and total suspended particulates. In addition, samples from wastewater outfalls, streams and rivers, groundwater and drinking water, and soils and sediment are analyzed for physical properties such as alkalinity, conductivity, and temperature, and for nonradioactive constituents such as metals, pesticides, and volatile organics.

Methods of data analysis are discussed. The lower limit of detection (LLD) is defined for the radiological detectors and counting procedures, and statistical measures used for reporting the data are explained.

INTRODUCTION

The environmental monitoring program at the Savannah River Site is one of the largest and most comprehensive in the United States. It includes both radiological and nonradiological monitoring encompassing a 30,000–square–mile area.

In 1988, a total of 25,000 air, water, soil, sediment, vegetation, milk, food, and wildlife samples were collected at specific routine monitoring locations and at appropriate specified locations during special surveys, and analyzed for radioactivity. In addition, measurements of environmental gamma radiation were routinely made at 452 locations.

Except for a few cases, the nonradioactive monitoring program is confined within the Savannah River Site. In 1988, 6,700 samples of water and wildlife were analyzed for nonradioactive pollutants. In addition, continuous monitoring of ambient air quality was also performed within the site boundary at five monitor stations. Nonradioactive measurements were made to determine the concentration of pollutants within the environment.

This chapter describes how samples are collected and prepared and the analytical techniques that are used to determine radiological and nonradiological constituent concentrations in environmental samples. Collection and analysis of radiological and nonradiological samples at the Savannah River Site are supported by SRS Health Protection (HP) environmental collections, chemistry, counting, and data analysis groups as well as 36 commercial subcontractors. In 1988, the environmental collections group utilized and maintained approximately 50 different types of sample collection and field analysis devices to obtain environmental field data and samples. Radiochemical sample preparation, chemical sample analyses, radioanalytical sample counting, and data management were primarily supported by HP Envi-

ronmental Monitoring supervisors, engineers, physicists, chemists, laboratory analysts, and commercial laboratory subcontractors. Approximately 211,500 analyses were performed on the 31,700 samples gathered in 1988.

RADIOLOGICAL DETECTION AND GENERAL ANALYSIS PROCEDURES

Program Goals

Many of the Savannah River Site effluents contain radioactivity. The types of radioactivity discharged and the pathways that the effluents follow vary greatly with the source facility. The goal of the environmental monitoring program is twofold: first, to carry out routine sampling, and in some cases continuous monitoring, of the pathways (i.e. downwind air, downstream and river water, deposited soil, etc.) of the effluent radioactivity; and second, to analyze the samples to determine types and quantities of radioactivity in the media.

Detectors and Counting Geometries for Radiological Analysis

Detection of a variety of radionuclides in environmental samples require detectors that respond to one of the three types of radiation (alpha, beta, and gamma). Because no one detector is applicable in all situations, five different types of radiation detectors are used. Listed below are instruments and types of detectors used for radiological measurements:

- gas-flow proportional counters for alpha and beta emitters
- liquid scintillation counters (LSC) for low-energy beta emitters
- silicon surface barrier detectors for isotope-specific quantification of alpha emitters
- high-purity germanium (HPGe) detectors for high-resolution gamma quantification
- sodium iodide [NaI(Tl)] detectors for high-efficiency detection of gamma emitters

The listed detectors are all stationary counting room equipment. The first three detectors are used in conjunction with chemical separation processes, while the last two have no need for chemical treatment. A wide variety of chemical processes and counting instruments are required to perform accurate analyses. The procedures used in these analyses are extremely complex. A very basic description of the general step by step procedures used in many of the analyses is as follows:

- A sample is routinely collected from the sample location.
- The sample is placed in its designed container (geometry).
- The sample is then normally taken to the counting room and placed on a high purity germanium detector to determine whether gamma emitting isotopes are present and if so, which isotopes and their quantities.
- The sample is then taken to the chemistry laboratory and chemically treated by standard procedures, dependent on the type of sample and the type of radioactivity being investigated. The chemical treatment is performed to separate matter from the sample which would interfere with the eventual radiological analysis. This chemical separation enables the identification of radionuclides and the measurement of their quantities.
- The treated sample is then placed in the appropriately prescribed container (geometry) and returned to the counting room for further radiological analyses.
- Many radioactive isotopes are investigated in the environmental monitoring program. Following are a few examples of the detectors which are used for certain analyses. If gross alpha and gross beta analyses are desired, the sample is counted in a gas-flow proportional counter. Other specific analyses include $^{89,90}Sr$, chemical cesium, uranium/plutonium, americium/curium. If tritium analysis is desired, the sample is counted in a liquid scintillation counter. Other analyses include ^{35}S, ^{32}P, ^{147}Pm, and ^{91}Y. If separation and determination of the amount of plutonium, uranium, americium or curium is required, the sample is counted on a silicon surface barrier detector.

Samples that are to be measured with the HPGe or NaI(Tl) gamma detectors are prepared in standard geometries that correspond to the sizes and shapes of standardized sources. To achieve accurate analyses,

specific traceable sources with known quantities of radioactive materials are used to calibrate the detection instruments. These sources are directly traceable to the National Institute of Standards and Technology (NIST) (formerly called the National Bureau of Standards (NBS)).

Brief descriptions of the standard gamma spectrometry counting geometries for environmental samples follow:

Geometry #1 (Air Filter Geometry)
Geometry #1 is used for analyses of samples physically similar to flat 3-in.-diameter air filters. All air filters of this type are analyzed, either individually or by collective composite, using this geometry. All analyses using Geometry #1 are performed on systems using APOGEE® software.

Geometry #2 (Charcoal Geometry for Water and Air)
Geometry #2 is used for analyses of samples physically similar to 200 mL of water in a 500-mL 3.25-in.-diameter polyethylene bottle. Air sample charcoal cartridges are also routinely analyzed using this geometry.

Geometry #3 (Water Geometry)
Geometry #3 is used for analyses of samples physically similar to 1 L of water in a 1-L polyethylene Marinelli beaker. This configuration is the standard analysis geometry for liquid environmental samples with low activities.

Geometry #4 (Air Charcoal Geometry)
Geometry #4 is used for analyses of samples physically similar to 500 mL of charcoal in a 500-mL 3.25-in.-diameter polyethylene bottle. Charcoal is used to collect gamma-emitting nuclides from air samples. This charcoal source is new for 1988 and is the geometry most often used for ^{131}I stack analyses.

Geometry #5 (Water Geometry)
Geometry #5 is used for analyses of samples physically similar to 500 mL of water in a 500-mL 3.25-in.-diameter polyethylene bottle. This geometry was used for all direct-mount liquid sample analyses prior to 1986, and is now used in analysis of samples with a limited available aliquot.

Geometry #6 (Air Charcoal Geometry)
Geometry #6 was previously used for analysis of charcoal in a 2-L polyethylene bottle. This geometry was taken out of service in 1988 and replaced with Geometry #8, a more suitable and efficient charcoal analysis geometry.

Geometry #7 (Soil Geometry)
Geometry #7 is used for analyses of samples physically similar to 500 mL of soil in a 500-mL 3.25-in.-diameter polyethylene bottle. This soil source is new for 1988.

Geometry #8 (Air Charcoal Geometry)
Geometry #8 is used for analyses of samples physically similar to 1 L of charcoal in a 1-L polyethylene Marinelli beaker. The Marinelli beaker geometry with the standard charcoal source is new for 1988. It provides improved efficiency over the 1-L polyethylene bottle.

Geometry #9 (Soil Geometry)
Geometry #9 is used for analyses of samples physically similar to 1 L of soil in a 1-L polyethylene Marinelli beaker. The Marinelli beaker geometry with the standard soil source is new for 1988. It provides an improved efficiency over the 1-L polyethylene bottle.

New HPGe detector systems, with improved geometries and sources better matched to sample geometry type, were placed in service during 1988. Many samples such as stream and river water, soil, foodstuffs, groundwater, and charcoal filters are now analyzed more efficiently and accurately using new state-of-the-art detector systems.

The following tables in Vol. II present sample media and counting data:

- Table 1-1 Sample Media Data
- Table 1-2 Gas-Flow Proportional Counting Data
- Table 1-3 Liquid Scintillation Counting Data
- Table 1-4 Alpha Spectrometer Counting Data

Radiological sampling and analysis frequency of all key environmental sample media are presented in Table 1-1.

External Radiation

In order to identify any regions within the SRS environment and its vicinity that have external gamma radiation levels above normal background levels, 8,696 thermoluminescent dosimeters (TLDs)

are placed in 452 locations within a 2,000-square-mile area. The TLDs are annealed, placed in holders, and stored inside plastic bags which are heat sealed. Routinely, five TLDs are placed at each monitoring location. The TLD bags are mounted on stands 1 m above the ground at each onplant and offplant TLD monitoring location. The TLDs are collected quarterly and analyzed to determine environmental gamma radiation exposure. The radiation exposure is measured by analyzing the TLD calcium sulfate crystals which react from interaction with external gamma radiation. Calibration TLDs accompany each set of field TLDs to assure accurate measurements.

Complete conversion from the SRS-designed TLD to the Panasonic TLD system was accomplished in 1988 after a 1986-1987 special study comparing the two systems. Dosimeters of both types were exposed at

Table 1-1. General Radiological Analysis Sampling Schedule

Environmental medium	Frequency
Air	Continuous sampling; weekly analysis (Air Silica Gel; biweekly, quarterly)
External radiation	TLDs analyzed quarterly
Streams	Continuous sampling; weekly analysis
Savannah River	Continuous sampling; weekly analysis
Seepage basins	Grab samples analyzed quarterly (F- and H- treblers; weekly)
Groundwater	Quarterly
Milk	Biweekly analysis for I, Cs, and tritium; quarterly analysis for ^{90}Sr
Food	Annually (eggs; quarterly)
Drinking water	Analyzed for gross alpha, beta, and tritium. All sites analyzed annually for ^{90}Sr except treatment plants
Onsite	Monthly or quarterly
Offsite	Semiannually
Water treatment plants	Sampled daily; monthly analysis
Wildlife	Annually
Rainwater	Sampled continuously; monthly analysis (100-mile radius; quarterly)
Soil and sediment	Annually
Vegetation	Monitoring station locations and outside Burial Ground; Quarterly; Separation Areas, Seepage Basins and inside Burial Ground fence; annually

selected field locations to verify that variable environmental conditions (rain, temperature, humidity, and sunlight) would not adversely affect the results of the Panasonic dosimeters. Study results confirmed that the Panasonic TLDs provide accurate exposure results under variable environmental conditions.

The Panasonic dosimeter contains two calcium sulfate ($CaSO_4$) crystals and two lithium borate ($Li_2B_4O_7$) crystals. The Panasonic dosimeter was chosen for environmental radiation exposure measurements because the system used is more efficient, requires less labor, provides improved quality assurance, and allows for automated reading of the dosimeters.

The following improvements were added to the Panasonic environmental TLD program during 1988:

- use of desiccants to reduce moisture buildup and possible adverse affects on the calcium sulfate and lithium borate crystals
- automated data transfer of the Panasonic TLD raw data using a Digital Equipment Corporation (DEC) MicroVAX RS/1® data base program to retrieve data from the Panasonic TLD reader
- automated exposure calculation of the Panasonic TLD raw data using a DEC MicroVAX RS/1® data base program

Panasonic TLDs contain two types of crystals that measure environmental gamma radiation

RADIOLOGICAL SAMPLE COLLECTION AND ANALYSIS PROCEDURES

Air

Air samples are collected for analysis of gross alpha, nonvolatile beta, gamma-emitting isotopes, tritium, and radioactive isotopes of strontium, plutonium, and iodine.

Particulate airborne radioactivity is sampled continuously at each monitoring station by drawing air through a 2-in.-diameter, high-efficiency paper filter at approximately 70 L/min (2.5 ft^3/min). The volumetric rate of air passing through the filter and the total sampling time are recorded. In addition to filter paper sampling, charcoal for iodine and desiccants for tritium are all located at each sampling station. Sample filters and charcoal filters are collected weekly from 35 monitoring stations for analyses. Tritium desiccants are collected every two weeks. An air sampling station diagram is presented in Figure 1-1.

Gross Alpha and Gross Beta

Alpha- and beta-emitting radionuclides are analyzed simultaneously by a direct gross count of individual particulate filters using a gas-flow proportional counter. Certain weekly filters are then composited monthly by location group (700 A, Burial Ground North, Burial Ground South, 200 F, 200 H, Waynesboro, HWY 21/167, plant perimeter, 25-mile radius, and 100-mile radius) and counted for gamma emitters on HPGe detectors. After gamma counting, each filter composite is cut in half; one-half is used for strontium analysis and the other for plutonium analysis.

Gamma-Emitting Radionuclides

Gamma-emitting radionuclides are analyzed using the HPGe or the NaI(Tl) detector. Chemical processing of the air filters are not needed to perform these analyses.

Strontium

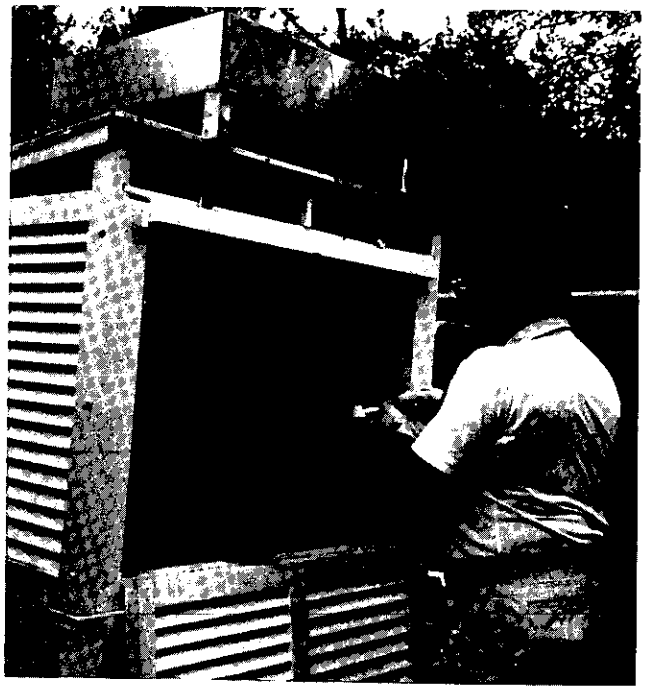
A new procedure for $^{89,90}Sr$, ^{89}Sr, and ^{90}Sr analysis was initiated in 1988. A single chemical separation method is now used to measure total radioactive $^{89,90}Sr$ or ^{90}Sr. This new procedure increases analytical precision and reduces material and labor costs.

Using this new method for $^{89,90}Sr$ analyses of air filter samples, a known amount of stable strontium is added to the sample as a carrier. The stable carrier

and the radioactive isotopes of strontium are separated from other elements by precipitation with fuming nitric acid. Separation of barium is then performed by precipitation as barium chromate in an acetate buffer solution. The separation of barium is necessary since it can be expected to interfere both as a fission product and, in its stable form, by interfering with weight recovery. The strontium carrier, together with radionuclides of strontium, is precipitated as strontium carbonate. The strontium carbonate is then dried, weighed to determine recovery of the carrier, and counted in a gas-flow proportional counter.

Plutonium

For $^{238,239}Pu$ analysis, each filter composite is dry ashed and leached with acid. The solution is evaporated to dryness, dissolved in 7.2*N* nitric acid, and passed through an anion exchange resin. The extracted plutonium is removed from the resin column with an ammonium iodide–hydrochloric acid solution, and then evaporated to dryness. The residue is redissolved in a sulfate medium so that the plutonium can be electroplated onto a stainless steel planchet. The electrodeposited plutonium (if any) is then counted in a silicon surface barrier detector system. This detector system is used to spectrally separate the alpha energies in order to verify the purity of the chemical separation and quantify the amount of $^{238,239}Pu$.



Air samples are collected weekly from 35 air monitoring stations on- and offsite

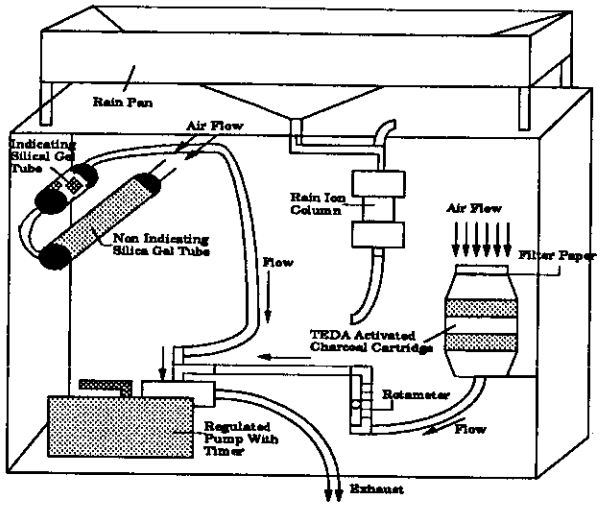


Figure 1-1. Air monitoring station diagram

Iodine

Samples for gaseous radioiodine are collected on charcoal cartridges containing 5% triethylenediamine (TEDA). The charcoal cartridges, located down-line from the particulate filters, are collected weekly. Iodine-131 is measured by a direct count of the charcoal cartridge on an HPGe detector. The HPGe detector is used to accurately distinguish the ^{131}I gamma energy from other nuclides using the HPGe detector's high spectral resolution.

Tritium

To determine tritium oxide, moisture is collected from the atmosphere by drawing air through a silica gel column at a continuous rate of 150 mL/min (0.005 ft^3/min). The column contains non-indicating silica gel, supported by an in-line column of indicating silica gel. The indicating silica gel changes color if moisture saturates the primary silica gel column during the sampling period. The change in color is an indicator of moisture which had not been trapped in the non-indicating silica gel. Such samples are then flagged as defective. These samples are collected twice a month for analysis.

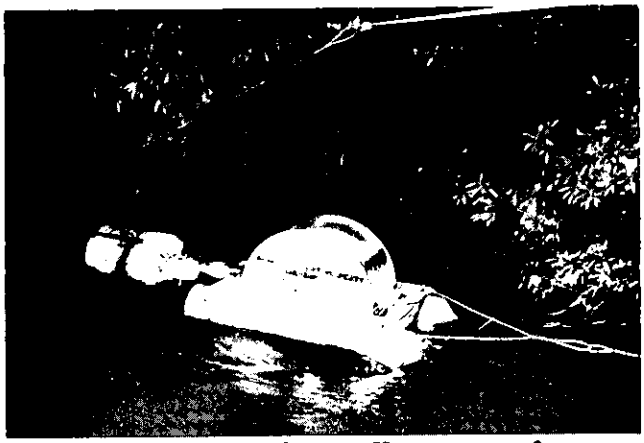
In the analysis, free water is removed by distilling the non-indicating silica gel over low heat. The distillate, consisting of the total moisture content in the air sampled, is suspended in a liquid scintillation cocktail, which consists of a fluorescent solute in an organic solvent. The concentration of tritium oxide in the moisture is determined by detection, using a liquid scintillation counter, of the photons given off by the fluorescent material as it absorbs the energy of the emitted beta particles. The tritium oxide concentration in the air is calculated from the tritium oxide in the atmospheric moisture (pCi/g) and the

absolute humidity (moisture in the air (g/m^3)) for the volume of air sampled to obtain pCi/m^3.

Streams

Site streams are monitored for gross alpha, nonvolatile beta, gamma-emitting isotopes, tritium, and radioactive isotopes of strontium, radioactive uranium/plutonium, sulfur, and cesium.

Site streams are sampled continuously by paddlewheel samplers and Brailsford motor pumps. The paddlewheel sampler, constructed of a Lexan® wheel suspended on two pontoons, is anchored in the stream. Samples are collected in small cups that are attached to the wheel of the paddlewheel sampler. Each cup



Paddlewheel samplers collect water from SRS streams and the Savannah River

samples approximately 0.5 mL of water. As the stream velocity rotates the paddlewheel, water is collected in the cups and then emptied into a trough attached to the sampler. The sample flows by gravity from the trough, through a connecting tube, into a polyethylene jug attached to the sampler. A paddlewheel sampler and diagram are presented in Figure 1-2. The Brailsford sampling device, which is stationed on a stand above the stream, consists of an all-plastic, valveless piston driven by a Brailsford AG fractional watt motor. The pump continuously samples stream water. The variable pump speed is set at 0.75 gallons/day. Samples are collected weekly.

Gross Alpha and Gross Beta

Alpha- and nonvolatile beta-emitting radionuclides are measured by a direct count of the residue remaining from evaporation of a 1-L water sample. The sample residue is transferred to a 2-in. stainless steel planchet. The planchet is flamed to remove residual moisture and volatile material, which might absorb the alpha and beta radiations, before being counted on a gas-flow proportional counter.

Gamma-Emitting Radionuclides

Gamma-emitting radionuclides are directly analyzed by counting a 500-mL, 1,000-mL, or a 6-L aliquot of the sample which has passed through an anion-cation exchange column on an HPGe detector. Chemical processing of the stream samples are not needed to perform these analyses.

Uranium and Plutonium

Alpha-emitting radionuclides are extracted from a 1-L sample with triisooctylamine (TIOA) in xylene. Uranium and plutonium together are stripped from the TIOA organic layer with 0.1*N* hydrochloric acid (HCl), and the acid solution is then evaporated to dryness to remove the HCl since it would damage the

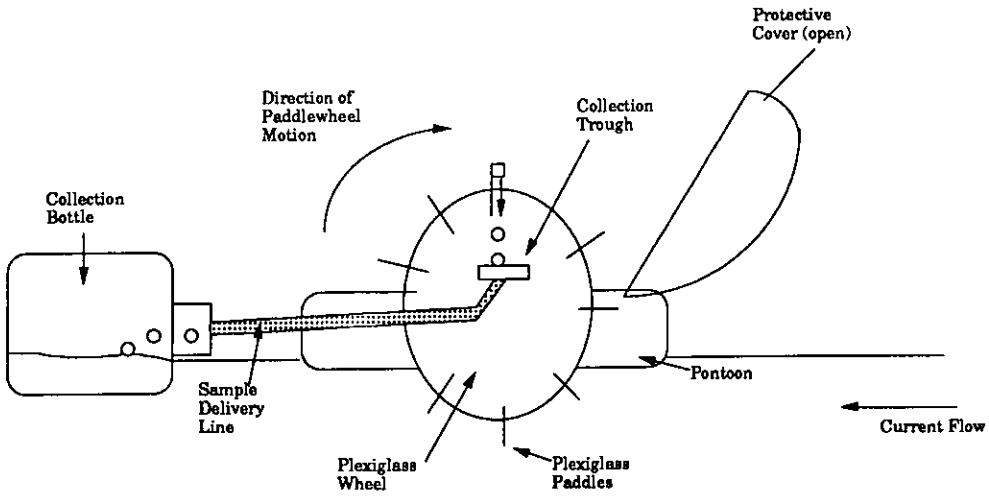


Figure 1-2. Paddlewheel sampler and component diagram

stainless steel planchet. The residue is dissolved in 8*N* nitric acid and transferred to a stainless steel planchet for counting in a gas-flow proportional counter.

Tritium
Tritium is measured in a 5-mL undistilled aliquot of the sample by liquid scintillation counting.

Strontium
Strontium-89,90 concentrations are measured by the same procedures used for air filter samples. To determine ^{90}Sr concentrations, the beta emissions of $^{89,90}Sr$ are resolved by observing the in-growth of ^{90}Y and the decay of ^{89}Sr with at least two counting intervals in the gas-flow proportional counter, over a 7- to 14- day period. Two equations are solved simultaneously to express the individual count rate of the two strontium isotopes.

Chemical Cesium
Chemical cesium is selectively precipitated from a sample using phosphotungstic acid. The precipitate is slurried in ammonium hydroxide and transferred to a planchet for chemical counting in a gas-flow proportional counter.

Savannah River

Analyses on samples from the Savannah River are performed to determine concentrations of gross alpha, nonvolatile beta, gamma-emitting isotopes, sulfur, tritium, and radioactive isotopes of strontium and plutonium. The river is sampled continuously by paddlewheel samplers equipped with 26-L polyethylene collection containers. Samples are collected weekly.

Gross Alpha and Gross Beta
Alpha- and beta-emitting radionuclides are measured by direct count of the residue remaining from evaporation of a 1-L water sample aliquot. The sample residue is transferred to a 2-in.-diameter stainless steel planchet and flamed to remove volatile material before being counted in a gas-flow proportional counter.

Gamma-Emitting Nuclides
Gamma-emitting radionuclides are measured by passing 20 L of the sample through a cation-anion exchange column to achieve increased analytical sensitivity by concentrating the radionuclides that are present. The column is counted on an HPGe detector. Radionuclides are then eluted from the resin column with 3*N* nitric acid, followed by 14*N* nitric acid for subsequent analyses.

Plutonium
Plutonium-238,239 is determined from an aliquot of the eluate, from the ion exchange column. The analytical procedure is the same as that used for air filters.

Strontium
Strontium-89,90 is recovered from an aliquot of the column eluate by the same procedure used for air samples. Strontium-90 is then analyzed by the same procedure described for stream samples.

Tritium
Tritium concentration is determined by liquid scintillation counting of a 5-mL aliquot of the distilled sample.

Seepage Basins

Two-liter grab samples (full samples collected at one time) are collected quarterly from the seepage basins. Analytical procedures for gross alpha, gross beta, tritium, strontium, uranium and plutonium, and gamma-emitting radionuclides are the same as those used for surface water samples.

Groundwater

Most groundwater wells are sampled quarterly. Wells which are not sampled quarterly are either sampled semiannually or annually. Samples are removed from wells by pumping a minimum of four well volumes before collecting a representative sample, or by lowering a weighted 1-L bailer into the well to collect the sample. Wells sampled by the grab-sample technique are equipped with a stainless steel bailer that remains at the well to prevent cross-contamination. The normal sample volume collected for analysis is approximately 2 L (or what can be sampled if less than 2 L of water is in the well).

Each monitoring well has gravel packing in the screen zone. Bentonite and cement grout seal the well from leakage of shallow groundwater into the well. The top of the well is either capped or sealed to prevent introducing atmospheric water into the well. A monitoring well construction diagram is shown in Figure 1-3.

Analytical procedures for gross alpha, gross beta, tritium, strontium, chemical cesium, and gamma-emitting radionuclides are the same as described for stream and river samples.

Milk

Fresh raw milk is collected from local dairies every two weeks and analyzed for iodine, cesium, and tritium. Once per quarter the samples are also analyzed for ^{90}Sr.

Iodine-131 and ^{137}Cs concentrations are determined by direct count of a 1-L aliquot using an HPGe detector. Once per quarter the samples are also analyzed for ^{90}Sr. Strontium and yttrium are separated from the milk using a cation exchange resin and eluted as chlorides. Strontium-90 is determined by evaporating the sample to dryness and dissolving the residue in 0.08*N* hydrochloric acid. Yttrium-90 is stripped from the strontium using di-2-ethylhexyl phosphoric acid (HDEHP) in toluene, for the initial start of ^{90}Y ingrowth. Equilibrium of ^{90}Y is approached over a 15-day period and the short-lived ^{90}Y daughter is stripped once again. The yttrium is transferred to a stainless steel planchet and counted in a gas-flow proportional counter. The amount of ^{90}Sr is calculated by relating the ^{90}Y buildup to the original ^{90}Sr concentration. Tritium oxide concentrations are determined by liquid scintillation counting in 5-mL aliquots that have been distilled to reduce quenching interferences.

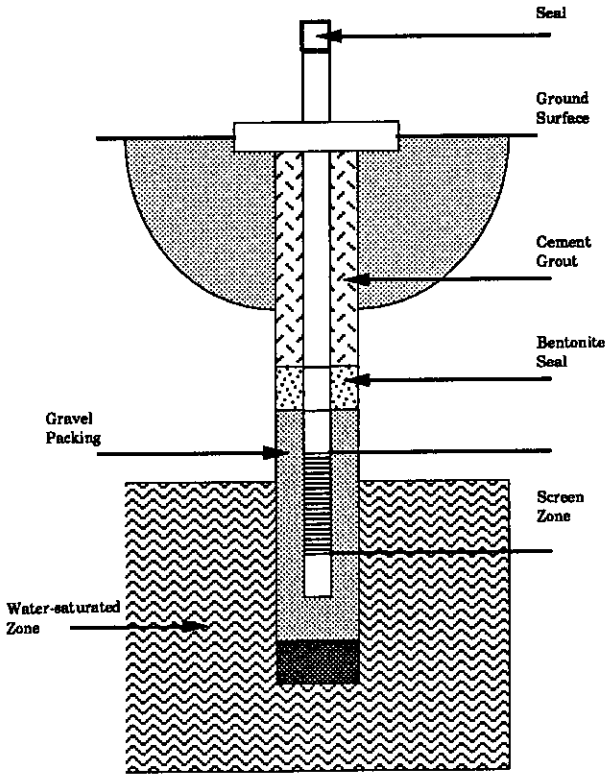


Figure 1-3. Monitoring well installation

Food

Local foods are obtained from farms located within a 25-mile radius of SRS. With the exception of grains, all foods are prepared as though for human consumption; peelings, seeds, and other inedible parts are removed. Wheat, containing only the whole grains, and oats, containing both grains and husks, are processed unwashed. A portion of the original sample is retained for tritium analysis. The remaining sample is dried and ashed and the residue is dissolved in a hydrochloric acid solution.

Gamma-emitting radionuclides are determined by direct count on an HPGe detector. Plutonium-238,239 is determined by the same procedure as described for river samples. Strontium-90 analysis of the prepared solution is performed with the same procedure used for stream water. Tritium is measured in the free water obtained by freeze-drying a portion of the original sample. The water is counted in a liquid scintillation counter.

Drinking Water

Drinking water samples are collected at onplant sampling locations and in communities surrounding SRS to monitor for alpha- and beta-emitting radionuclides and tritium. Samples are collected from faucets and drinking fountains. Some onplant samples are collected monthly, while others are collected quarterly. Offplant samples are collected semiannually except from water treatment plants, where the raw and finished drinking water samples are collected in a daily composite and analyzed monthly. Samples are taken annually and analyzed for ^{90}Sr. Analytical procedures for drinking water are the same as those used for other water samples.

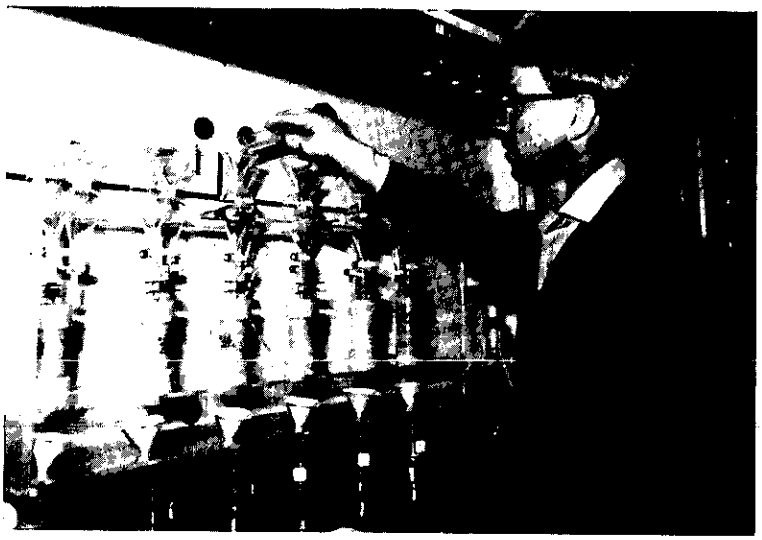
Wildlife

The collection of fish, furbearers, and waterfowl for analysis purposes is authorized by the federal government and the South Carolina state government. Under federal permit number PRT-718398 and South Carolina state permit number GF-0028-88, Environ-

mental Monitoring Collections personnel were authorized to collect wildlife specimen during 1988.

Fish

Fish are caught in traps or by hook and line. Whole fish are analyzed for gamma-emitting radionuclides on a 9 × 9-in. NaI well detector or on an HPGe detector depending on the projected level of gamma-emitting radioactivity, as explained earlier. Alpha-and beta-emitting radionuclides are measured by a direct count of residue remaining from the evaporation of acid solutions of a blended sample. The residue is placed on a 2-in.-diameter stainless steel planchet and counted in a gas-flow proportional counter.



Elution of rain ion column in an SRS laboratory

Deer and Hogs

Annually, deer and hogs are monitored through onplant controlled hunts during the November and December hunting season. Field analyses of ^{137}Cs are performed on the deer and hogs at the hunt site using 2 × 2-in. NaI detectors. The detectors are calibrated so that ^{137}Cs concentrations in flesh may be derived from the field measurements. The accuracy of the calibrations is verified by laboratory analyses of tissue samples for approximately 5-10% of the deer and hogs. Laboratory samples are counted on an HPGe detector. Flesh samples are collected randomly from deer during each controlled hunt. The samples are later analyzed for ^{90}Sr and tritium by the same procedures described for stream samples and for food samples, respectively. Muscle tissue and thyroids are randomly collected from deer during each hunt and analyzed for ^{137}Cs and ^{131}I on either an HPGe or NaI(Tl) detector.

Furbearing Animals

Furbearing animals, including raccoons, opossums, foxes, and beavers are trapped. All animals except beavers are counted whole for gamma-emitting radionuclides in a 9 × 9-in. NaI well detector or on an HPGe detector. Beavers are monitored in the field with a portable NaI detector.

Ducks

Ducks such as coots, buffleheads, ruddys, scaups, and mallards are trapped and counted whole for gamma-emitting radionuclides in a 9 × 9-in. NaI well detector or on an HPGe detector.

Rainwater

Samples of rainwater are analyzed for gross alpha, nonvolatile beta, gamma-emitting isotopes, tritium, strontium, plutonium, and radioisotopes of plutonium and strontium.

Radioactivity in rainwater is determined from monthly rainfall samples. Rainwater is collected in 2-ft-square metal pans located on top of ambient air stations. At stations equipped with ion exchange columns, the water passes through the column and into a polyethylene jug. At stations not equipped with ion exchange columns, the water is simply collected in the pan and drained directly into the jug.

The ion exchange columns are counted directly for gamma-emitting radionuclides on an HPGe detector. The columns are then eluted, and the eluate is counted for gross alpha, nonvolatile beta, plutonium, and strontium determinations and analyzed by the same procedures described earlier for other media. Tritium concentrations are determined by analysis of the rainwater collected in the jugs.

The amount of each radionuclide deposited and collected at a station during the year is obtained by adding all values that are greater than the lower limit of detection (LLD).

Soil and Sediment

In addition to the special soil surveys, routine soil samples are collected annually from each of the four quadrants around F and H Areas, at the SRS bound-

ary, and at the 100-mile-radius locations. Ten soil cores, each 8 cm deep, are taken 30 cm apart in a straight line at each sampling location. Soil cores are combined into composites by location and analyzed for ^{90}Sr, $^{238,239}Pu$, and gamma-emitting radionuclides.

Sediment samples are collected annually from SRS streams and Savannah River sampling locations. Sediment collection techniques for streams and rivers are designed to obtain samples from the top 8 cm of sediment in areas where fine sediment has accumulated. The samples are not intended to be representative of the entire stream bed.

Soil and sediment samples are dried, sieved, and pulverized before analysis. For determination of gamma-emitting radionuclides, an aliquot of the prepared soil is placed in a 500-mL plastic bottle and counted on an HPGe detector. Analysis of the soil and sediment for $^{238,239}Pu$ follows the same procedure as described earlier for other media.

For ^{90}Sr, a portion of the prepared soil is leached with 1.0*N* ammonium acetate and the solution is evaporated to dryness. The residue is dissolved in 8.0*N* nitric acid (HNO_3) and the sample is analyzed by the same method used for water.

Vegetation

Vegetation samples are collected onplant and within a 100-mile radius of SRS. Vegetation samples are generally collected annually; however, at specific key locations, samples are collected quarterly.

Gross Alpha and Gross Beta
For gross determination of alpha- and beta-emitting radionuclides, a portion of dried and ashed vegetation is dissolved in nitric acid and transferred to a planchet for counting in a gas-flow proportional counter.

Gamma-emitting Radiouclides
Gamma-emitting radionuclides are determined by counting dried vegetation in a 1-L Marinelli beaker on an HPGe detector.

Strontium
Strontium-89,90 is determined using the same procedure as described for air samples.

Vegetation is counted for gross alpha and bêta in a gas-flow proportional counter

Tritium
Tritium is measured by liquid scintillation counting of water obtained by freeze-drying the sample.

NONRADIOLOGICAL SAMPLE COLLECTION AND ANALYSIS PROCEDURE

Program Goals

The SRS Environmental Monitoring program is not only committed to radiological surveillance of the SRS environment and effluents, the program also focuses on nonradiological monitoring. Monitoring the environment for chemicals, organics, and metal pollutants in SRS liquid effluents, streams, groundwater, drinking water, the Savannah River, air, as well as in fish and wildlife, has increased significantly in recent years. Water quality monitoring has been an integral part of the environmental monitoring program since analyses of the Savannah River began in 1959. This program has expanded significantly in the past 10 years. In 1980, just over 5,000 analyses were performed on the 1,000 samples collected. In 1988, these numbers increased to 98,000 laboratory analyses and 6,700 samples collected. Nonradiological sampling and analysis frequency of key environmental sample media are provided in Table 1-2.

Table 1-2. General Nonradiological Analysis Sampling Schedule

Environmental medium	Frequency
Air	Continuously for SO_2, NO_x, O_3; 6-day intervals for TSP*
NPDES (wastewater effluents)	Varies with conditions
Streams and river	metals & organics; River; monthly, composited quarterly; Streams; weekly, composited quarterly; Monthly for chlorides & total solids; Monthly (streams)/ weekly (river) for pH, temperature, dissolved oxygen, conductivity
Groundwater	Quarterly for pH, temperature, depth, conductivity; Bi-annual comprehensive chemical analysis; Annually for site-specific constituents
Drinking water	Primary supplies: annually; Smaller systems: varies with use
Soil and sediments	Annually

*Total suspended particulates.

Air

Five onsite ambient air monitoring stations house instruments that continuously monitor for sulfur dioxide (SO_2), oxides of nitrogen (NO_x), and ozone (O_3). Total suspended particulates (TSP) are monitored every six days over a 24-hour period. The fifth monitoring station was restored to service during November 1988 to provide a uniform ambient air sampling coverage around the site.

Measurements are made using five NO_x analyzers, three SO_2 analyzers, two O_3 analyzers, and six TSP samplers. One monitoring station contains two adjacent TSP samplers for quality assurance purposes. Sampling and analysis are performed in accordance with EPA requirements and South Carolina Department of Health and Environmental Control (SCDHEC) guidelines.

NPDES Outfall Samples

Samples from SRS wastewater effluents (outfalls) are regulated by SCDHEC under the National Pollutant Discharge Elimination System (NPDES). All samples are collected according to procedures consistent with EPA and SCDHEC methods.

All outfall samples are routinely analyzed for temperature, pH, total nonfilterable residue, oil and grease, and fecal coliform. Some outfalls are also tested for pesticides and organic chemicals. The sampling frequency varies with the outfall location and the chemicals or properties measured.

All NPDES analyses, except those for fecal coliform and field parameters (flow, temperature, and pH), are performed by offsite laboratories. The fecal coliform analyses are performed by the onsite laboratory in D Area to ensure that analyses begin within six hours of sample collection as required by EPA-approved methods. The D-Area laboratory and offsite laboratories analyzing NPDES samples are certified by SCDHEC.

Streams and River

The Savannah River and SRS streams are extensively monitored for chemicals, metals, and physical and biological properties.

River and streams laboratory analyses, except for fecal coliform, are performed in the SRS Environmental Monitoring laboratory. The fecal coliform analyses are performed in the D-Area laboratory. All procedures for sample collection, preservation, and analysis are in accordance with EPA-approved methods. Some of the analytical methods used are shown in Table 1-3.

Site streams and the Savannah River are sampled continuously by paddlewheel. samplers for metals analyses. Weekly samples are collected, preserved according to EPA procedures, and combined into composites monthly. Aliquots from the three months in each quarter are combined to create a quarterly composite which is analyzed for metals by atomic absorption spectroscopy.

Because of short EPA-recommended holding times and restrictive preservation requirements for parameters such as total dissolved solids and chlorides, composited samples are not used for non-metals analyses. Grab samples are collected monthly and analyzed for non-metal parameters according to EPA procedures.

Table 1-3. Chemical Analyses and Methods for Stream and River Samples

Analysis	Method[a]
Non-Metals	
Alkalinity	EPA 310.1
Total Solids, Volatile Solids, Fixed Residue, Suspended Solids, Total Dissolved Solids	EPA 160
Chemical Oxygen Demand	EPA 410.2
Chloride	EPA 325.3
Nitrate-Nitrite-Nitrogen	EPA 253.2
Sulfate	EPA 375.4
Phosphate - Phosphorus	EPA 365.1
Ammonia - Nitrogen	EPA 350.1
Metals	
Aluminum	EPA 202.2
Cadmium	EPA 213.2
Calcium	EPA 215.1
Chromium	EPA 218.2
Copper	EPA 220.2
Iron	EPA 236.2
Lead	EPA 239.2
Magnesium	EPA 242.1
Manganese	EPA 243.2
Mercury	EPA 245.1
Nickel	EPA 249.2
Sodium	EPA 273.1
Zinc	EPA 289.2
Hardness	SM 314A

[a] Methods from *Methods for Chemical Analyses of Water and Wastes*, USEPA, EPA-600/4-79-020 (March 1979); and *Standard Methods for the Examination of Water and Wastewater*, 15th Edition, APHA/AWWA/WPCF.

Measurements of pH, dissolved oxygen, conductivity, and temperature are made weekly for river locations and monthly for streams at all sampling locations.

Groundwater

Groundwater samples are collected according to procedures that are consistent with EPA and SCDHEC methods. In most cases, a pump is installed in each well. This allows convenient purging before a sample is collected. Generally, four times the volume of water standing in the well is purged to ensure that a representative groundwater sample is obtained. EPA-recommended preservatives and sample handling procedures are used during each sample collection.

Field measurements are made quarterly at each well for pH, temperature, conductivity, and water depth. A comprehensive chemical analysis is performed on every well every two years. At least once a year, samples are analyzed for suspected constituents (sulfate in wells near coal piles, for example). The frequency of additional sampling for a constituent depends on concentration levels in the sample and on special requests to satisfy EPA and SCDHEC regulations. A computer program flags results that are above specific limits. Samples with flagged results are analyzed once or twice during the year for the constituents of concern. Occasionally, additional special analyses are

requested. In response to a special request in 1988, four replicate analyses were performed for pH, conductivity, total organic carbon (TOC), and total organic halogens (TOH) at the Radioactive Waste Burial Ground perimeter wells. Also during 1988, in anticipation of issuance of RCRA Part B permits for the H-Area Seepage Basin, "Appendix IX" [40 CFR 264: List of Hazardous Constituents for Groundwater Monitoring] analyses were performed on samples from the H-Area Seepage Basin wells. "Appendix IX" analyses were also performed on samples from the M-Area Seepage Basin wells as a requirement under the SRS Hazardous Waste Permit.

A certified offsite laboratory, Envirodyne Engineers, Inc. (EE) of St. Louis, MO, performed all routine analyses in 1988 using EPA-approved procedures. A representative list of analyses performed and methods used is shown in Table 1-4.

Drinking Water

The 30 separate drinking water systems at SRS are operated by the Power Department. Most of the larger drinking water systems draw water from the Black Creek-Middendorf formations (also known as the Tuscaloosa aquifer). Most of the smaller systems utilize shallow wells which draw from the Congaree or McBean formations. The domestic water system in D Area is supplied with surface treated water from the Savannah River.

Chlorine is added at each facility for bacteriological control. The larger systems are pH adjusted by the addition of caustic (NaOH) or soda ash (Na_2CO_3). Polyphosphates are added to three systems for iron and corrosion control. All 30 systems are monitored daily to determine the concentration of chemicals added to the water. Bacteriological samples are col-

Table 1-4. Chemical Analyses and Methods for Groundwater Samples

Analysis	Method[a]
Conductivity	EPA 120.1
Arsenic and Selenium	EPA 270.3
Silver and Lead	EPA 200.0 (Auto Analyzer flameless)
Barium, Cadmium, Chromium, Copper, Iron, Lithium, Manganese, Sodium, Nickel, Lead, Uranium, and Zinc	EPA 200.7 (plasma torch)
Chloride	EPA 325.3
Cyanide	EPA 335.2
Fluoride	EPA 340.1
Mercury	EPA 245.1
Volatile Organics	EPA 624.0 (gas chromatograph Mass spectrophotometer) or EPA 601.0 (gas chromatograph)
Endrin, Lindane, Methoxychlor, and Toxaphene	EPA 608
Silvex and 2,4-D	EPA 615

[a] Methods from *Methods for Chemical Analysis of Water and Wastes*, USEPA, EPA-600/4-79-020 (March 1979) and *Methods for Organic Chemical Analysis of Municipal and Industrial Wastewater*, USEPA, EPA-600/4-82-057 (July 1982).

lected at frequencies ranging from daily to monthly, depending upon the size and type of the system.

Samples are collected annually by a certified offsite laboratory, Environmental and Chemical Sciences/ Normandeau Associates, Inc. (ECS/Normandeau), from the 16 largest domestic drinking water systems. These samples are analyzed for an extensive list of chemical and physical attributes and contaminants to ensure that all systems meet SCDHEC and EPA limits.

Soil and Sediment

Sediment samples are collected annually at seven stream locations and two Savannah River locations. In 1988, a 1-L grab sample was taken at each location, shipped to EE, and analyzed for 32 pesticides, herbicides, and polychlorinated biphenyls (PCBs) using EPA methods 608 and 615. This program, in conjunction with stream and river water sampling, has been conducted since 1976 to assess concentrations of these materials in SRS streams and in the Savannah River.

DATA ANALYSIS

Reliable data is the final product of a thorough collection and sampling system as well as an accurate laboratory and counting room program. This section describes how the SRS Environmental Monitoring program reports data, the significance of the data, and how to interpret the reported values.

Lower Limits of Detection (LLDs) of Radioactivity

The radiological monitoring programs at SRS measure radioactive concentrations in samples with a certain confidence at certain activity levels. It is important that analytical results are presented with minimum possible error or uncertainty. An objective of the environmental surveillance program is to utilize the counting systems and sample parameters to provide the most desirable degree of measurement accuracy. Concentrations of radioactivity in samples are measured and the results are presented together with statistical estimates of uncertainty. In most cases, the measured levels of radioactivity are given in the form $m \pm L$, where m is the sample mean of the measured quantity and $m - L$ and $m + L$ are 95% confidence limits. An important term used by SRS in quantification of uncertainty in measurements is lower limit of detection (LLD), sometimes refered to as minimum detectable concentration (MDC). At SRS this term refers to the smallest concentration of radioactivity that can be detected with 95% confidence. This statistic can be influenced by such factors as detector efficiency, sample yield for each procedure, length of counting time, counting system background count rate, sample geometry, sample volume and density, radioactive decay between collection and analysis of the sample, and the number of radionuclides present in the sample.

Definition of the LLD

The radiological counting procedure consists of performing two radiological counting operations with the same apparatus and under identical conditions, except that in one operation the sample is absent and in the other the sample is present. The operation without the sample furnishes a "background count" that is characteristic of the detection system and the counting procedure. The operation with the sample in place produces a total count, which accounts for any radioactivity in the sample in addition to the system background. The difference of the two counts (total minus background) is the estimate for the sample.

The LLD is defined in connection with an acceptance limit, L_A, according to the following rule:

Decision Rule: If the net sample count (total count with the sample in place minus the background count) exceeds L_A, radioactivity is detected in the sample. Otherwise, radioactivity is not detected in the sample. These two cases are referred to as detection and non-detection, respectively.

If the Environmental Monitoring counting systems analyze a sample with 95% probability, with only a 5% probability of a false detection, it is possible to show on the basis of the normal approximation to the Poisson distribution that the appropriate value of L_A is

$$L_A = k\sqrt{2}\, s = 2.32\, s$$

where $k = 1.64$ is the 95th percentile of the standard normal distribution (i.e., the probability that this value will be exceeded by a random observation with the standard normal distribution, is 5%); and where s is the (true) standard deviation of the background count. The number L_D given by

$$L_D = k^2 + 2L_A = k^2 + k\, 2\sqrt{2}\, s = 2.71 + 4.65\, s$$

can be shown to correspond to the radioactivity level in the sample that will be detected with 95% probability by the decision rule given above. The value L_D is called the detection limit for the detection equipment and counting procedure. The detection limit is a lower limit only in the sense that an analysis of a long run of samples, with each containing a radioactivity level less than the L_D, would produce more than the prescribed 5% of false non-detections (failures to detect radioactivity when it is present in the sample). [NCRP78, NUREG84, HPSR80]

The LLD, as that term is used in this report, is computed from the detection limit (L_D) by converting the latter quantity from a count over the specified time interval to a concentration of radioactivity appropriate to the particular sampling medium (e.g., pCi/mL, pCi/g).

The LLD is useful as a measure of the sensitivity of the apparatus and counting procedures in planning radiological surveys and interpreting the radiological data at SRS. The values of the LLD are listed in the LLD tables in Vol. II. The tables contain corrections for sample aliquot, chemical yield, radioactive decay (where specified), and detector efficiency, although the uncertainty in these factors is not always propagated into the reported measures of uncertainty (e.g., confidence limits).

It is important to also note that the reported LLD or counting uncertainty generally does not include any other random or systematic components of error. The error implicit in sample collection and preparation is not accounted for in the analytical process. Accordingly, total system or measurement error is likely to be significantly higher.

LLD Derivation For Gamma Spectrometry

The LLD values for gamma spectroscopy of individual environmental samples, such as streams, foodstuffs, and groundwater, may vary significantly as a result of factors listed below:

- Specific geometries for certain sample types can improve the sensitivity of the detector system. The geometry types used by Environmental Monitoring are described earlier in this chapter in the "Sample Collection and Analytical Procedures" section.
- Performance characteristics of the primary counting systems cause LLDs to vary. The four counting systems used by Environmental Monitoring range from 25% to 44% relative efficiency, when compared with the standard 3x3-in. sodium iodide (NaI(Tl)) detector reading the 1,332-keV gamma line from a ^{60}Co point source at a distance of 25 cm.
- The length of the counting time interval plays an important role in determining LLDs. Longer counting intervals increase the relative accuracy of the analysis, resulting in a lower relative uncertainty.
- The LLD depends directly on the radioactive background level of the detector, which is counted before the sample. The LLD increases with the background level.
- The size of the sample aliquot is an important factor in LLD calculations. When the volume or size of the initial sample is large and the distribution of the sample (geometry) around the detector is increased, the sensitivity of the system and the LLD are improved.
- The length of time from sample collection to sample analysis is important to the LLD calculation when the radionuclide being investigated has a relatively short half-life. Therefore, when the time between sample collection and sample analysis is brief, the LLD is improved.
- The amount of radioactivity and the number of radionuclides present influence the uncertainty and LLD of the analysis.

The LLDs for nuclides in certain sample media are listed in Tables 1-5, 1-6, and 1-7, of Vol. II. The LLDs for HPGe systems using different geometries and a proprietary gamma spectrum analysis software are shown in Table 1-8 of Vol. II. All values are based on counts obtained from detectors of midrange efficiency.

Environmental samples are analyzed using gamma spectrometry over 50-, 83-, 167-, and 1,000-minute intervals, depending on the desired sensitivity for the specific sample. Shorter counting intervals elevate the LLD or decrease the sensitivity of the sample analysis.

LLD Derivation For Other Systems

Generally, LLDs for instrumental analyses (other than gamma spectrometry) are more consistent within the specific sample and analysis type. Major factors influencing the LLD of gross alpha and beta radioactivity, tritium, and strontium using gas-flow proportional counters, liquid scintillation counters, and silicon surface barrier detectors are listed below:

- The size of the sample aliquot is the major source of LLD variation in an analytical process other than gamma spectroscopy.

- Self-absorption, an uncompensated contributing factor due to the mass of the sample preparation, has significant influence in the LLD for gross alpha and nonvolatile beta analyses performed when using gas-flow proportional counters. Correction for source self-absorption was generally performed for individual analyses of specific samples during 1988. However, the correction was not routinely reflected in determinations of chemical recoveries or yields of batch analyses. During the third quarter of 1988, Environmental Monitoring laboratories began including self-absorption correction for gross alpha and nonvolatile beta results. Other analyses, such as those for chemical cesium and ^{90}Sr, also include self-absorption factors within their derived procedural recovery factors. In 1989, self-absorption compensation for each individual sample will be provided and factored into measurement uncertainty and LLD determinations.

- The length of the counting interval is usually standard among systems other than gamma spectrometry. Counting intervals, therefore, have relatively less effect on the LLD than that for gamma spectroscopy.

Significance and Interpretation of Reported Values

It is important to distinguish LLDs from the uncertainty or error statistics that accompany analysis results. The LLD is an *a priori* or pre-measurement estimate of a system's minimum quantitative detection capability based on knowledge of its physical performance characteristics and predetermined analysis parameters. The uncertainty statistic (±) places an *a posteriori* or post measurement confidence window around an actual measurement value or a collection of values. When comparing LLD and uncertainty values to analysis measurements of environmental samples, the value of an analytical result is sometimes less than the LLD and uncertainty for a particular measurement. This situation, however, does not invalidate the measured value.

Many radioactive concentrations in ambient environmental samples approach zero and should statistically show a distribution around zero. Therefore, when an instrument background or control is subtracted from an environmental measurement, it is possible to obtain net values less than the LLD. Zero and negative net values may also occur; a real zero activity level should yield an equal number of positive or negative results distributed about the theoretical mean of zero. Note that gamma spectrometry analytical results for samples of this activity level are usually not reported as activity concentration values, but as null values with their associated 95% confidence level LLD.

Analytical results less than the LLD or MDC should not necessarily be interpreted as non-detectable. Values greater than one-half the LLD can be interpreted as probably indicating a positive analyte presence. In many cases, values less than one-half the LLD, less than the accompanying uncertainty (±) statistic, or even less than zero (negative) are reported (except for gamma spectrometry results). This practice ensures an uncensored data set that will yield a better estimate of the mean based on all values, both negative and positive. Using this approach, all data are reported, trends and biases are identified, and the accuracy and precision of analytical processes are clarified.

In some cases where sets of data are collected from sample locations with a near stable or uniform analyte presence, a collective evaluation of the mean may yield a reliable estimate of the activity concentration that is considerably lower than the LLD for a single analysis. In this event, as in the case where multiple replicate samples are taken, the result is an improvement in overall analytical sensitivity.

In some tables, the standard deviation is not calculated because of the small number of sample results (designated "insufficient data"). When "plus-or-minus" accompanies an individual result, such as the maximum or minimum, it represents the statistical counting uncertainty at the 95% confidence level which can sometimes exceed the net value of the sample. Maximum and minimum refer to the greatest and smallest concentrations found in a single analysis for a specific sample collected during the year.

1988 HIGHLIGHTS

- Approximately 113,500 radiological analyses were performed on 25,000 samples gathered in 1988.
- Complete conversion from the SRS-designed thermoluminescent dosimeter (TLD) to the Panasonic TLD system was accomplished in 1988 after results of a 1986-1987 comparative study showed that the Panasonic TLDs provide similarly accurate exposure results under the range of environmental conditions experienced at SRS, while utilizing overall improved automation.
- In 1988, the SRS Environmental Monitoring program carried out 98,000 nonradiological laboratory analyses on 6,700 samples collected.
- An onsite air monitoring station was restored to service in 1988, bringing the total to five. These stations provide a uniform air sampling coverage around the site.
- Analyses specified by 40 CFR 264 Appendix IX were performed on samples from the H-Area and M-Area Seepage Basin wells.

2
Methods for Calculating Offsite Radiation Doses

SUMMARY—The methodology for calculating radiation doses to individuals and populations in the vicinity of the Savannah River Site (SRS) is described. Radiation dose terms, including *absorbed dose, dose equivalent, effective dose equivalent, and collective dose,* are defined, and applicable dose standards are given.

Dosimetry and environmental behavior of tritium, which accounts for a dominant fraction of the offsite dose due to SRS releases, are discussed in a special section. Finally, the mathematical models used for calculating the SRS offsite doses are described. These radiation transport and exposure pathway models are necessary because conventional monitoring methods do not detect the very low concentrations of radioactive materials dispersed in the atmosphere and diluted in streams and the Savannah River once they are released from SRS.

These models are implemented at SRS in three different computer programs: MAXIGASP, which calculates dose to offsite individuals from atmospheric releases; POPGASP, which calculates collective doses from atmospheric releases; and LADTAP, which calculates offsite individual and collective doses from liquid releases.

Transport of radionuclides routinely released to the atmosphere is modeled by the XOQDOQ computer program, which applies the widely-used Gaussian plume representation. Transport of unplanned releases to the atmosphere is simulated by several programs that are part of the WIND system methodology.

INTRODUCTION

This chapter discusses radiation dose terminology and describes how the offsite doses determined in the atmospheric and surface water monitoring programs were calculated. The results of these calculations are presented in Chapters 3 and 4 and summarized in the Executive Summary.

RADIATION DOSE TERMINOLOGY: DEFINITIONS AND UNITS

Implicit in the idea of radiation dose is a measure of possible harm to individuals that could result from their exposure to radiation. In the methodology of the International Commission on Radiological Protection (ICRP), radiation-induced health effects have been separated into two categories:

- **Stochastic health effects** are principally fatal malignant and genetic disorders which randomly do or do not occur in a given exposed individual. The effects may be assigned a probability of occurence based on the level of exposure.
- **Nonstochastic health effects** include such physical impairments as cataracts in the lens of the eye, nonmalignant damage of the skin, and gonadal cell damage causing impairment of fertility. The severity of the effect tends to increase or decrease according to the degree of exposure of the affected organ. A threshold of exposure may exist, below which health effects do not occur.

In considering radiation exposures and possible consequences to exposed individuals, the term "radiation dose" has come into common use. When an organ of the body is exposed to a source of ionizing radiation, the organ is said to receive a radiation dose. The term indicates that the organ has absorbed some of the energy emitted by the source. But for purposes of radiation protection, the term "radiation dose" has been replaced by more precise definitions, which are discussed below.

Absorbed Dose and Dose Equivalent

The measure of dose to an organ is the **absorbed dose,** defined as the quantity of radiation energy absorbed by the organ divided by its mass. The

International System of Units (SI) unit of absorbed dose is the gray (Gy). An organ receives an absorbed dose of 1 Gy when it absorbs 1 joule of radiation energy per kilogram of its mass. The conventional unit of absorbed dose is the rad (100 rad = 1 Gy).

Absorbed dose depends only on the radiation energy that the organ absorbs, not on the radiation type (alpha particles, beta particles, gamma rays, or neutrons). But for a given absorbed dose, the degree and kinds of biological effects in the exposed tissues may vary depending on the radiation type. For this reason, absorbed dose is considered to be inadequate for prediction of health effects associated with radiation exposure.

The **dose equivalent** to an organ exposed to a source of ionizing radiation is defined as the absorbed dose to the organ multiplied by a **quality factor**, which takes the radiation type into account. For the radiation types that are of concern in this report, the ICRP has recommended the following approximate quality factors:

Gamma rays and x-rays	1
Beta particles and other electrons	1
Alpha particles	20

The SI unit of dose equivalent is the sievert (Sv). The conventional unit is the rem (100 rem = 1 Sv).

Effective Dose Equivalent

The **effective dose equivalent** combines the dose equivalents received by all organs of the body into a single weighted average that is related in a simple way to the individual's total risk of experiencing stochastic health effects. To calculate the effective dose equivalent, each organ dose equivalent is multiplied by an appropriate weighting factor that expresses the relative susceptibility of that organ to stochastic effects from one sievert of dose equivalent. The effective dose equivalent is then calculated by summing the factored organ dose equivalents. The weighting factors can be derived from Table 2-1.

The risk tabulated for each organ is interpreted as the probability of the eventual occurrence of a stochastic health effect for each sievert of dose equivalent received by the organ. The weighting factor to be used for each organ is the risk per sievert for the organ divided by the total risk per sievert (0.0165).

Table 2-1. Organ-Specific Risk Factors for Effective Dose Equivalent[a]

Organ	Risk per sievert[b]
Gonads	0.004
Breast	0.0025
Red marrow	0.002
Lung	0.002
Thyroid	0.0005
Bone surfaces	0.0005
Remainder[c]	0.005
Total	0.0165

[a]Source: ICRP Publication 26 [ICRP77].

[b]Probability of a stochastic health effect resulting from 1 Sv dose equivalent to the organ.

[c]Each of the five remaining organs receiving the highest dose equivalents is assigned risk per sievert of 0.001.

The effective dose equivalent is computed as follows:

Effective dose equivalent =
(0.004 × dose equivalent to gonads
+ 0.0025 × dose equivalent to breast
+ . . .
+ 0.005 × dose equivalent to remainder)/0.0165

The effective dose equivalent combines the dose equivalents to individual organs into a single number. Effective dose equivalents can be added to summarize the impacts of multiple radionuclides and radiation from both internal and external sources.

As defined, the effective dose equivalent, multiplied by the total risk per sievert, 0.0165, is equal to the probability of occurrence of a stochastic health effect associated with *some* organ or tissue of the body. When applied to individuals in environmental assessments, this interpretation usually produces probabilities so small that they are meaningless. But in the context of collective dose to populations over time, the meaning of effective dose equivalent can be clarified.

Collective (Population) Dose

The term **collective (population) dose** refers to the sum of the individual doses received by all members of a population. In this report, the measure of individual dose used to compute the collective dose is the effective dose equivalent. The unit of collective effective dose equivalent is the person-sievert (person-Sv) or the person-rem. For example, if each

individual in a population of 10,000 receives an effective dose equivalent of 1 mrem (0.01 mSv) each year, the annual collective effective dose equivalent to the population is calculated using the following method:

10,000 persons	10,000 persons
× 0.01 mSv per year	× 1.0 mrem per year
× 10^{-3} Sv per mSv	× 10^{-3} rem per mrem
= 0.1 person-Sv per yr.	= 10.0 person-rem per yr.

Using the risk factor per sievert and multiplying the collective effective dose equivalent by the individual's total risk per sievert, 0.0165, gives an estimate of the expected number of stochastic health effects in the population. The following method derives the statistical risk of stochastic health effects:

0.1 person-Sv per year
× 0.0165 health effects per person per Sv
= 0.00165 health effects per yr.

This number corresponds to a statistical expectation of one stochastic health effect in the population every 1/0.00165 = 606 years, provided the number of exposed individuals and the levels of exposure remain constant over time.

Committed Dose

Radiation dose to an individual from an external source is received essentially instantaneously and only while the individual is exposed to the source. But when the source of the radiation is a radionuclide inside the body, the situation is more complicated.

When radioactivity is taken into the body by ingestion of radioactive material in food and drinking water, by inhalation of airborne radioactive particles or vapors, or by absorption of a radionuclide through the skin, it is distributed among the body's organs according to each organ's metabolism of the particular element or compound. Even after the intake of radioactive material stops, the organs of the body continue to be irradiated from the distributed internal source. The rate at which the source irradiates the internal organs diminishes over time and is due to the removal of the source by biological processes and radioactive decay. Because some materials are rapidly eliminated from the body, exposure from their emitted radiations is short-lived. Similarly, some materials are radiologically short-lived (their radioactivity decays rapidly), and the irradiation rate of the organs of the body from those materials also diminish quickly. Other materials, however, are radiologically long-lived and firmly retained. These types of radioactive sources may remain in the body emitting radiation for months or years. As a result, dose to the organs continues to accumulate after the intake ceases. The continued irradiation and accumulation of dose to an organ depends on the type of intake and the radiological and biological properties of the radioactive material taken into the body as shown in Figure 2-1.

The total dose that results from an intake, accumulated over a projected lifetime of an individual, is referred to as *committed* dose. When discussing committed dose, **committed dose equivalent** refers to an organ's committed dose and **committed effective dose equivalent** refers to an individual's committed dose from a specified intake. In using mathematical models to make calculations of committed dose, 50 years—the approximate residual life expectancy of a young adult—has ordinarily been used as a time beyond which the irradiation has ended. For adults, the 50-year time span is conservative and tends to overestimate the committed dose to older individuals.

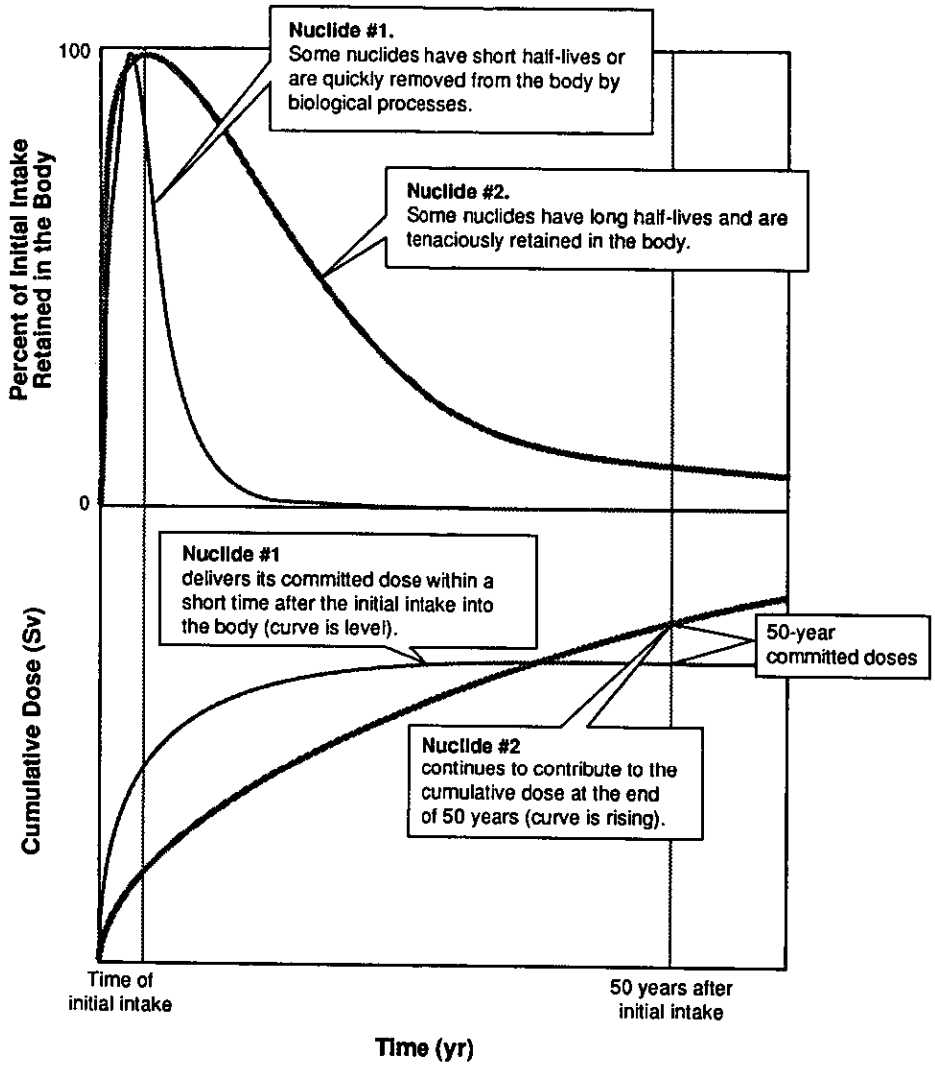
Internal Dose Factors

Internal dose factors used to calculate the committed dose equivalent to an organ and the committed effective dose equivalent to an individual are specific to the radionuclide and the intake mode (inhalation or ingestion). The factors express the 50-year committed dose that would result from the intake of a unit quantity of radioactivity, normally 1 becquerel (1 Bq) or 1 picocurie (1 pCi). The units of the factors may be, for example, Sv per Bq or mrem per pCi. Table 2-2 (below) shows sample internal dose factors for committed effective dose equivalent to an adult for several radionuclides.

Table 2-2. Fifty-Year Committed Effective Dose Equivalent for an Adult (mrem/pCi)[a]

Radionuclide	Inhalation	Ingestion
Tritium oxide	9.5×10^{-6}	6.3×10^{-8}
Sr-90	1.3×10^{-3}	1.3×10^{-4}
I-131	3.2×10^{-5}	5.3×10^{-5}
Cs-137	3.2×10^{-5}	5.0×10^{-5}
Pu-239	5.1×10^{-1}	4.3×10^{-4}

[a] Source: Based on methods and data from ICRP79.



An intake of a radionuclide into the body commits the individual to a radiation dose that will be delivered over a subsequent period of time, the duration of which depends on the radionuclide taken in. The graphs above suggest the dynamic behavior in the body of two radionuclides with different characteristics. The intake of each nuclide occurs during a brief initial period. Nuclide #1 is quickly removed from the body, so that the percent that is retained falls quickly to zero (top figure). Nuclide #2 is radiologically long-lived and is avidly retained by the body because of its physical and chemical characteristics; the top figure indicates that some of the nuclide remains at the end of the nominal 50-year commitment period. The dose from each nuclide (bottom figure) accumulates, at a declining rate, as long as the nuclide remains in the body. When all of nuclide #1 has been removed, the cumulative dose curve is flat, and the dose commitment was attained before the end of the 50-year period. The cumulative dose curve for nuclide #2 is still rising when the 50-year period is over.

Figure 2-1. Committed dose

Below is an example of how actual intakes are determined by exposure to environmental media.

Intake of a radionuclide by inhalation (pCi) =
concentration of the radionuclide in air (pCi/m^3)
× breathing rate during exposure (m^3 of air breathed per unit time)
× time duration of exposure.

Intake of a radionuclide by ingestion depends on levels of the radionuclide in foods and drinking water, and on consumption patterns.

The product of the actual intake of a radionuclide and the appropriate dose factor is the estimate of committed effective dose equivalent resulting from the intake.

The estimates of internal radiation doses presented in this report were calculated using internal organ dose factors developed by the ICRP [ICRP79] for approximately 20 organs of the body. Because the current ICRP methodology is relatively new, internal dose factors for most radionuclides are available only for adults at present. Age-specific dose factors for infants, children, and adolescents may not be generally available for some time. As an interim procedure, the doses for all age groups are calculated with the adult dose factors. However, age-specific intake rates of food and drinking water are used in the dose calculations. The intake rates are shown in Tables 2-1 and 2-2 of Vol. II.

Extended Intakes: Environmental Dose Commitment

When radioactivity is released from a facility to one or more environmental media (e.g., air, water), only a small fraction of it reaches the public, and that fraction undergoes delays as it moves through the environment. For a release of a certain nuclide which begins on January 1 and is continued throughout the year at a constant rate until it ceases December 31, consider the resulting intake of that radionuclide over time by an average individual in the exposed population. The corresponding rate of intake by an individual living in the vicinity would increase from zero at the beginning of the release to a maximum sometime after the end of the release. It would then begin to decline. But the intake would not decline to zero immediately because of the transit times required for the radionuclide to move through one or more environmental pathways and reach the average individual.

The intake-rate curve shown in Figure 2-2 declines gradually from its maximum as the radionuclide is depleted in the environment over time. Figure 2-2 also shows a curve for the accumulated collective dose, which increases until depletion of the radionuclide from the environment causes the intake rate to reach zero. At this point, the population has received its total collective dose from the release. This total collective dose is called the **environmental dose commitment** (also called the **collective dose commitment**) resulting from the release. The accumulation of dose over time depends on the radiological longevity and environmental behavior of the released radionuclide.

APPLICABLE DOSE STANDARDS

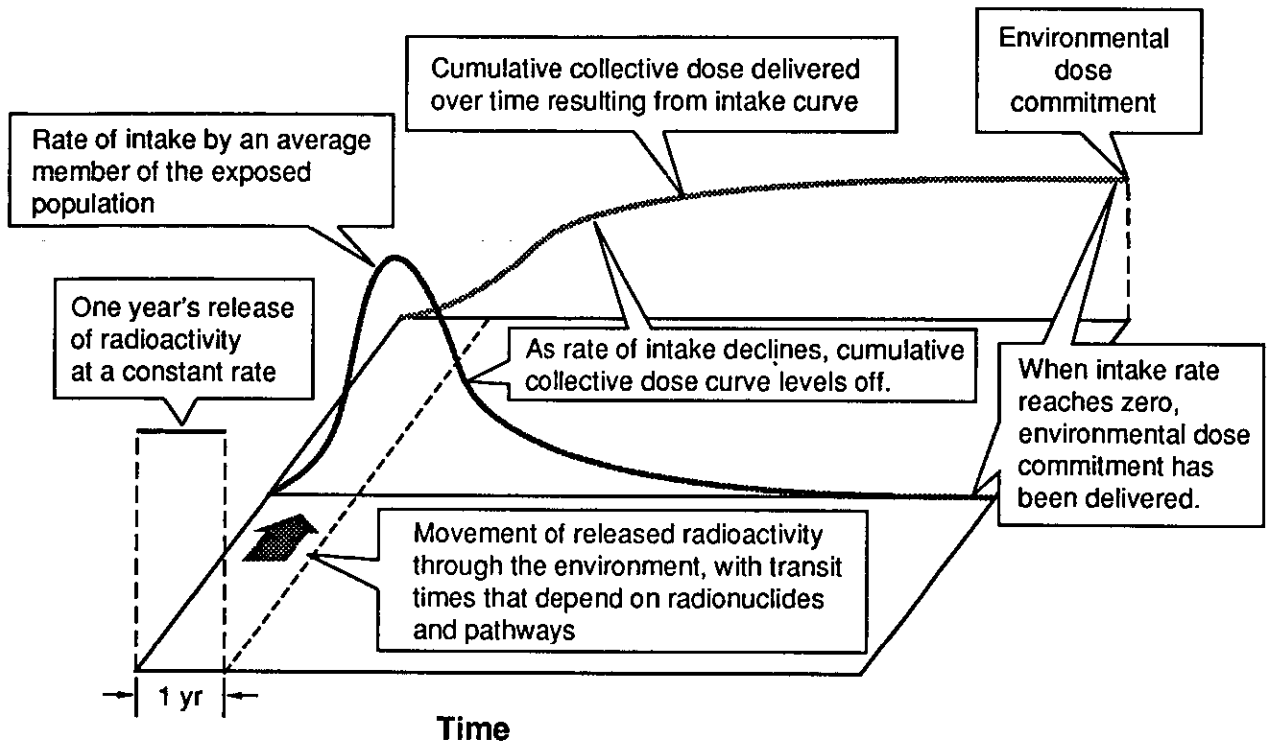
The DOE radiation standards for the protection of the public in the vicinity of the SRS are given in DOE Order 5480.1A. These standards are based on recommendations of the ICRP and the National Council on Radiation Protection (NCRP).

The draft DOE Order 5400.xx was issued to update the portions of DOE 5480.1A that address public and environmental radiation protection standards and control practices. DOE 5400.3 contains revised interim standards which incorporated the recommendations and dose models contained in ICRP Publications 26 and 30 [ICRP77, ICRP79]. These revised interim standards, which supercede previous standards based on ICRP Publications 2 and 10 [ICRP 59, ICRP 68], also include EPA limits for the atmospheric pathways contained in 40CFR61, subpart H (EPA 85). Publications DOE/EH-0070, "External Dose-Rate Conversion Factors for Calculation of Dose to the Public" and DOE/EH-0071, "Internal Dose Conversion Factors for Calculation of Dose to the Public", provide dose rate and dose conversion factors for external and internal environmental radiation. The revised interim standards and limits for atmospheric pathways are given in Table 2-3.

EPA drinking water standards that apply at downriver water treatment plants are based on an annual whole body dose (effective dose equivalent) of 4 mrem (0.04 mSv) from the consumption of 2 L of water per day [EPA75]. SRS dose estimates are based on similar criteria and can be compared with the EPA dose standard.

SRS Doses

In this report, offsite doses for SRS releases of radioactive materials (atmospheric and liquid) are given



Just as an individual's intake of radioactivity commits an individual to a radiation dose subsequently delivered over time, a release of radioactivity to the environment commits an exposed population to a collective dose that accumulates during a period of time, depending on the environmental behavior of the radionuclides in the release. This figure illustrates this concept with a one-year release of radioactivity that will result in internal dose to members of a population. The released radioactivity moves through environmental pathways with various transit times, and some fraction of the radioactivity results in an average intake-rate curve for the exposed population. The dynamics of the curve are reflected in the cumulative collective dose curve, which rises at a decreasing rate after the maximum intake rate and becomes flat where the intake rate is zero. When the intake rate reaches zero, the environmental dose commitment has been delivered to the exposed population.

Figure 2-2. Environmental dose commitment

for several scenarios for all affected individuals and population groups. Maximum radiation dose commitment is given for a hypothetical individual living at the site boundary. This hypothetical individual eats a maximum amount of foliage from the land and a maximum amount of fish from the Savannah River. He also drinks the water of the Savannah River. The average individual's committed effective dose equivalent is also provided for the average individual at the site boundary. Collective (population) dose commitment from SRS atmospheric releases is provided for people who live within 50 miles (80 km) of the center of the site. This dose is based on the average individual dose within the 50-mile radius. Average, maximum, and collective effective dose commitments are also provided in this report for individuals and population groups downstream of the Savannah River Site. These doses are based on water consumption from the two water treatment plants downstream of SRS. The age-specific demographic data used to calculate the doses for the population within the 50-mile (80 km) radius of the SRS (555,100 persons), the population served by the Cherokee Hill Water Treatment Plant at Port Wentworth, GA (near Savannah, GA; 20,000 persons), and the population served by the Beaufort-Jasper Water Treatment Plant (near Beaufort, SC; 51,000 persons) are provided in Table 2-3 in Vol II.

The individual and collective dose commitments for 1988 SRS releases, calculated by the methods described in this chapter, are compared with the average annual dose commitments from natural and medical sources and are provided in Table ES-2 in the Executive Summary.

Also note that an individual in the Central Savannah River Area (CSRA) receives an average annual committed effective dose equivalent of about 295 mrem (2.95 mSv) from *natural* sources of ionizing radiation [NCRP87a]. Of this annual dose, approximately 95 mrem (0.95 mSv) is from external radiation (cosmic and terrestrial sources) and from naturally occurring radionuclides that have been taken into the body. The remaining 200 mrem (2.00 mSv) is from the inhalation of radon gas (^{222}Rn), which forms from the decay of naturally occurring ^{226}Ra in the soil and seeps into homes [NCRP87a]. Many individuals also receive additional exposures from medical examinations or treatments.

Table 2-3. DOE Revised Interim Radiation Dose Limits

All Pathways. The effective dose equivalent for any member of the public from all routine DOE operations[a] (excluding natural background and medical exposures) shall not exceed the values given below:

	Effective dose equivalent[b]	
	mrem/year	(mSv/year)
Occasional annual exposure	500	(5)
Prolonged period of exposure[c]	100	(1)

No individual organ shall receive a committed dose equivalent of 5 rem/year (50 mSv/year) or greater.

Air Pathway Only (Limits of 40 CFR 61, Subpart H)

	Dose equivalent	
	mrem/year	(mSv/year)
Whole body dose (effective dose equivalent)	25	(0.25)
Any organ	75	(0.75)

[a]"Routine DOE operations" means normal planned operations and does not include additional routine or nonroutine releases.

[b]Effective dose equivalent is expressed in rem (or mrem) with the corresponding value in Sv (or mSv) in parentheses.

[c]For the purpose of these standards, a prolonged exposure is one that lasts, or is predicted to last, longer than 5 years.

RELATIVE EFFECTS OF DIFFERENT CHEMICAL FORMS OF TRITIUM IN THE ATMOSPHERE

Of the several radionuclides released from SRS, tritium regularly accounts for a larger fraction of the offsite collective dose than all of the other radionuclides combined. In 1988, atmospheric tritium accounted for approximately 67% of site perimeter dose from atmospheric releases. Liquid effluent tritium accounted for approximately 90% of the doses received from the public water supplies at Port Wentworth and Beaufort-Jasper. Because of the prominence of tritium in the release, its dosimetry and environmental behavior are discussed in greater detail in this section.

Tritium released to the atmosphere from SRS operations is primarily in two chemical forms: tritium oxide, which is water vapor (HTO and T_2O), and elemental tritium, which is a gas (HT and T_2). Because the effective dose equivalent factors for exposure to tritium in air differ by four orders of magnitude for the oxide and the elemental forms and because these two forms of tritium behave differently in the environment, releases of tritium to the atmosphere are identified by chemical form, and the doses from each form are calculated separately.

The different ways in which tritium is biologically assimilated by the body are considered in the dose calculations. Tritium oxide is readily absorbed by the body when tritiated water vapor is inhaled or when tritium oxide is ingested with drinking water or with food. In order to account for this efficient uptake of tritium, the effective dose equivalent factors for tritium oxide were calculated from a model of body water that assumes instantaneous absorption into body fluids of 100% of ingested or inhaled tritium oxide. A third mode of intake is also important for tritium oxide: an individual exposed to airborne tritiated water vapor normally absorbs about one-half as much tritium through the skin as by inhalation [ICRP79]. The effective dose equivalent factor corresponding to intake by inhalation has been calculated to account for this uptake of tritium oxide through the skin. All of the dose factors for tritium oxide are based on the assumption that tritium oxide assimilated by the body is eliminated at the same rate as body water.

Elemental tritium is not efficiently assimilated by the human body. Of the elemental tritium gas inhaled, only about 0.004% is converted to the oxide form and retained as free water [NCRP79]. The need for limiting exposure to elemental tritium in air is governed by the dose to the lung as the airborne gas passes through the organ.

Because of the different environmental behavior and dosimetry of tritium oxide and elemental tritium, this report identifies releases of tritium to the atmosphere by chemical form.

CALCULATIONAL MODELS

Most of the radioactive materials released from SRS have such low concentrations that they are not detectable by conventional monitoring procedures when dispersed in the environment. Therefore, radiation doses to offsite populations are calculated with mathematical models. These models use known transport mechanisms for atmospheric and liquid releases and known major pathways of exposure to man. Environmental measurements of tritium oxide, which had been released in small quantities during routine operations, are used to verify atmospheric dispersion in the transport models [Mar84].

The models used for calculating the SRS average annual offsite doses are radiation transport and dose models developed for the nuclear industry [USNRC71] to assess the effects of the operations of licensed commercial nuclear facilities. The models are implemented at SRS in the following computer programs:

- MAXIGASP: calculates maximum and average doses to offsite individuals from atmospheric releases.
- POPGASP: calculates population doses from atmospheric releases.
- LADTAP: calculates both maximum and the average doses to offsite individuals and the population from liquid releases.

MAXIGASP and POPGASP are SRL-modified versions of the Nuclear Regulatory Commission (NRC) programs called XOQDOQ and GASPAR. The modifications were made to meet the requirements for input of physical and biological data which are specific to SRS. The basic calculations in the XOQDOQ and GASPAR programs were not modified. LADTAP is an unmodified version of the NRC program of the same name. (Details on these environmental models and computer programs are available in [USNRC71], [Ec80], and [Si80].)

The EPA requires the use of the CAAC (Clean Air Act Code, formerly AIRDOS-EPA) computer code to calculate offsite doses from existing and proposed facilities. The purpose of this program is to demonstrate compliance with the National Emission Standards for Hazardous Air Pollutants (NESHAP). At SRS, the CAAC dose estimates are computed to show NESHAP compliance, but they are not included among the offsite dose estimates prepared for this report. SRS did not adopt the CAAC-calculated methodology primarily because of its conservative approach to calculating doses from tritium oxide in food. The CAAC model assumes that airborne tritium oxide at a given location is diluted with atmospheric moisture, and a generic specific humidity of 8 g H_2O/m^3 is used by the code. The code makes no provision for user input of a specific humidity value appropriate for the particular site and season. Because of this parameter value, CAAC doses are substantial overestimates for the humid SRS area. The MAXIGASP and POPGASP codes allow the input of a specific humidity parameter of 11 g H_2O/m^3, determined by a review of weather bureau records for Augusta, GA. Another conservative assumption of the CAAC methodology is that the water content of foods reaches an equilibrium content of tritum equal to the tritium content of atmospheric moisture.

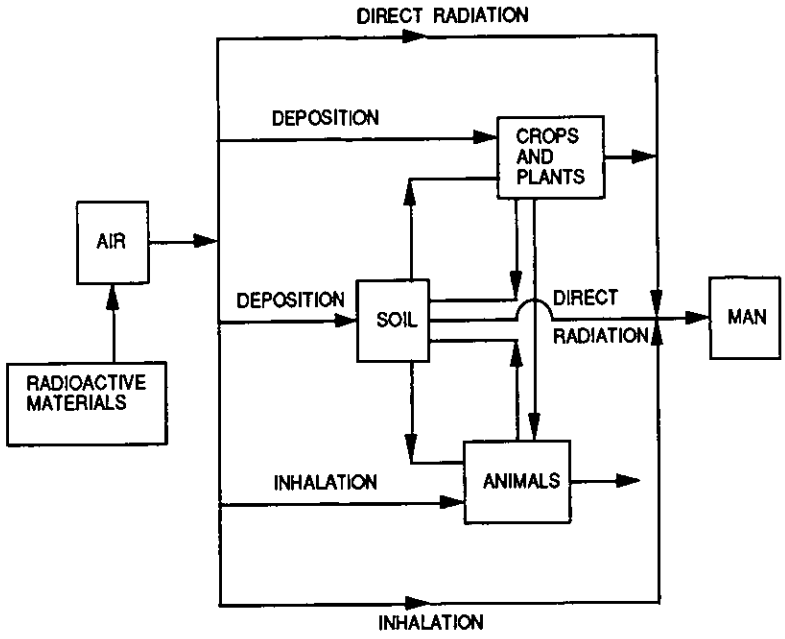


Figure 2-3. Simplified pathways between radioactive materials released to the atmosphere and man

Using the CAAC code for calculation of the 1988 maximum offsite dose from atmospheric releases, a dose of 1.01 mrem is computed using a specific humidity parameter of 8 g H_2O/m^3. By substituting a specific humidity parameter of 11 g H_2O/m^3 and still using the other conservative assumptions in the CAAC code, a dose of 0.82 mrem is computed. These computed doses are appreciably more than the 0.46 mrem dose computed using the MAXIGASP code.

Modeling the Dispersion of Radioactive Releases to the Atmosphere

Radioactive materials released to the atmosphere generally undergo a complex series of physical, chemical, and biological processes. Some of these processes involve dilution, while others involve physical or biological reconcentration. Transport of the atmospheric released radioactive materials then follow various pathways to man. A simplified representation of the more important transport pathways is shown in Figure 2-3.

Meteorological Data Base. The transport of radioactive materials from SRS by the atmosphere is calculated on the basis of meteorological conditions. Meteorological conditions are continuously measured at seven onsite meteorological towers and at a 1,200-ft television transmitting tower which is 30 km (18.8 miles) northwest of the geometric center of SRS.

Calculations of atmospheric transport and deposition for the dose estimates given in this report are based on meteorological dispersion and deposition which were calculated from meteorological measurements made over a five-year period (1982–1986). These measurements were collected from a meteorological tower located near the center of SRS (H-Area Separations). These data are presented in Table 2-4 of Vol. II. These data were used to prepare a frequency table of wind speed, wind direction, and atmospheric stability category for SRS (Table 2-4 of Vol. II). Such meteorological frequency tables are used as input for either a plume- or puff-type atmospheric transport model, which accounts for the motion of the wind and the vertical and horizontal dispersion of the released radionuclides within the

moving air mass, and for their removal from the air by deposition and radioactive decay. The model estimates the radionuclide concentration in air per unit release rate (sometimes called "chi over Q") at prescribed ground-level positions in the vicinity of the point of release. Deposition of the radionuclide on the ground at these locations is also estimated.

These atmospheric transport models are based on methods that are widely used in the nuclear industry [USNRC73]. The versions used for assessing routine releases from SRS are implemented in the computer program XOQDOQ [Sa77]. Measured annual average concentrations of tritium oxide in the atmosphere and in other environmental media are compared with concentrations calculated with XOQDOQ [Mar84]. The comparisons are published annually in the *SRS Environmental Report* (see Chapter 3).

Dose Calculations for Atmospheric Releases. Calculations of offsite individual and population dose commitments due to atmospheric releases of radioactivity are provided by MAXIGASP and POPGASP programs. Measured annual radioactive releases, average annual radioactive concentration and deposition factors, population distribution, and production data for vegetables, crops, milk, and meat are all used in the MAXIGASP and POPGASP programs. Individual and population radioactive intakes are based on population distribution, and inhalation and consumption rates for food and water as shown in Tables 2-1, 2-3, 2-5, and 2-6 of Vol. II.

Radioactive intakes by offsite populations are converted to dose commitments by use of the DOE internal effective dose equivalent factors. These effective dose equivalent factors, described previously, provide estimates of a 50-year dose commitment for intake of a unit quantity of radioactivity. The term environmental dose commitment, previously explained, refers to population dose which is calculated to account for the continued contribution of internal and external radiation dose to the population in the vicinity of SRS. This dose is calculated exclusively as the result of radioactivity in the environment due to operations at SRS. The calculated population doses in this report include an estimate of environmental dose commitment for a 100-year period following the release of radioactivity.

The Weather INformation and Display (WIND) System is used to calculate offsite doses resulting from nonroutine releases from SRS. The internal dose estimates use the 50-year committed effective dose equivalent factors from ICRP Publication 30 and the breathing rate of an active adult. The models on the WIND System which provide the individual dose estimates are PFPL, a Gaussian puff/plume model, and 2DPUF, a sequential puff model. External doses from a plume or a puff that emits gamma radiation are also calculated by PFPL.

Modeling the Dilution and Transport of Radioactivity Released to Surrounding Streams

Radioactive materials released to SRS streams flow to the Savannah River. Although many of the radionuclides are measurable at the point of release, they fall below the minimum detectable concentration after dilution with river water. Only tritium oxide

Weather INformation and Display (WIND) System

and trace amounts of ^{90}Sr and ^{137}Cs are routinely detected in the river. To account for the offsite doses from all releases to the streams, it is necessary to employ an analytical model.

The radioactive materials released into the streams, like those released to the atmosphere, become involved in complex physical, chemical, and biological processes. Some of these processes involve dilution, while others involve physical or biological reconcentration. Transport of the radioactive materials released in liquid effluent then follow various pathways to man. A simplified representation of the more important transport pathways is shown in Figure 2-4 [ICRP65]. Before 1987, dose calculations for the irrigation water pathway were not included because no use of river water for irrigation downriver from SRS was known. However, because irrigation along the river by a small farming operation is a possibility, potential doses via this pathway were calculated for 1988.

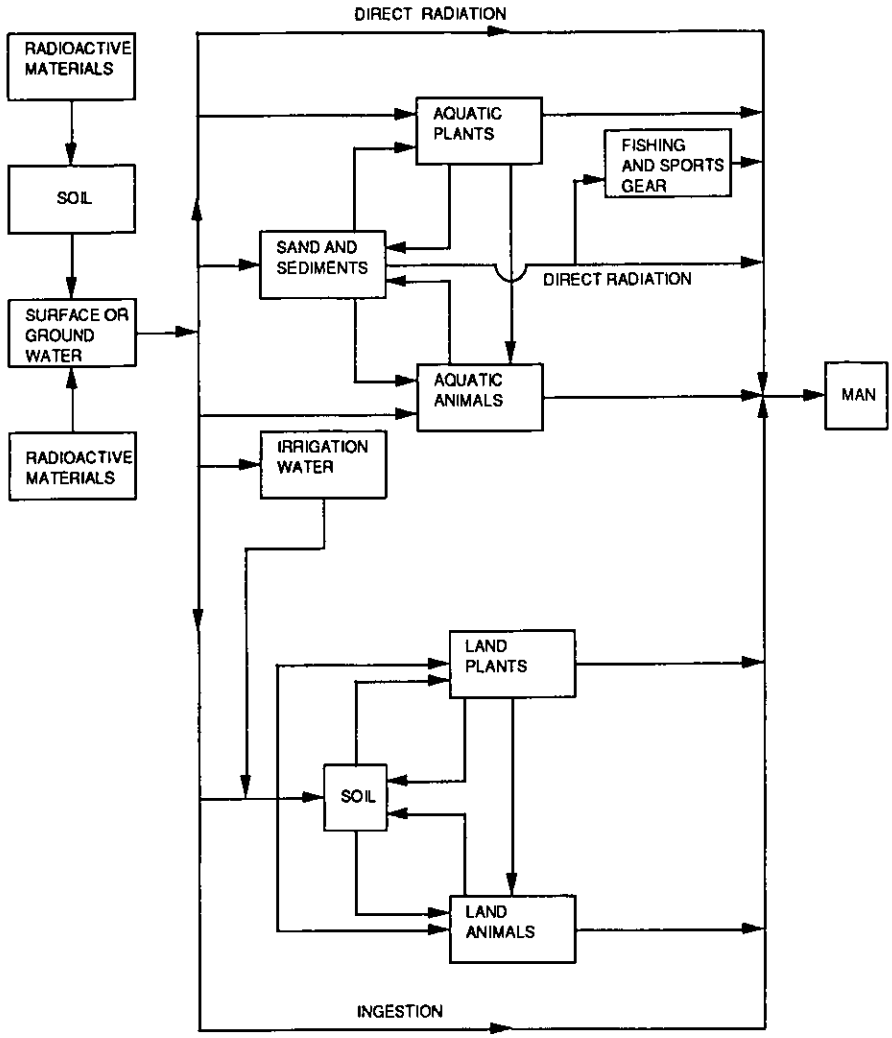


Figure 2-4. Simplified pathways between radioactive materials released to the ground or to surface waters and man

Flow-Rate Data. Dilution of radioactive materials in the river is based on continuous flow-rate measurements made at SRS by the United States Geological Survey (USGS). The average river flow rate in 1988 was about 5,151 ft^3/sec and represents 50% of the 1987 flow rate of 10,328 ft^3/sec. The flow rate varies annually, depending on the amount of rainfall in the river watershed area and the quantity of water released by Thurmond Lake Dam (formerly Clark Hill Dam).

Dose Calculations for Stream Releases. Calculation of offsite individual and population dose commitments due to liquid releases of radioactivity from SRS are provided by the LADTAP program. Annual measured releases of radioactivity to the river, average river flow rates, population data, data for sports and commercial fish harvests, community water consumption, and recreational use of the river are all used in the LADTAP program [Tu83; Tu83b]. The data used in these calculations, as well as human consumption rates for water and fish, are shown in Tables 2-2, 2-3, 2-5, 2-6, and 2-7 of Vol. II.

1988 HIGHLIGHTS

- Internal dose factors for adults, which are the only internal dose factors available that incorporate the new ICRP methodology, are used for calculating doses for all age groups. However, age-specific intake rates of food and water have been used in the dose calculations.
- NRC computer programs developed for the nuclear industry are used for calculating offsite doses to the public.
- Predictions of atmospheric transport of released radionuclides use meteorological data measured continuously at seven onsite meteorological towers and at a 1,200-ft television transmitting tower located 30 km (18.8 miles) northwest of the geometric center of SRS.
- The average Savannah River flow rate in 1988 of 5,151 ft^3/sec was 50% less than the 1987 Savannah River flow rate of 10,328 ft^3/sec.

Part II

Environmental Monitoring Programs

3
Air Monitoring Program

SUMMARY—Results of radiological and nonradiological monitoring of atmospheric emissions, environmental gamma radiation measurements made with TLDs, and ambient air quality measurements of total suspended particulates, sulfur dioxide, oxides of nitrogen, and ozone are presented in this chapter.

Airborne radioactive materials are measured by analysis of filter papers, charcoal filters, and tritium desiccants located at monitoring stations on the site, around the plant perimeter, and at distances of 25 and 100 miles. The major gamma-emitting radionuclide routinely detected in air was naturally occurring ^{7}Be.

The offsite radiation dose commitments from radioactivity released to the atmosphere from SRS facilities during normal operations were calculated for individuals closest to the plant site by potential pathways, and for populations out to a distance of 80 km (50 miles) from the center of the site.

The highest potential dose commitment from atmospheric releases of radioactivity to a hypothetical person at the plant boundary was 0.46 mrem (0.0046 mSv) which is 0.46% of the DOE Revised Interim Radiation Dose Limit of 100 mrem and 0.2% of the annual dose commitment of 295 mrem (2.95 mSv) received from natural radiation sources.

Atmospheric emissions from the five coal-fired power plants located at SRS that burned a total of 373,935 tons of coal in 1988 were within applicable standards. A comparison of data from SRS ambient air monitoring stations with Georgia and South Carolina standards clearly shows that air quality in the SRS area is within EPA standards.

RADIOLOGICAL MONITORING

Atmospheric Emissions

Description of Monitoring Program. Concentrations of radioactive materials in the air are measured at six monitoring stations on the site, 13 monitoring stations around the plant perimeter, and 12 stations at distances of approximately 25 miles from the center of the plant (called 25-mile-radius stations). The stations at the plant perimeter and the 25-mile-radius stations are strategically located to permit continuous sampling within each 30° sector around SRS. The placement of each monitoring station increases the probability of detecting any routine or nonroutine release of airborne radioactivity from the Savannah River Site (SRS) regardless of wind direction. Air filters are collected weekly for analysis (see Chapter 1). The locations of the air monitoring stations are shown in Figure 3-1 (Figure 3-1, Vol II).

Additional air monitoring stations located at Savannah and Macon, GA, and at Columbia, and Greenville, SC (100-mile-radius stations), are so distant from SRS that the effect of SRS operations at these locations is negligible. The stations serve as reference points for determining background radioactivity levels from natural sources and from worldwide fallout. Distant air monitoring stations are shown in Figure 3-2, Vol. II.

Airborne radioactive materials are measured by analysis of filter papers, charcoal filters, and tritium desiccants placed at the monitoring stations for specified periods. The filter papers and charcoal filters remain in place for one week; tritium desiccants are changed every two weeks (see Chapter 1).

Applicable Standards. The guides for concentrations of radionuclides in air are given in DOE Draft Order 5400.xx (Rev.10/10/88). These guides are based on recommendations in Publications 26 and 30 of the International Commission on Radiological Protection [ICRP77; ICRP79].

The guides for radioactive concentrations are designated as Derived Concentration Guides (DCGs). The DCG for a radionuclide is defined as the air concentration of that radionuclide that will give a 50-year dose commitment of 100 mrem if breathed continuously for one year. The DCGs for radionuclides released to the atmosphere from SRS are listed in Table 3-1.

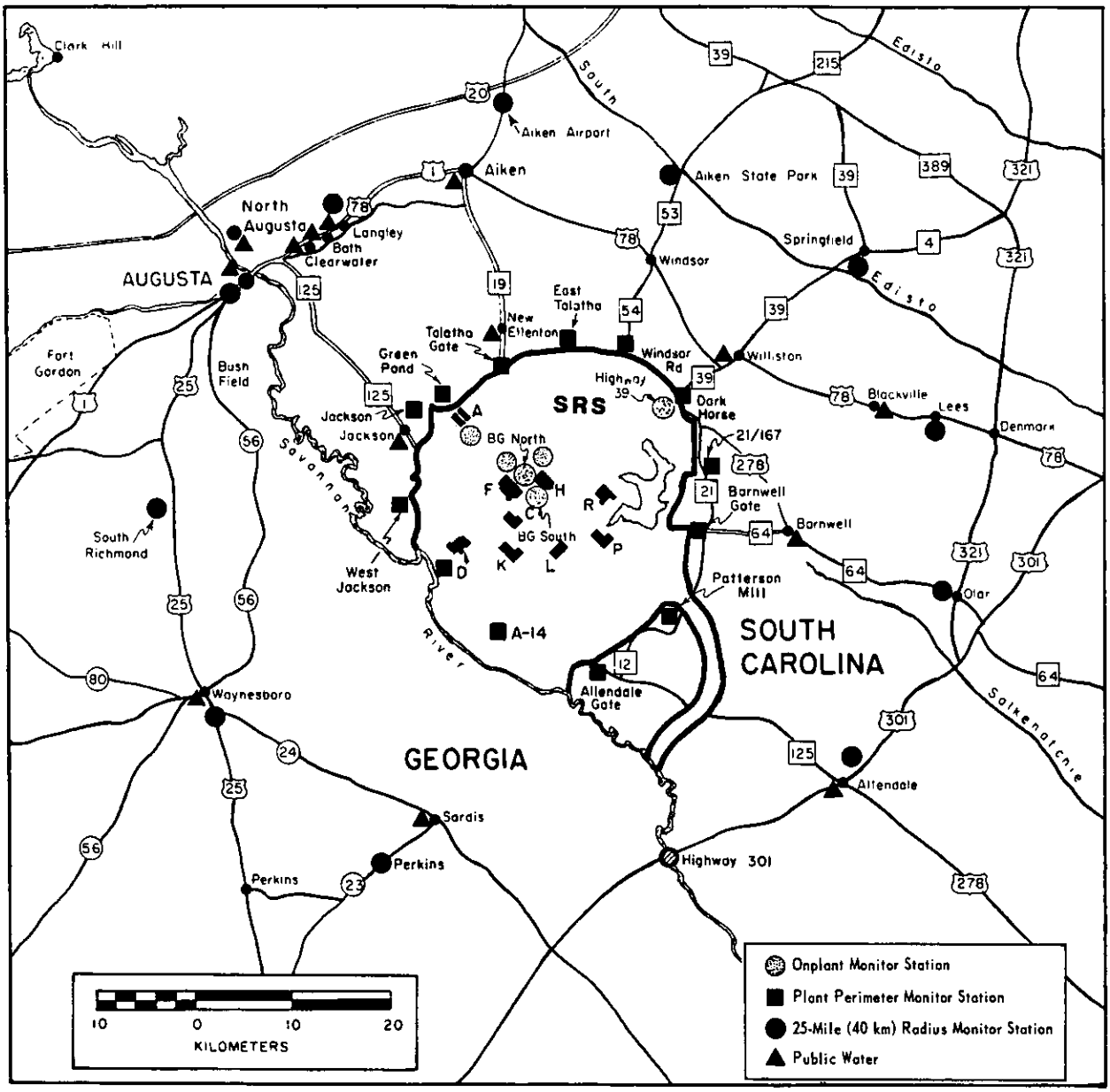


Figure 3-1. Locations of air monitoring stations

Table 3-1. DOE Derived Concentration Guides for Air (pCi/m³)[a]

H-3	100,000	Nb-95	3,000	Ce-141	1,000
C-14	6,000	Ru-103	2,000	Ce-144	30
Co-58	2,000	Ru-106	30	U-235	0.1
Co-60	80	I-129	70	U-238	0.1
Kr-85m	100,000	I-131	400	Pu-238	0.03
Kr-85	300,000	Xe-131m	400,000	Pu-239	0.02
Kr-87	20,000	Xe-133	300,000	Am-241	0.02
Kr-88	20,000	Cs-134	200	Cm-242	0.7
Sr-89	300	Xe-135	100,000	Am-243	0.02
Sr-90	9	Cs-137	400	Cm-244	0.04

[a]DOE Draft Order 5400.xx (Rev. 10/10/88) for soluble forms.

The revised DOE interim standards also include the EPA National Emission Standards for Hazardous Air Pollutants (NESHAP), "Standards for Radionuclides (40 CFR 61)," which apply to federal facilities. The NESHAP standards state that radioactive air emissions shall not result in a whole body dose greater than 25 mrem/year to any member of the public.

Changes in 1988 Program. The Hwy 39 air sampling station has changed from an onplant monitor station to a plant perimeter monitor station. A plant perimeter station is a more appropriate description since it is less than 0.5 miles from the plant perimeter, and over 10 miles from the nearest operating facility.

Monitoring Results. Atmospheric monitoring results are presented in Table 3-1, Vol II. The small contribution of particulate radioactivity from releases at SRS was not detectable at any of the site boundary monitoring stations. Tritium was the only radionuclide of site origin that was routinely detected in offsite air. The concentrations of all particulate radioactivity and tritium were only small percentages of the DCGs for air.

The small amount of particulate alpha and beta-gamma radioactivity released to the atmosphere, primarily from the F- and H-Area facilities, is generally obscured in the area surrounding SRS by worldwide fallout levels. The plant perimeter, 25-mile-radius, and 100-mile-radius sample groups had essentially the same average particulate alpha and nonvolatile beta concentrations as shown in Table 3-2.

These results indicate a slightly higher nonvolatile beta average for the "onplant" location group but are within ranges observed in previous years. The maximum onplant alpha concentration of 20 fCi/m³ was detected in an air sample from the A-Area sampling location, while the maximum onplant nonvolatile beta concentration of 160 fCi/m³ was detected in an air sample from the H-Area sampling location. The maximum alpha concentration of 20 fCi/m³ was elevated as a result of naturally occuring radon in a sample. The sample was inadvertantly discarded before a follow-up count could be made.

Table 3-2. Average activity concentrations (fCi/m3)[a]

	1988		1987	
Location	Alpha	Beta	Alpha	Beta
Onplant	1.2	20	1.1	28
Plant Perimeter	1.2	18	1.0	17
25-Mile Radius	1.1	17	1.0	16
100-Mile Radius	1.3	17	1.2	15

[a]1,000 fCi/m³ = 1 pCi/m³

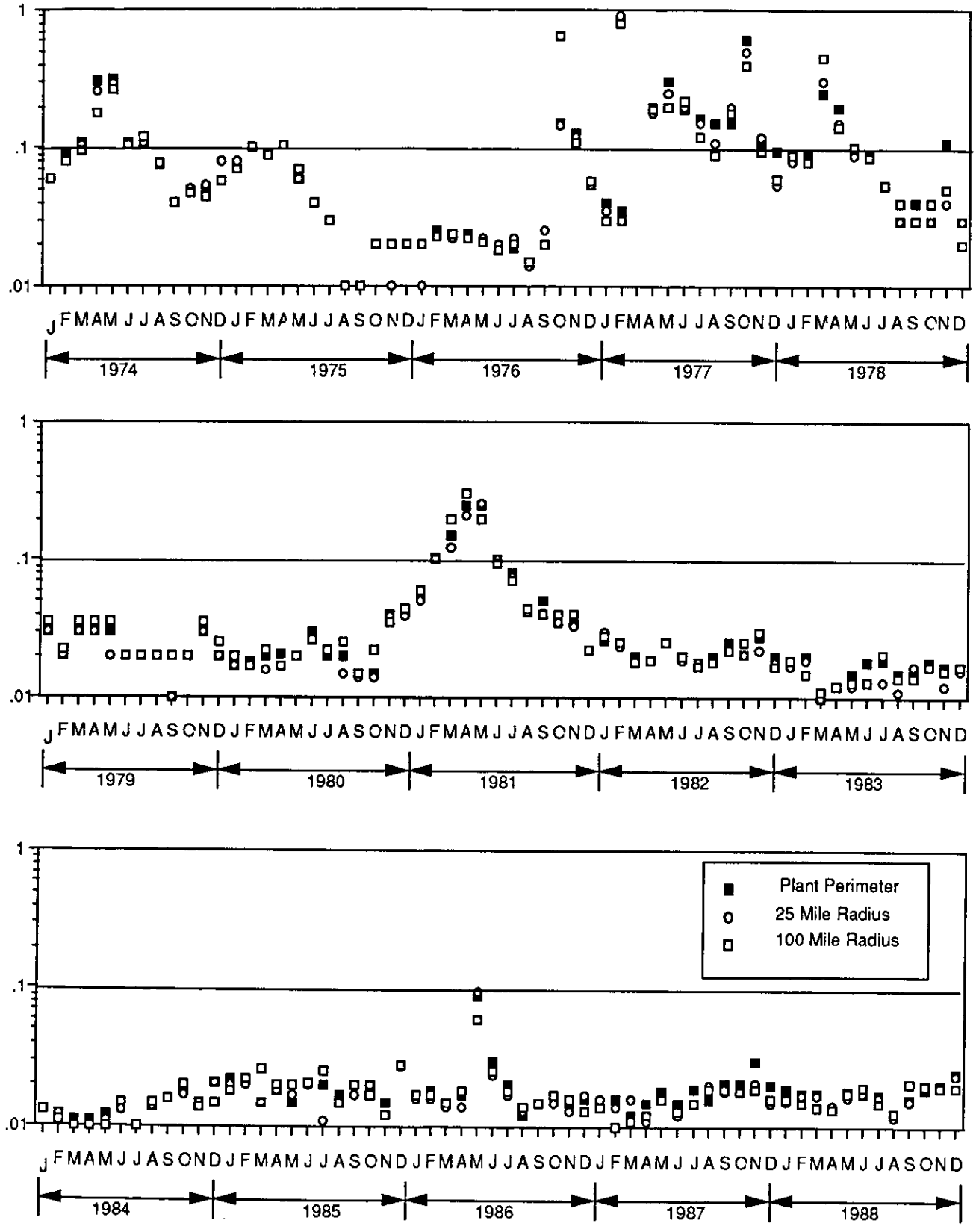


Figure 3-2. Average beta concentration in air (pCi/m³)

The historical influence of fallout from weapons tests on particulate nonvolatile beta activity in air is shown in Figure 3-2. Elevated nonvolatile beta concentrations were observed at all locations after atmospheric weapons testing was resumed during September 1961, and after atmospheric testing of nuclear weapons by nonparticipants in the 1962 atmospheric testing moratorium.

Table 3-4. Average tritium concentrations in the SRS vicinity

Location	1988 Tritium (pCi/m³)	1987 Tritium (pCi/m³)
Onplant	840	1,000
Plant Perimeter	54	81
25-Mile Radius	17	25
100-Mile Radius	12	9.9

Some increase in nonvolatile beta radioactivity in air has also generally occurred at all locations in the spring as a result of the mixing of the stratosphere with the troposphere. Depending on prevailing meteorological conditions, this phenomenon is usually observed between January and June.

The major gamma-emitting radionuclide routinely detected in air was ^{7}Be, which is naturally formed by the interaction of cosmic rays with oxygen and nitrogen in the upper atmosphere. In 1988, concentrations of naturally occurring ^{7}Be ranged from below the lower limit of detection (LLD) to 300 fCi/m³.

No significant difference was noted between average measurements of plutonium in air at the plant perimeter and offsite locations as shown in Table 3-3.

Higher values of plutonium were detected at the onsite monitoring stations near F and H Areas. Concentrations of ^{238}Pu ranged from below the LLD to 6,300 aCi/m³ at the F-Area sampling station. The 1988 maximum ^{238}Pu concentration is higher than the 1987 maximum concentration of 220 ± 28 aCi/m³. This elevated concentration is due to a plutonium release in January 1988 (see Chapter 9, Vol. I). Plutonium-239 concentrations ranged from below the LLD to 980 ± 45 aCi/m³ also at the F-Area monitoring station. This 1988 maximum concentration is greater than the 1987 maximum concentration of 93 ± 11 aCi/m³. This elevated concentration is also due to the plutonium release in January 1988. An elevated maximum concentration of 36 ± 3.9 aCi/m³ was detected from the 100-mile-radius monitoring station composite sample from Columbia, SC. This 1988 maximum ^{238}Pu concentration was four times higher than the 1987 maximum 100-mile-radius concentration. The 1988 maximum concentration data is suspected to be anomalous since gross alpha concentrations of the 100-mile-radius samples were within normal ranges during that time period and the plant perimeter and 25-mile-radius concentrations were also within normal ranges during that time period.

Table 3-3. Average plutonium concentrations in the SRS vicinity (aCi/m³)[a]

Location	Pu-238	Pu-239
Onplant	175	34
Plant Perimeter	0.70	1.9
25-Mile Radius	0.87	1.7
100-Mile Radius	3.6	3.1

[a]1,000,000 aCi/m³ = 1 pCi/m³

SRS-released tritium was detected at offsite monitoring stations and shows a decreasing trend with distance from the site as shown in Table 3-4.

Onsite tritium oxide concentrations in air ranged from 19 to 6,400 pCi/m³. The maximum value was detected at the H-Area sampling station. The 1988 maximum tritium concentration from the onplant sampling stations was less than the 1987 maximum concentration of 7,200 pCi/m³. Averge tritium concentrations at the plant perimeter and the 25-mile-radius monitoring stations were within or less than previous year's ranges. The 100-mile-radius monitoring station 1988 average tritium concentration was slightly higher than the 1987 average.

Summary of 1988 Atmospheric Releases and Concentrations

Radioactivity released to the atmosphere from SRS facilities during normal operations is monitored at the source of release for all atmospheric effluents. Releases of radioactive materials to the atmosphere in 1988 are shown in Table 3-5 (Table 3-2, Vol. II). Gases and vapors are the major constituents of the releases and also contribute most of the offsite dose.

Table 3-5. 1988 Radioactive Atmospheric Releases and Concentrations

Nuclide	Curies Released at Emission Source	Calculated Avg. Conc. at Plant Perimeter pCi/m³
Gases and Vapors:		
H-3 (oxide)	2.88E+05	8.7E+01
H-3 (elemental)	1.74E+05	5.2E+01
H-3 (total)	4.62E+05	1.4E+02
C-14	2.40E+01	7.2E-03
Ar-41	2.95E+04	4.8E+00
Kr-85	1.02E+03	2.4E-01
Kr-85	2.40E+05	7.2E+01
Kr-87	1.36E+03	1.7E-01
Kr-88	1.61E+03	3.2E-01
Xe-133	6.97E+03	2.1E+00
Xe-135	2.98E+03	7.9E-01
I-129	6.30E-02	1.7E-05
I-131	4.96E-04	1.4E-07
Total	7.46E+05	
Particulates:		
Co-60	3.00E-06	8.2E-10
Se-75	2.00E-05	<5.5E-09
Sr-89,90	3.01E-03	8.2E-07
Zr-95	7.60E-04	2.1E-07
Nb-95	2.22E-03	6.1E-07
Ru-103	4.61E-04	1.3E-07
Ru-106	3.02E-02	8.3E-06
Cs-134	1.00E-04	2.7E-08
Cs-137	1.78E-03	4.9E-07
Ce-141	1.60E-05	4.4E-09
Ce-144	4.56E-03	1.3E-06
Os-185	3.00E-05	<8.2E-09
Total U	1.47E-03	4.0E-07
Pu-238	6.16E-04	1.7E-07
Pu-239	6.87E-04	1.9E-07
Cm-242,244	1.18E-04	3.2E-08
Am-241,243	6.70E-05	1.8E-08
Total	4.58E-02	

Tritium is the only radionuclide of SRS origin which is monitored and detected routinely in offsite air. However, noble gases, which are not routinely monitored at ambient air monitoring stations because of sampling and analysis complexity, are detectable offsite and compose a significant percentage of the annual dose received offplant from SRS atmospheric releases. The dose from noble gases is determined from calculated release quantities and standard dose calculation models. The average tritium oxide concentration detected from the onsite monitoring stations was 840 pCi/m³. The average onsite concentration in 1988 was 16% less than the 1987 average tritium oxide concentration of 1,000 pCi/m³. Tritium concentrations were also calculated using computer codes and standard meteorological dispersion equations [USNRC73]. The average concentration of tritium oxide measured at plant perimeter monitoring stations was 54 pCi/m³, which was 33% less than the 87 pCi/m³ calculated value shown in Table 3-5 (Table 3-2, Vol. II). Thus, it appears that the calculated concentrations for 1988 are a reasonably conservative estimation of the offsite effect of releases of radioactive materials.

Offsite Radiation Doses from Atmospheric Releases

Offsite radiation dose commitments from atmospheric releases during 1988 were calculated for individuals nearest to the site and for cumulative population dose to a distance of 80 km (50 miles) from the center of the site using meteorological data for the period 1982 through 1986. Table 3-6 (Table 3-3, Vol. II) shows the calculated dose commitments to the average individual at the plant perimeter by pathway. Dose commitments, based on annual releases, were calculated for persons with normal living habits residing at 320 locations equidistantly spaced along the plant perimeter. These dose commitments were then averaged over the 320 locations to give the values in Table 3-6.

Table 3-6. Average Individual Doses at the Plant Perimeter from Atmospheric Releases

By Pathway

Pathway	Average Individual Dose, mrem[a]	% of Total Dose
Plume	3.59E-02	20.56
Ground	2.03E-04	0.12
Inhalation	6.80E-02	38.95
Vegetation	4.47E-02	25.60
Milk	1.24E-02	7.10
Meat	1.34E-02	7.67
Total	1.75E-01	

By Radionuclide

Radionuclide	Average Individual Dose, mrem[a]	% of Total Dose
Gases and Vapors:		
H-3	1.15E-01	65.71
C-14	4.01E-03	2.29
Ar-41	2.94E-02	16.80
Kr, Xe isotopes	6.46E-03	3.69
I-129	1.54E-02	8.80
I-131	1.40E-06	0.00
Particulates:		
Ru-106	9.73E-04	0.56
Cs-137	4.69E-05	0.03
U-235,238	4.59E-04	0.26
Pu-238	9.42E-04	0.54
Pu-239	1.17E-03	0.67
Am-241,243	2.08E-04	0.12
Cm-242,244	6.09E-05	0.03
Total	1.75E-01	

[a] Committed effective dose equivalent

The dose commitment of 0.18 mrem (0.0018 mSv) to the average individual assuming average dietary intake is 0.18% of the DOE Revised Interim Radiation Dose limit of 100 mrem and 0.06% of the normal average dose of about 295 mrem (2.95 mSv) from natural radiation sources in the Central Savannah River Area (CSRA) [NCRP87a].

Table 3-7 (Table 3-4, Vol. II) presents the dose by pathway to a hypothetical individual located at the plant perimeter at the point of maximum exposure (at the southwest corner of SRS during 1988). With an assumed average dietary intake, the dose to this individual is 0.29 mrem (0.0029 mSv). If the maximum intake of all types of food (milk, meat, and vegetables) is assumed, the dose is 0.46 mrem (0.0046 mSv) which is 2.0% of the NESHAP standard of 25 mrem/year to a member of the public.

Doses were calculated for individuals within 80 km (50 miles) of the SRS at normal places of residence, and the individual doses were summed to obtain the collective (population) doses shown in Table 3-8 (Table 3-5, Vol. II). The population dose commitment calculated in this manner for the population of 555,100 within 80 km of the site in 1988 was 21.0 person-rem (0.21 person-Sv), which is equivalent to an average dose of 0.04 mrem (0.0004 mSv). This collective dose of 21.0 person-rem is 0.013% of the dose of 163,754.5 person-rem received annually by the 80-km-radius population from natural radiation sources.

Table 3-7. Maximum Individual Doses at the Plant Perimeter from Atmospheric Releases

By Pathway

Pathway	Average Consumption Maximum Individual Dose, mrem[a]	% of Total Dose	Maximum Consumption Maximum Individual Dose, mrem[a]	% of Total Dose
Plume	6.38E-02	21.77	6.38E-02	13.99
Ground	3.32E-04	0.11	3.32E-04	0.07
Inhalation	1.13E-01	38.57	1.13E-01	24.78
Vegetation	7.37E-02	25.15	1.96E-01	42.98
Milk	2.05E-02	7.00	5.77E-02	12.65
Meat	2.22E-02	7.58	2.57E-02	5.64
Total	2.93E-01		4.56E-01	

By Radionuclide

Radionuclide	Average Consumption Maximum Individual Dose, mrem[a]	% of Total Dose	Maximum Consumption Maximum Individual Dose, mrem[a]	% of Total Dose
Gases and Vapors:				
H-3	1.91E-01	65.17	3.04E-01	66.71
C-14	6.64E-03	2.27	1.40E-02	3.07
Ar-41	5.27E-02	17.98	5.27E-02	11.56
Kr,Xe isotopes	1.12E-02	3.81	1.12E-02	2.45
I-129	2.52E-02	8.60	6.46E-02	14.18
I-131	2.29E-06	0.00	5.11E-06	0.00
Particulates:				
Ru-106	1.60E-03	0.55	2.03E-03	0.45
Cs-137	7.69E-05	0.03	1.23E-04	0.03
U-235,238	7.59E-04	0.26	9.00E-04	0.20
Pu-238	1.55E-03	0.53	2.43E-03	0.53
Pu-239	1.94E-03	0.66	3.04E-03	0.67
Am-241,243	3.43E-04	0.12	5.41E-04	0.12
Cm-242,244	1.00E-04	0.03	1.58E-04	0.03
Total	2.93E-01		4.56E-01	

[a] Committed effective dose equivalent.

Environmental Gamma Radiation

Continuous measurements of the intensity of gamma radiation levels at and around SRS were made with thermoluminescent dosimeters (TLDs). In the unlikely event of a significant unplanned radioactivity release, these 452 monitoring stations would provide a quick and reliable method to determine external gamma radiation doses to population groups within an 8,000-square-mile area in the vicinity of SRS. Five Panasonic TLDs are placed at each station with a 90-day collection cycle (two TLDs are placed at inside building locations). The TLDs are placed at stations up to a 100-mile radius from SRS. The number of stations and their locations are shown in Table 3-9.

Changes to 1988 Monitoring Program. Complete conversion from SRS-designed TLDs to Panasonic TLDs was accomplished in 1988 (see Chapter 1). Two TLD locations were added to Z Area in October 1988.

Monitoring Results. Environmental gamma radiation fields vary significantly from one location to another because of differences in the terrestrial and cosmic components of natural background radiation. The differences are influenced by ^{238}U, ^{232}Th, and ^{40}K which are the primary components contributing to terrestrial natural background radiation.

Table 3-10 provides a comparison of 1988 TLD results with 1987 results. Summaries of all TLD results are presented in Tables 3-6, 3-7, 3-8, 3-9, and 3-10, Vol. II, and locations are shown in Figure 3-3, and Figure 3-4, Vol. II.

Table 3-8. 80-km Collective Dose - 1988 Atmospheric Releases

By Pathway

Pathway	Collective Dose person-rem[a]	% of Total Dose
Plume	1.65E+00	7.87
Ground	8.47E-02	0.40
Inhalation	8.76E+00	41.76
Vegetation	7.20E+00	34.33
Milk	1.74E+00	8.30
Meat	1.54E+00	7.34
Total	2.10E+01	

By Radionuclide

Radionuclide	Collective Dose person-rem[a]	% of Total Dose
Gases and Vapors:		
H-3	1.60E+01	76.23
C-14	5.73E-01	2.73
Ar-41	1.22E+00	5.81
Kr,Xe isotopes	4.28E-01	2.04
I-129	2.29E+00	10.91
I-131	3.37E-04	0.00
Particulates:		
Ru-106	9.48E-02	0.45
Cs-137	9.24E-03	0.04
U-235,238	6.59E-02	0.31
Pu-238	1.22E-01	0.58
Pu-239	1.52E-01	0.72
Am-241,243	2.69E-02	0.13
Cm-242,244	7.89E-03	0.04
Total	2.10E+01	

[a] Committed effective dose equivalent for a population of 555,100.

Table 3-9. TLD Stations and Locations

Location	TLD Stations
Onplant	110
Plant Perimeter	198
SC Cities and Towns	94
GA Cities and Towns	50

Radiation levels above background were detected at the fences around operating facilities. The maximum was 2.0 mR/day around H Area as a result of reflected radiation from process equipment or work being performed inside the area. The F-Area maximum was 0.52 mR/day.

Plant Perimeter Radioactivity Monitoring Stations. In addition to the general onplant, plant perimeter, 25- and 100-mile radius sampling stations, 12 unrelated plant perimeter monitor stations monitor gamma radiation levels and tritium concentrations. These stations supplement the site's emergency response capability by continuously measuring and periodically reporting gamma radiation levels and tritium concentrations from each 30° sectors around SRS. The gamma monitors are capable of detecting radiation levels from 10 μR/hr to 1,000 R/hr. Tritium ion chambers can detect tritium concentrations from 1×10^{-6} μCi/mL to 1×10^{-2} μCi/mL. Implementation of these monitoring stations is planned in 1989.

The monitors are housed in temperature-controlled buildings. Using a U.S. Geologic Survey satellite telemetry system, each monitoring station transmits data at least once per day. Should an emergency occur, the monitors can be set to transmit data at six-minute intervals. The data are transmitted to the WIND (Weather INformation and Display) system computers and integrated into the overall emergency response system.

NONRADIOLOCICAL MONITORING

Atmospheric Emissions

Description of Monitoring Program. Five coal-fired power plants located at SRS

Table 3-10. Comparison of 1988 TLD Gamma Radiation Measurements with 1987 Results

Air Sampling Station Locations	No. of Locations	Maximum (mR/yr) 1988	Maximum (mR/yr) 1987	Minimum (mR/yr) 1988	Minimum (mR/yr) 1987	Average (mR/yr) 1988	Average (mR/yr) 1987
Plant Perimeter	13	91	135	40	47	58	73
1-Mile Intervals	79	124	135	47	40	62	69
25-Mile Radius	12	102	113	51	51	73	77
100-Mile Radius	4	131	124	66	62	99	95
Cities and Towns (South Carolina and Georgia)							
Inside Buildings	72	201	219	55	47	112	113
Outside Buildings	72	168	164	62	47	105	102

burned a total of 373,935 tons of coal in 1988. This is lower than the 452,980 tons of coal burned in 1987. The location, number of boilers and capacity of each boiler for each of these plants are listed in Table 3-11.

The four D-Area boilers use pulverized coal; all of the other boilers are stoker fed. The D-Area boilers also burn waste oil. The content of the coal delivered to the site for burning is determined by analyses for sulfur, carbon, ash, water, and Btu output.

There are six other onsite process stacks with major emissions of nonradioactive materials. They include three 313-M stacks and one 321-M stack in M Area and the two 291 stacks in the F and H Areas.

Applicable Standards. Nonradioactive atmospheric emissions from SRS stacks are regulated by permits issued by the South Carolina Department of Health and Environmental Control (SCDHEC), NESHAP subpart U and by the National Ambient Air Quality Standard (NAAQS) for particulate matter. Air emissions standards are listed in Table 3-12.

Monitoring Results. Atmospheric emissions of sulfur dioxide, oxides of nitrogen, and total suspended particulates from power plants at SRS were within applicable standards in 1988. Compliance with the sulfur dioxide (SO_2) emissions standard at power plants is determined by analysis of the coal received. The sulfur content of coal burned at SRS in 1988 averaged 1.1%, which yielded an average of 1.77 lb $SO_2/10^6$ Btu input. This is 51% of the South Carolina standard.

The day-to-day control of total suspended particulates and oxides of nitrogen is maintained by use of opacity meters in all SRS powerhouse stacks. These measurements indicated that SRS boilers were within limits more than 99% of the time in 1988.

Table 3-11. Power Plant Boiler Capacities

Power Plant Location	No. of Boilers	Capacity of Each Boiler 10^6 Btu/hr Input
A-Administration Area	2	71.7
D-Powerhouse Area	4	396
H-Separations Area	3	71.7
K-Reactor Area	2	194.5
P-Reactor Area	2	194.5

Compliance with standards for oxides of nitrogen and total suspended particulates is determined by air compliance tests. These tests conducted every two years by air emissions specialists testing under contracts issued by SRS. All SRS boilers were within compliance limits during the latest series of tests conducted in 1988.

A new regulation limiting the opacity of oxides of nitrogen went into effect in February 1986. As indicated in Table 3-12, the new

Table 3-12. Air Emission Standards

Sulfur dioxide	3.5 lb/10^6 Btu input
Total suspended particulates	0.6 lb/10^6 Btu input
Opacity	40%[a]

[a]Applicable for process stacks in existence prior to January 1, 1986, and powerhouse stacks built before February 11, 1971, when these standards became effective. For stacks that came on line after these dates, the standard is 20%.

Table 3-13. South Carolina and Georgia Air Quality Standards Compared to SRS Ambient Air Quality

Air Quality Standard	South Carolina[a]	Georgia	SRS Maximum	Percent Standard[b]
Sulfur dioxide ($\mu g/m^3$)				
3 hour	1300[c]	1300	196	15
24 hour	365[c]	365	73	20
Annual	80	80	39	49
Total suspended particulates ($\mu g/m^3$)				
24 hour	150	150	135	90
Annual geometric mean	50	75	29.6	59
Ozone (ppm)				
1 hour	0.12[d]	0.12	0.096	80
Nitrogen dioxide ($\mu g/m^3$)				
Annual	100	100	8	8

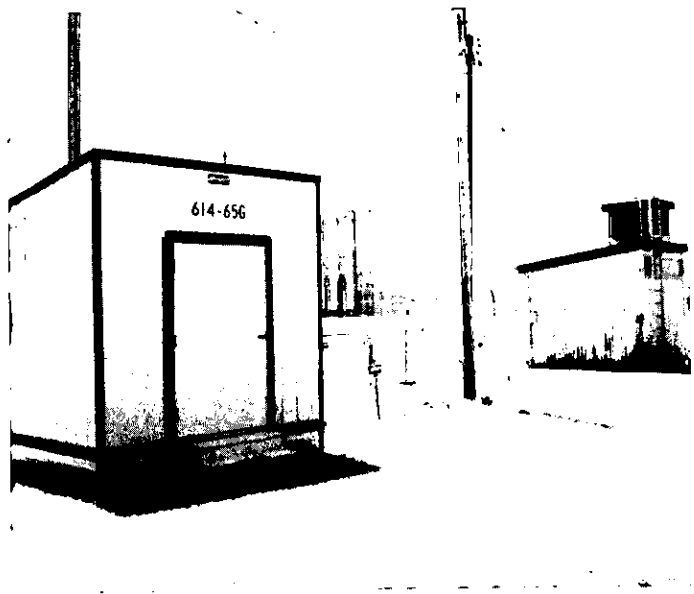
[a]Lead, carbon monoxide and gaseous fluorides are not monitored because the potential release is insignificant compared to the standard.
[b]Compared to the most restrictive standard.
[c]Not to be exceeded more than once a year.
[d]Not to be exceeded more than one day a year.

standard is 20%, with the exception of stacks that existed before January 1, 1986 and powerhouse stacks built before February 11, 1971. These existing stacks are subject to a 40% opacity limit. All SRS process stacks, including the four 300-M stacks and 291-F and -H stacks, are subject to the 40% limit. In 1988, all stacks met the 40% opacity requirement except for the 291-F stack, which occasionally exceeded the limit. Rework of the deteriorating acid absorption column in the 291-F stack reduced the opacity of the stack to borderline compliance. A number of programs (including a multi-million dollar absorber column control project) are being pursued to ensure that the opacity is below 40% on all occasions. The absorber column project is scheduled for completion in December 1989.

Ambient Air Quality

Description of Monitoring Program. The quality of air at SRS is monitored at several locations around the site for total suspended particulates, sulfur dioxide, oxides of nitrogen, and ozone. The operation of these stations is consistent with EPA and SCDHEC requirements. Additional monitoring of ambient air quality near SRS is performed by the states of South Carolina and Georgia as part of the network associated with the Clean Air Act Amendments of 1970.

Changes in 1988 Monitoring Program. One ambient air monitoring station, 614-36G, was re-



Ambient air monitoring stations

started after re-evaluation of the nonradiological air quality program.

Applicable Standards. A comparison of Georgia and South Carolina air quality standards are shown in Table 3-13.

Monitoring Results. Also listed in Table 3-13 are monitoring data from the SRS ambient air monitoring stations compared to the Georgia and South Carolina standards.

The locations of the SRS monitoring stations and analyses performed at each station are shown in Figure 3-5, Vol. II, and monitoring data are presented in Table 3-11, Vol II.

Measurements of state monitored air quality from the South Carolina and Georgia network in the vicinity of SRS are presented in Tables 3-12, and 3-13, Vol II. The measurements indicate that the air quality near SRS is within standards set by the EPA.

1988 HIGHLIGHTS

- Onsite tritium concentrations in air ranged from 19 to 6,400 pCi/m^3. The maximum value was detected at the H-Area monitoring station. Tritium was the only radionuclide of plant origin routinely detected offsite in air.
- No significant difference was noted between average measurements of gross alpha, beta, and plutonium in air at the site boundary and offsite. The highest values were detected onsite at the F- and H-Area monitoring stations.
- The maximum dose commitment to a hypothetical individual at the SRS boundary from atmospheric releases was 0.46 mrem (0.0046 mSv), or 0.46% of the DOE Revised Interim Dose Limit from prolonged exposure and 0.16% of the normal average dose of about 295 mrem (2.95 mSv) from natural radiation sources. The average dose commitment to a hypothetical individual at the SRS boundary from atmospheric releases was 0.18 mrem (0.0018 mSv), or 0.18% of the DOE Revised Interim Dose Limit from prolonged exposure and 0.06% of the average dose from natural radiation sources.
- Continuous measurements from 452 monitoring stations provide a quick and reliable method to determine external gamma radiation doses to population groups within an 8,000-square-mile area in the vicinity of SRS.
- The 12-station plant perimeter radioactivity monitoring systems are capable of continuously measuring gamma radiation from 10 μR/hr to 1,000 R/hr, and tritium levels from 1 x 10^{-6} μCi/mL to 1 x 10^{-2} μCi/mL.
- The sulfur content of coal burned at SRS in 1988 averaged 1.1%, which yielded an average of 1.77 lb $SO_2/10^6$ Btu input. This is 51% of the South Carolina standard.
- One ambient air monitoring station was returned to service in 1988, bringing the total number of monitoring stations to five.

4
Surface Water Monitoring Program

SUMMARY—The surface water monitoring program at SRS involves the sampling and analysis of water from the Savannah River, SRS streams, and seepage basins for both radioactive and nonradioactive constituents. This chapter also provides an inventory of tritium, liquid releases, and concentrations in 1988, and offsite radiation doses from liquid releases.

The chapter begins with a description and monitoring results of the radioactive monitoring program. Paddle wheel samplers continuously collect Savannah River samples above, adjacent to, and below SRS for analyses of alpha, nonvolatile beta, tritium and a variety of specific radionuclides. The release of tritium accounted for more than 99% of the total radioactivity introduced into the Savannah River from SRS activities during 1988.

Water samples, which were collected from seepage basins located in F, H, P, K, L, and C Areas, generally reflected concentrations observed in the wastewater releases to the basins. During 1988, to remain in compliance with state and federal orders, use of the F-, and H-Area Seepage Basins was discontinued. The tritium migrating from seepage basins represents 72% of the total SRS tritium released to streams.

The highest potential dose commitment from releases of radioactivity from SRS to the Savannah River to a hypothetical individual is 0.79 mrem (0.0079 mSv), which is 0.79% of the DOE Revised Interim Radiation Dose Limit of 100 mrem and 0.3% of the annual dose commitment of 295 mrem (2.95 mSv) received from natural radiation sources. The maximum dose received from use of the water supplies from the water treatment plants downriver of SRS was 0.13 mrem (0.0013 mSv) which is 3.3% of the EPA standard 4 mrem (0.04 mSv) to the body or any organ from public water supplies.

Nonradioactive materials and physical properties were measured in surface water collected at effluent outfalls from site facilities, at locations along the six site streams, and at three locations in the Savannah River. Effluents from SRS facilities discharge through 71 active SCDHEC-permitted, point source outfalls. Water and sediment samples from seven site stream locations, which were analyzed for 30 pesticides, herbicides, and polychlorinated biphenyls (PCBs) during 1988, had less than the minimum detectable concentrations. In addition, temperature profile surveys were conducted on the Savannah River and SRS streams as part of a comprehensive study of the thermal effects of SRS operations upon the waters of the state of South Carolina.

INTRODUCTION

The Savannah River flows along a 35-mile stretch of the western boundary of the Savannah River Site. Five major Savannah River Site (SRS) streams (Upper Three Runs, Four Mile Creek, Pen Branch, Steel Creek, and Lower Three Runs) feed into the river. The Savannah River and the contributing SRS streams are continuously sampled at strategic locations both downstream of production areas and downriver of stream effluent inlets to the Savannah River. These samples are analyzed for a large number of radioactive and nonradioactive constituents. The Savannah River is also monitored extensively by other groups including South Carolina Department of Health and Environmental Control (SCDHEC) and the Georgia Department of Natural Resources (GDNR).

RADIOLOGICAL MONITORING

Savannah River

Description of Monitoring Program. The Savannah River is continuously sampled with paddlewheel samplers at strategic locations above the SRS to obtain

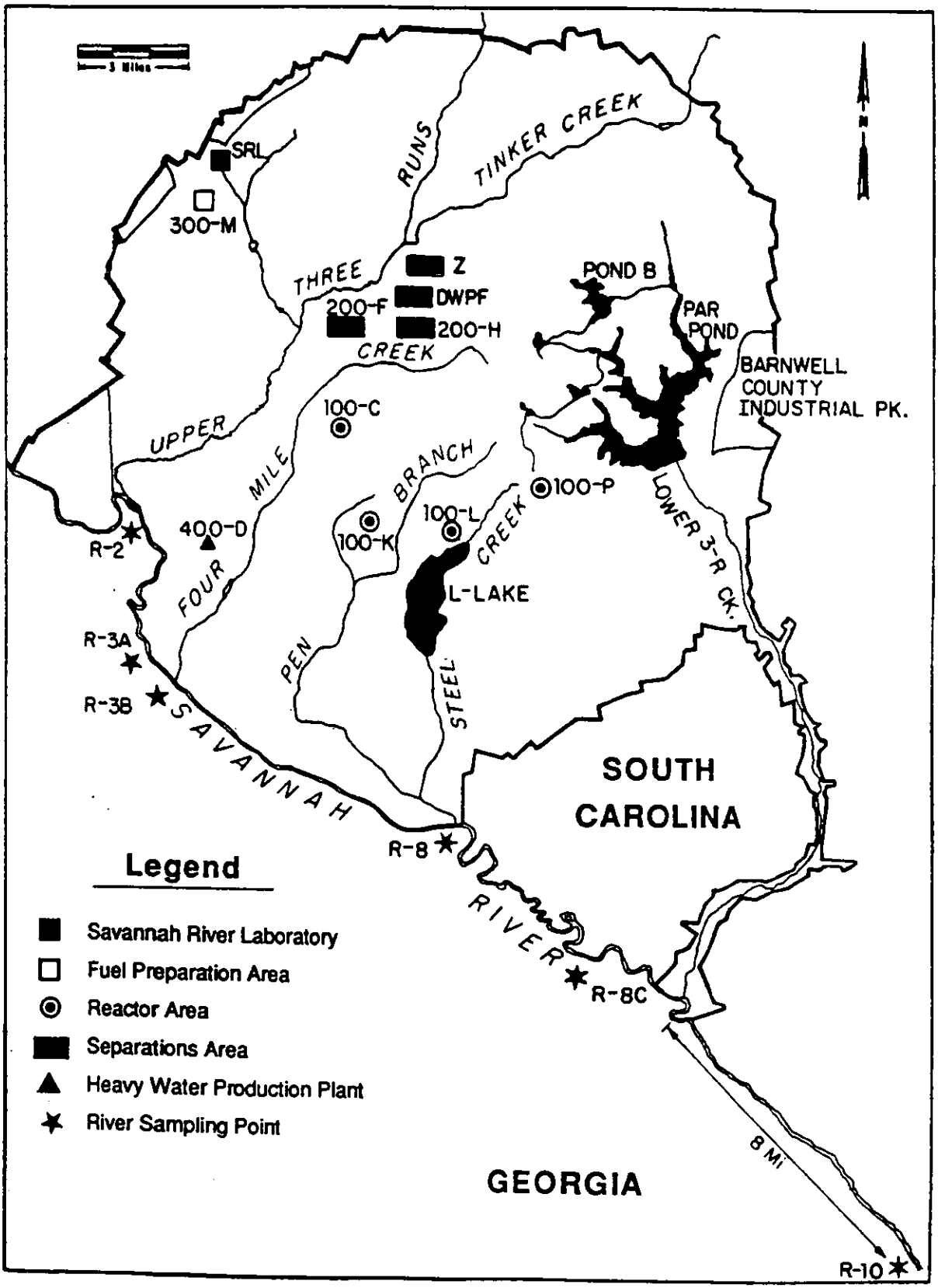


Figure 4-1. River sampling locations for radiological monitoring

background analysis data. Monitoring adjacent to and below SRS serves to measure radioactivity released to the Savannah River via SRS streams and Georgia Power Company's Plant Vogtle nuclear power plant. The river sampling locations are presented in Figure 4-1 (Figure 4-1, Vol. II). River flow is measured with United States Geological Survey (USGS) flow recorders at paddlewheel sampling stations R-2 above SRS and R-10 below SRS. The river radioactive sampling program consisted of six sampling locations in 1988.

Paddlewheel samplers continuously sample river water based on flow rate. In most cases the samples are collected weekly for analyses of alpha, nonvolatile beta, tritium and a variety of specific radionuclides. The frequency and type of analyses vary from location to location and are based upon the potential quantity and type of radioactivity likely to be present; changes in SRS operations and variations in radiological conditions can create variations as well.

Applicable Standards. DOE derived concentration guides (DCGs) for drinking water apply to SRS releases to the Savannah River. Table 4-1 gives the DOE DCGs for surface waters. EPA drinking water standards apply at the downriver water treatment plants.

Monitoring Results. In 1988, no measurable differences were detected between upriver and downriver alpha and beta concentrations in the Savannah River. Alpha and nonvolatile beta concentrations in river water samples at stations R-2 (upriver) and R-10 (downriver) were determined in both dissolved and suspended portions of the samples. Average concentrations of alpha activity were near or less than the minimum detectable concentration of approximately 0.3 pCi/L. Maximum nonvolatile beta concentrations for 1988 (excluding tritium) ranged 2.0 pCi/L to 3.3 pCi/L, compared to a range of 0.8 pCi/L to 4.1 pCi/L in 1987. River monitoring data are presented in Table 4-1, Vol. II.

The release of tritium accounted for more than 99% of the total radioactivity introduced into the Savannah River from SRS activities during 1988. Figure 4-2 (Figure 4-2, Vol. II) shows tritium releases at the source for the years 1984 through 1988. Tritium activity measured in transport in the river was 14,600 Ci in 1988, compared to 26,145 Ci in 1987. The average river flow in 1988 was about 5,151 ft^3/sec, which is 50% of the 1987 flow rate of 10,328 ft^3/sec. After dilution by SRS streams and the Savannah River, tritium concentrations in 1988 averaged 3.1 pCi/mL in the river below SRS at Highway 301 compared to 3.3 pCi/mL in 1987. Though the amount

Table 4-1. DOE Derived Concentration Guides for Drinking Water (pCi/L)*

H-3	2,000,000	Cs-134	2,000
C-14	70,000	Cs-137	3,000
Co-58	40,000	Ce-141	50,000
Co-60	5,000	Ce-144	7,000
Sr-89	20,000	U-235	600
Sr-90	1,000	U-238	600
Zr-95	40,000	Pu-238	40
Nb-95	60,000	Pu-239	30
Ru-103	50,000	Am-241	30
Ru-106	6,000	Cm-242	1,000
I-129	500	Am-243	30
I-131	3,000	Cm-244	60

*Department of Energy Draft Order DOE 5400.xx (Rev. 10/10/88) for soluble forms.

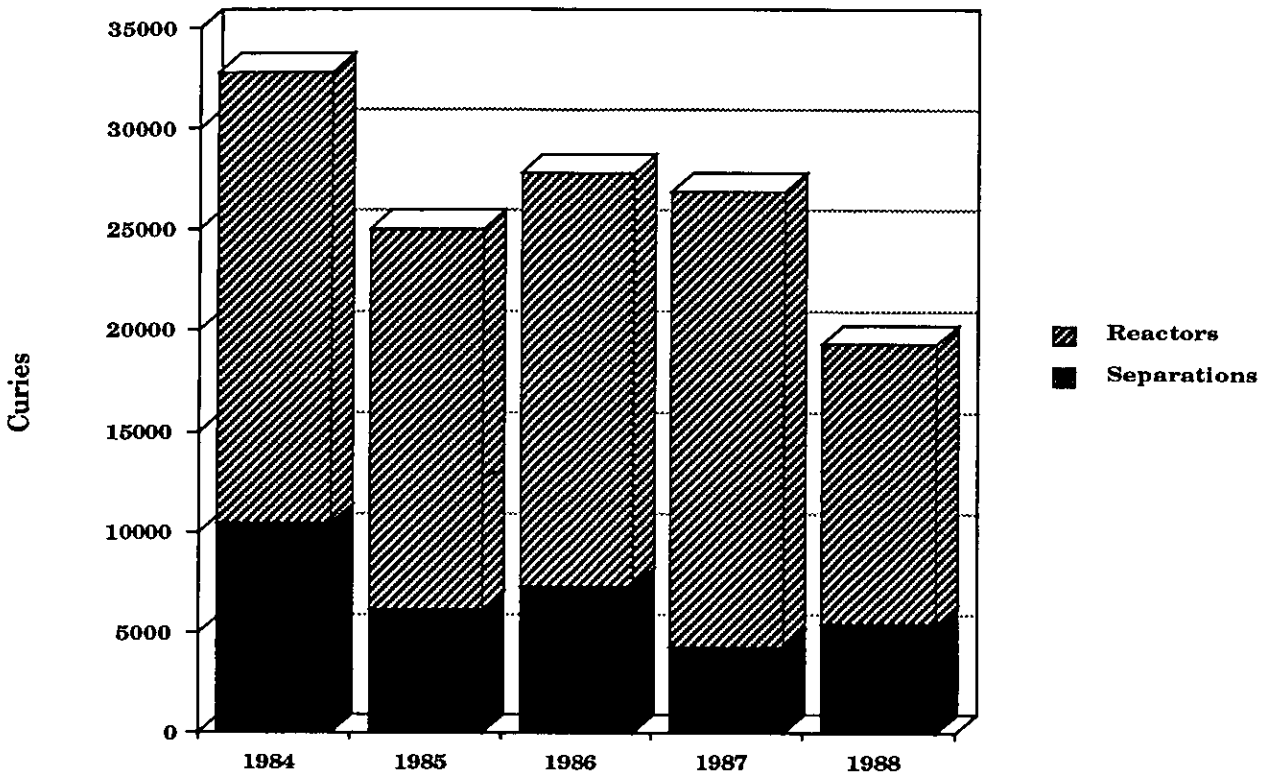


Figure 4-2. Tritium releases to the Savannah River 1984-1988

of liquid effluent tritium released in 1988 was lower than in 1987, the flow rate in 1988 was 50% lower compared to 1987 resulting in similar average tritium concentrations for the two years. As an example, if the total tritium released in 1988 was the same as in 1987, the average tritium concentration in 1988 would be significantly higher since the flow rate in 1988 was 50% lower than in 1987. Savannah River flows over the past 10 years are shown in Figure 4-3.

Savannah River water is routinely monitored for gamma-emitting radionuclides by concentrating the radioactivity in about 20 L of water on ion exchange columns. Ion columns are counted directly for gamma emitters and then chemically analyzed for strontium. The only radionuclide other than tritium detected in river water by routine analytical techniques was ^{90}Sr in trace quantities. Routine analytical techniques are described in Chapter 1. Other radionuclides may be detected by ultra-low-level analysis techniques as described in Chapter 9. Table 4-1, Vol. II also includes ^{137}Cs concentration analyses measured by SRL from Savannah River samples at R-10 (downriver from SRS) and at R-2 (upriver from SRS).

Water sample collection from a paddlewheel sampler on the Savannah River

The quantity of ^{90}Sr measured in transport in the river was 3.3 Ci in 1988. The average ^{90}Sr concentration at R-10 sample location below SRS was 0.72 pCi/L. The average ^{90}Sr concentration at the R-2 sampling location (above SRS) was 0.32 pCi/L.

Low levels of ^{239}Pu were detected at river sampling locations above, adjacent to, and below SRS. The maximum ^{239}Pu concentration was 15.88 ± 5.79 fCi/L (0.016 pCi/L) detected at R-10 below SRS. The maximum concentration observed above SRS was 13.10 ± 4.43 fCi/L (0.013 pCi/L). The 1988 average ^{239}Pu concentration at R-10 (below SRS) was 4.15 fCi/L, and the average ^{239}Pu concentration at R-2 (above SRS) was 3.55 fCi/L. Since the plutonium concentrations above and below the plant are essentially the same, the plutonium detected in the river water is not due to plant operations.

SRS Streams

Description of Monitoring Program. All streams located on the SRS site are continuously sampled at strategic locations to monitor radioactivity released in effluent water from SRS facilities. This comprehensive program consists of monitoring at 35 SRS stream locations. Stream sample locations are presented in Figure 4-4 (Figure 4-3, Vol. II). At most locations stream flows are determined with USGS flow recorders. Sampling is maintained on all major streams near Road A (Hwy 125), which provides convenient sampling locations near the SRS boundary. Continuous water samples from streams are generally collected weekly for analyses of alpha, nonvolatile beta, tritium, and numerous specific radionuclides. The analyses vary in frequency and type from one location to another and are based upon the potential quantity and type of radioactivity likely to be present. The sample locations and frequencies of analyses are sometimes changed in accordance with changes in SRS operations and variations in radiological conditions.

Applicable Standards. The DOE DCGs (Table 4-1) apply only at the site boundary, which is the Savannah River. DCGs, however, are reasonable references for gauging the impact of radioactivity in stream water. In addition, offsite surface water is sampled to provide background data (i.e., data from comparable waterways that are unlikely to have been significantly influenced by SRS operations). A good indication of background radioactivity concentrations in offsite surface water similar to SRS streams is provided by radioactivity measurements in the Edisto River, a small river in South Carolina that is similar in many characteristics to SRS streams. The maximum concentrations detected in the Edisto River during 1988 are shown in Table 4-2.

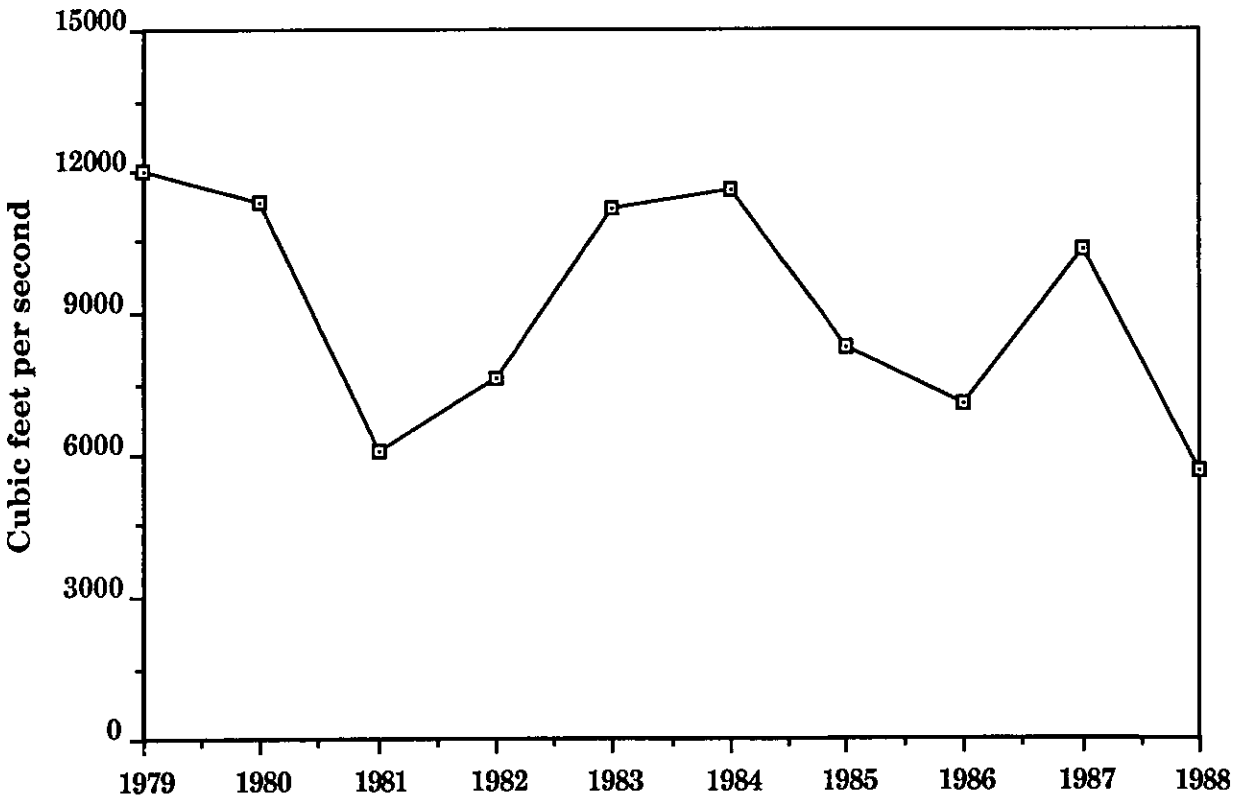


Figure 4-3. Average annual flow rates of the Savannah River at Highway 301 location

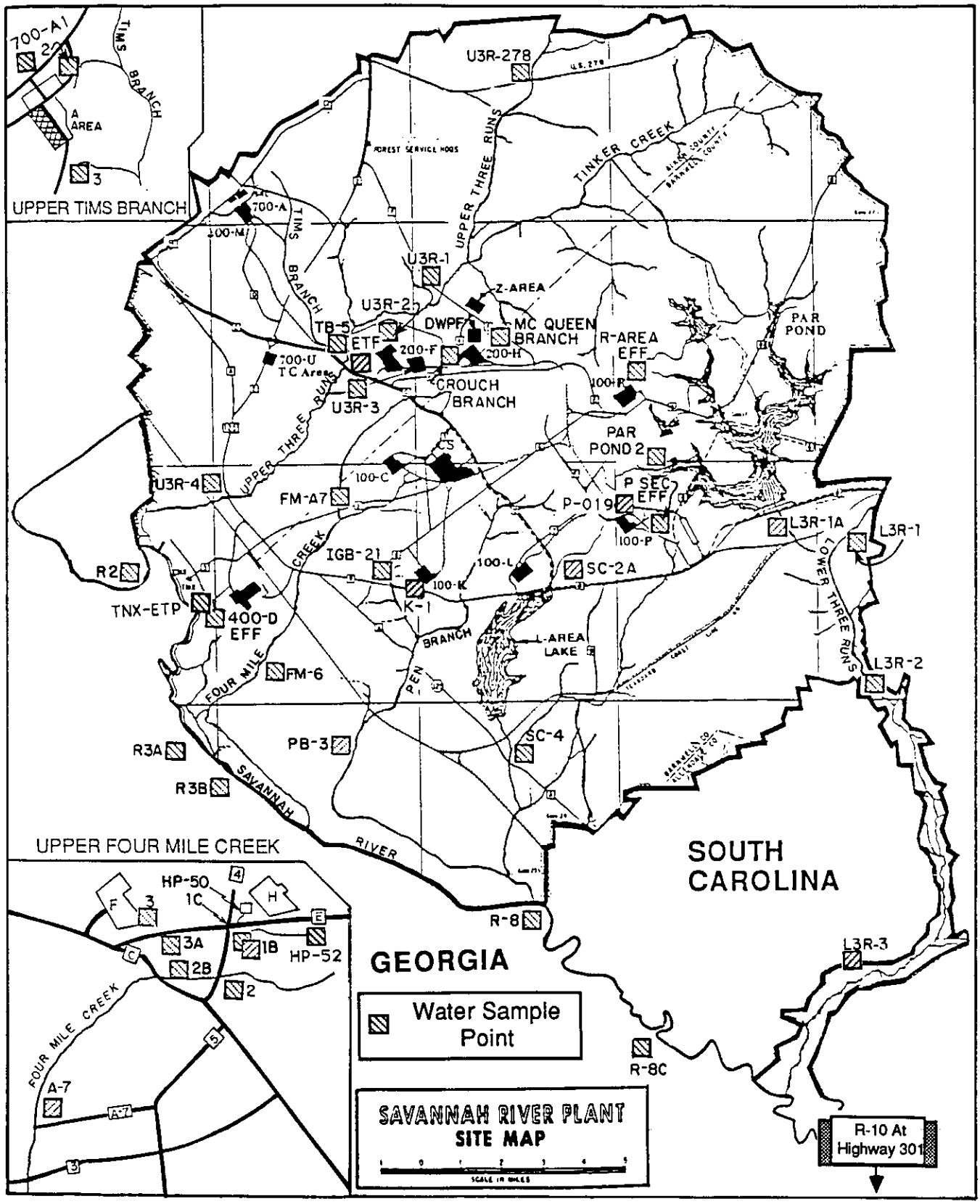


Figure 4-4. Stream sample locations on SRS

Table 4-2. Background Radioactivity Levels in an Offsite River[a]

Radiation type	Maximum concentration in 1988 (pCi/L)
Alpha	1.9
Nonvolatile beta	3.4
Tritium	750

[a]Based on measurements taken in the Edisto River, a small river that is similar to SRS streams.

Program Changes. A continuous sampler at location Upper Three Runs-2A (U3R-2A) was added due to the startup of the Effluent Treatment Facility (ETF). A continuous sampler has been added to the McQueen Branch creek below the S-Area effluent. Samples for both locations will be collected weekly.

Monitoring Results. Stream monitoring data are presented in Table 4-2, Vol. II. The use of background values and DCGs provide references for evaluating stream data. Table 4-3 presents maximum, average, and minimum radioactivity values for plant streams and the Edisto River. Direct liquid tritium releases to plant streams for the years 1984 through 1988 are represented in Figure 4-5 (Figure 4-4, Vol. II).

Tims Branch (TB) received effluents from M Area and SRL. SRL releases were negligible. The M-Area effluent contained small quantities of uranium. The average alpha and nonvolatile beta concentrations in the M-Area effluent were 4.1 pCi/L and 8.7 pCi/L, respectively. M-Area releases to TB flow downstream and enter Upper Three Runs Creek (U3R). Average 1988 alpha and nonvolatile beta concentrations in TB, before entering U3R, were 0.68 and 2.8 pCi/L, respectively.

Upper Three Runs Creek (U3R) receives stormwater runoff from parts of F and H Areas and the ETF. This is the largest contributor to radioactivity in U3R Creek. The maximum concentrations of alpha and nonvolatile beta for 1988 in U3R at the stormwater runoff were 23 pCi/L and 62 pCi/L, respectively. These maximum concentrations were well below the 1987 alpha and nonvolatile beta concentrations of 230 pCi/L and 11,000 pCi/L, respectively. The maximum tritium concentration was 14 pCi/mL from the ETF. This is greater than the 1987 measurement of 3.3 pCi/mL.

Beaver Dam Creek (BDC) received effluents from the heavy water rework and laboratory facilities in 400-D Area. Tritium oxide was the principal radionuclide released. The 1988 maximum concentration of tritium in BDC was 160 pCi/mL. The average tritium concentration in BDC for 1988 was 41 pCi/mL. Average alpha and nonvolatile beta concentrations in BDC for 1988 were 0.13 and 2.2 pCi/L respectively. These concentrations are within the ranges observed in the Edisto River.

Four Mile Creek (FMC) received effluents from fuel reprocessing facilities in F, H, and C Areas. C Reactor was not in operation in 1988 and, due to maintenance processes, released only 10.8 Ci of tritium in 1988. FMC also received tritium and ^{90}Sr migrating from

Table 4-3. Radioactivity in SRS Stream Water

Location[a]	Alpha (pCi/L) Max	Min	Avg	Nonvolatile Beta (pCi/L) Max	Min	Avg	Tritium (pCi/mL) Max	Min	Avg
Tims Branch	3.3	0.16	0.68	6.9	1.0	2.8	2.6	0.5	1.5
Upper Three Runs	3.6	-0.12	1.2	4.9	0.25	1.7	14	1.2	3.4
Beaver Dam Creek	0.6	0.33	0.13	5.2	1.1	2.2	160	0.82	41
Four Mile Creek	6.5	-0.28	0.81	170	0.21	37	2,900	92	934
Indian Grave Branch	0.86	0.16	0.32	1.6	0.44	1.1	12,000	56	3,298
Pen Branch	0.77	-0.20	0.13	4.8	0.62	2.0	96	1.7	48
Steel Creek	1.0	0.17	0.20	12	1.1	5.0	130	1.2	47
Lower Three Runs	1.1	-0.18	0.12	12	2.1	4.4	13	0.91	5.5
Control									
Edisto River	1.9	-0.09	0.64	3.4	-0.26	1.2	0.75	-0.14	0.33

[a] Does not include effluent sampling points.

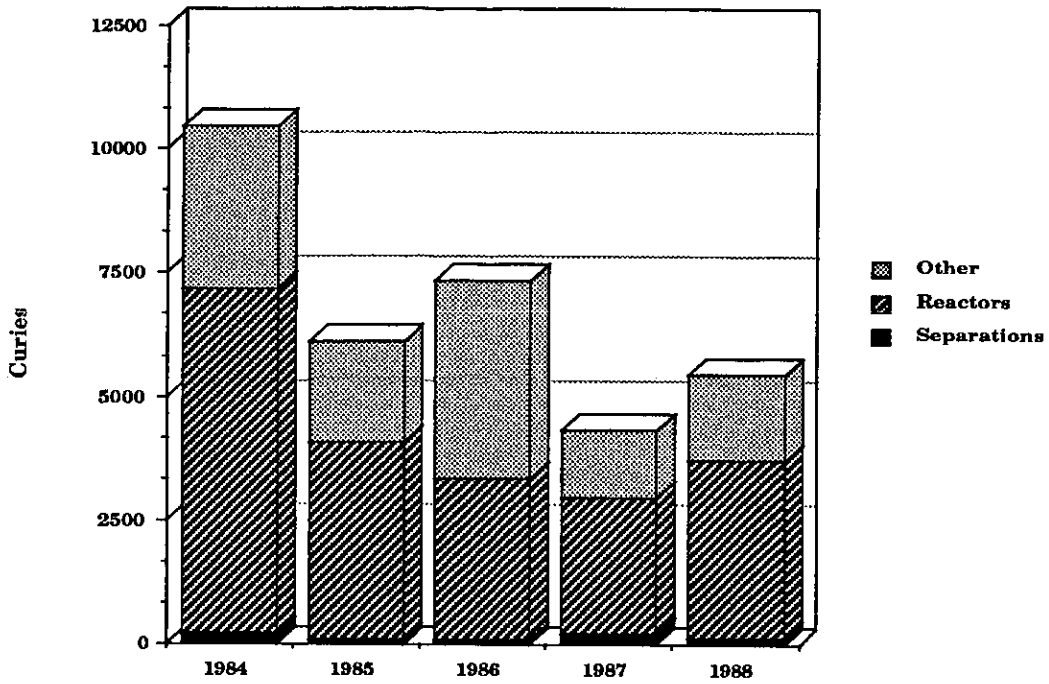


Figure 4-5. Direct tritium releases to site streams 1984-1988

the F and H Area seepage basins and the Radioactive Waste Burial Ground (RWBG).

The maximum tritium concentration in FMC in 1988 was 2,900 pCi/mL at FM-3A, which contained releases from F Area. This maximum concentration was lower than the maximum concentration in 1987 of 5,200 pCi/mL which was collected from a sample at FM-1C. The 1987 maximum was attributed to a tritium release from H Area.

The maximum of the averaged tritium concentrations of the individual FMC sampling points was 2,000 pCi/mL. After dilution by other waterways in FMC, the average concentration of tritium in FMC before entering the river (Road A) was 630 pCi/mL.

Elevated nonvolatile beta and ^{137}Cs activities were detected from the FM-1C sampling location to the FM-3 sampling location. The elevated activity resulted from a discharge of contaminated water from the H-Area Retention Basin. The release of 27 mCi of ^{137}Cs occurred in July 1988 (see Chapter 9). Maximum concentrations of nonvolatile beta ranged from 150 pCi/L at FM-2B to 170 pCi/L at FM-2. Maximum ^{137}Cs and ^{134}Ce (which often accompanies ^{137}Cs) concentrations of 3.7 pCi/L and 31 pCi/L respectively were detected at FM-6.

Indian Grave Branch (IGB) receives tritium migration from the K-Reactor containment basin. IGB flows into Pen Branch (PB) which also receives heat exchanger cooling water from K-Reactor Area. The maximum tritium concentration was 12,000 pCi/mL at sampling location IGB-21, which is downgradient from the containment basin. After dilution, the maximum tritium concentration measured in PB at Road A was 96 pCi/mL. Alpha and nonvolatile beta concentrations in PB at Road A were at or near background levels.

Table 4-4. Steel Creek Monitoring Data

Analysis	1986 Max	1986 Avg	1987 Max	1987 Avg	1988 Max	1988 Avg
Alpha, pCi/L	0.78	0.15	0.41	0.10	0.43	0.07
Nonvolatile Beta, pCi/L	0.3	2.4	3.5	2.0	4.3	2.2
Tritium, pCi/mL	0.7	2.5	4.5	2.8	4.5	2.7
Sr-89,90, pCi/L	0.75	0.15	0.51	0.11	2.4	0.57

Steel Creek received radioactive releases from the migration of tritium from P-Area Seepage Basin and from effluents from L Area. These releases enter L Lake, which overflows to Steel Creek near Road A. Most radionuclide concentrations in Steel Creek below L Lake represent no-

table decreases from their 1985 levels. The decreases likely resulted from the increased flow of river water used in L Reactor. Maximum and average concentrations for Steel Creek are presented in Table 4-4.

Par Pond receives P-Reactor heat exchanger cooling water and other effluents from P Area. Par Pond also receives all storm sewer outfalls from the deactivated R Area and from a few storm sewers from P Area. The average concentrations detected in Par Pond water in 1988 were 0.06 pCi/L of alpha, 6.3 pCi/L of nonvolatile beta, and 8.5 pCi/mL of tritium.

The overflow from Par Pond goes to Lower Three Runs Creek (L3R). Maximum concentrations in L3R at Road A were 0.42 pCi/L of alpha, 6.1 pCi/L of nonvolatile beta, and 4.5 pCi/mL of tritium. These concentrations for 1988 were similar to 1987 maximum concentrations.

There were no radioactive releases from TNX Area. Radioactivity concentrations in the TNX-Area outfalls were at or near background ranges.

Seepage Basins

Description of Monitoring Program. Seepage basins are shallow, earthen excavations used to receive wastewater containing low concentrations of chemicals and radionuclides. The wastewater seeps downward through the sides and floor of a basin to the shallow groundwater. After mixing with the groundwater, the contaminants generally flow slowly in a horizontal direction, eventually outcropping into a surface stream. During its slow travel through the soil, the wastewater loses some of its contaminants by precipitation, filtration, adsorption, ion exchange, and radioactive decay [St83].

Water samples from seepage basins located in F, H, P, K, L, and C Areas generally reflect concentrations observed in the wastewater released to the basins. The settling basin at 300-M Area was taken out of service in July 1985 when the Liquid Effluent Treatment Facility (LETF) was placed in operation. Wastewater is released to Tims Branch after treatment in the LETF. The results of seepage basin sample analyses are presented in Table 4-3, Vol. II, and the seepage basin locations are shown in various figures in Vol. II. Figure 4-6 (Figure 4-5, Vol. II) shows tritium migration from seepage basins for the years 1984 through 1988.

In November 1988, to comply with state and federal regulations, use of the F-, and H-Area Seepage Basins was discontinued. The M-Area Seepage Basin was taken out of service in July 1985 and sampling at

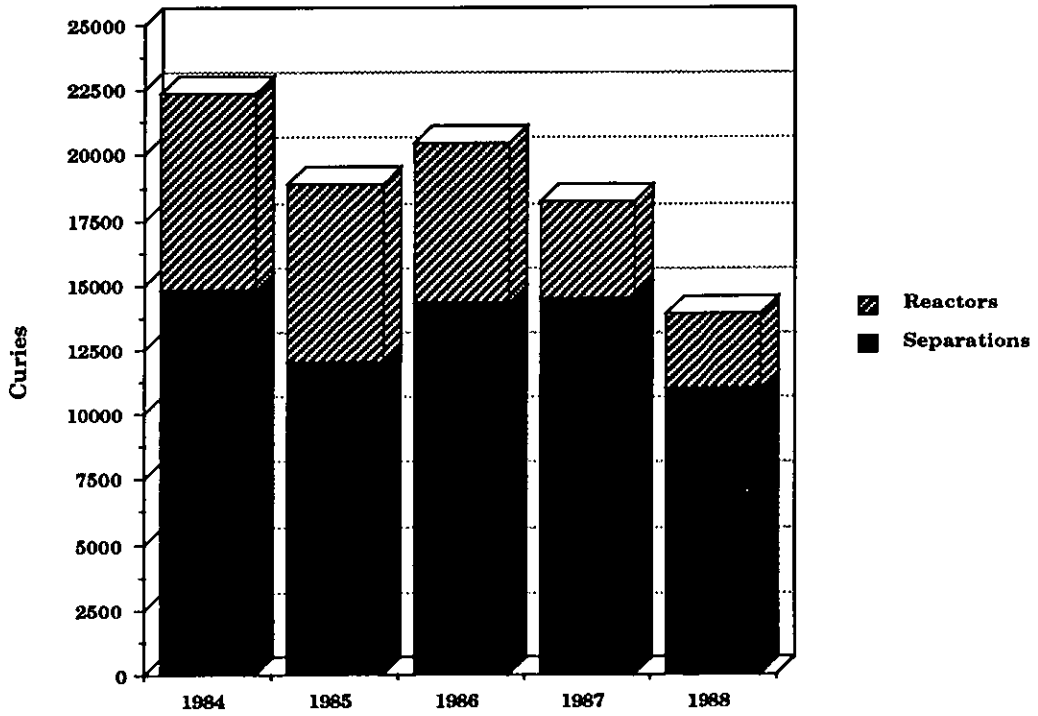


Figure 4-6. Tritium migration from seepage basins 1984-1988

the M-Area Seepage Basin was discontinued in August 1988. Monitoring at the F- and H-Area Seepage Basins will continue until the basins are dry and until it is determined that sampling is no longer required.

Migration of Radioactivity from F- and H-Area Seepage Basins and K-Area Containment Basin. Tritium was the only radionuclide detected migrating from the K-Area Containment Basin to Pen Branch. Weekly flow measurements combined with tritium concentrations measured in Indian Grave Branch (a tributary of Pen Branch) indicated migration of 2,780 Ci in 1988. This quantity represents a 23% decrease from 1987. This migration is subsequently diluted by heat exchanger cooling water from K-Area before entering the river.

Migration of radioactivity from F-and H-Area seepage basins was measured with continuous samplers and flow recorders in Four Mile Creek. Groundwater from the F-Area seepage basins outcrops into Four Mile Creek (FMC) between sampling locations FM-3A, FM-2B, and FM-A7. Most of the H-Area Seepage Basin outcropping from basins 1 through 3 occurs between FM-1C and FM-2B. Additional outcropping from H-Area Seepage Basin 4 and the Solid Waste Storage Facility occurs between FM-3 and FM-3A. The radioactivity from these two sources mixes during the groundwater migration to FMC. Therefore the radioactivity from the two sources cannot be distinguished at the outcrop point. Four Mile Creek sample locations are shown in Figure 4-4 (Figure 4-3, Vol. II).

Measured migration of tritium in 1988 was 3,330 Ci from F-Area Seepage Basins (18% increase from 1987), 3,670 Ci from H-Area Seepage Basin 4 and the Solid Waste Storage Facility (41% decrease from 1987), and 3,980 Ci from the other H-Area Seepage Basins (29% decrease from 1987).

The quantity of tritium migrating from all seepage basins to SRS streams was 13,893 Ci in 1988, compared with 18,266 Ci in 1987, a 24% decrease. The tritium migrating from seepage basins represents 72% of the total SRS tritium released to streams.

The amount of ^{90}Sr migration was 0.12 Ci from F-Area Seepage Basins and 0.08 Ci from H-Area Seepage Basins. Cesium-137 migration, if it occurs, cannot be measured because of the desorption of ^{137}Cs in the stream bed from previously released ^{137}Cs. Desorption is calculated by subtracting the F- and H-Area contributions (sampling locations FM-3, FM-1C, FM-1B) from the total curies of ^{137}Cs at FM-A7.

Migration of radionuclides from seepage basins is presented in Table 4-4, Vol. II. Radioactivity in transport at sample points on Four Mile Creek and desorption of ^{137}Cs from Four Mile Creek are shown in Table 4-5, Vol. II.

Table 4-5. 1988 Radioactive Liquid Releases and Concentrations

Nuclide	Curies Released At Emission Source	Below SRS[a] (mCi/mL)	Beaufort-Jasper[b] (mCi/mL)	Port Wentworth[c] (mCi/mL)
H-3	1.93E+04[d]	3.4E-06[e]	2.6E-06[e]	2.5E-06[e]
Co-60	0.00E+00	0.0E+00	0.0E+00	0.0E+00
Sr-90	3.77E-01	3.8E-10[e]	5.0E-11	4.8E-11
I-129	2.20E-02	3.8E-12	2.9E-12	2.8E-12
Cs-137	5.65E-01	1.1E-10[e]	7.6E-11	7.3E-11
Pm-147	1.97E-02	3.4E-12	2.6E-12	2.5E-12
U-235,238	5.51E-03	9.6E-13	7.4E-13	7.1E-13
Pu-239	5.54E-03	9.6E-13	7.4E-13	7.1E-12

[a] Savannah River just downriver from SRS.
[b] Beaufort-Jasper drinking water.
[c] Port Wentworth drinking water.
[d] Includes releases to streams and groundwater migration from seepage basins.
[e] Measured concentrations. All other concentrations were calculated using models that were verified using tritium measurements.

Migration from P- and C-Area Seepage Basins. Liquid purges from the P-and C-Area disassembly basins have been released to their respective seepage basins since 1978. Purge water is released to the seepage basins so that a significant part of the tritium can decay before the water outcrops to surface streams and flows to the Savannah River. The delaying action of the basins reduces the dose that users of water from downriver treatment plants receive from SRS tritium releases.

During the period between 1970 and 1978, disassembly basin purge water was released to SRS streams, but the seepage basins had been previously used for purging the disassembly basins (from the 1950s to 1970). The earlier experience with seepage basins indicated that the extent of radioactive decay during the holdup was sufficient to recommend their reinstatement in the P and C Areas.

Equipment was installed at locations downgradient from each basin to measure tritium migration from the P-and C-Area seepage basins. Results from paddlewheel samplers installed on Twin Lakes and Castor Creek at C Area indicated no measurable tritium that could be attributed to migration from the C-Area Seepage Basin in 1988. Results from a paddlewheel sampler installed on Steel Creek, above L Lake, indicated 133 Ci of tritium migrated from the P-Area Seepage Basin during 1988.

Inventory of Tritium Released

A comparison of the amount of tritium released from SRS facilities in 1988 to the amount of tritium measured in transport in SRS streams and in the Savannah River continued to show relatively good agreement. Point-of-release measurements are calculated from known concentrations contributed to the streams. Stream transport is measured at the last sampling point before entry into the river. Results showed that point-of-release and stream transport measurements agreed within 5% and that the point-of-release measurements were less than the river transport measurements by 24%. The differences are due to sampling error and statistical uncertainties associated with measurements. Tritium inventory in the SRS streams and in the Savannah River is summarized in Table 4-6, Vol. II.

Sources of tritium in liquid effluents include direct releases from plant facilities (28% in 1988 compared with 20% in 1987) and migration of tritium from the RWBG, F-, H-, and P-Area seepage basins, and K-Area Containment Basin (72% in 1988 compared with 80% in 1987). Migration occurs when tritium released to the seepage basins in previous years reaches SRS streams via groundwater outcropping into the streams.

Relatively good agreement in the inventory of tritium measured at three locations (the point of release, plant streams before entry into the river, and the river below SRS) has been observed each year since the totals have been compiled (1960) as shown in Figure 4-7 (Figure 4-6, Vol. II). A tritium inventory summary from 1960 to 1988 is presented in Table 4-7, Vol. II.

Table 4-6. Maximum Individual Doses - Liquid Releases

By Pathway

Pathway	Maximum Individual[a] mrem[b]	% of Total Dose
Fish	7.00E-01	89.02
Water	8.56E-02	10.89
Shoreline	7.13E-04	0.09
Swimming	1.34E-06	0.00
Boating	4.03E-06	0.00
Total	7.86E-01	

By Radionuclide

Radionuclide	Maximum Individual[a] mrem[b]	% of Total Dose
H-3	8.44E-02	10.74
Sr-90	1.18E-02	1.50
I-129	9.41E-04	0.12
Cs-137	6.86E-01	87.28
U-235,238	3.96E-06	0.00
Pm-147	9.63E-06	0.00
Pu-239	2.02E-03	0.26
Total	7.86E-01	

[a] Hypothetical person just downstream of SRS. There are no known persons who meet the hypothetical situation.
[b] Committed effective dose equivalent.

Before 1959, low-level measurement techniques needed for routine measurements of tritium concentrations in streams and the river were not available. The lower limit of detection for the vibrating reed electrometer, used at that time, was 1,000 pCi/mL. Liquid scintillation counters, developed in the late 1950s, made low-level measurements practical (the LLD is now 1 pCi/mL).

SRS began routine use of liquid scintillation counting in 1959 and made river and stream measurements beginning in the last half of that year. During some of the early years (1960–1964), noticeable differences occurred between releases and the amount of tritium measured in streams and the river. This discrepancy led to additional effluent monitoring points where small amounts of tritium were released (miscellaneous reactor releases), and the measurement of leakage from reactor heat exchangers to accomplish further sampling refinements.

As shown in Figure 4-7, tritium releases to the Savannah River have decreased significantly since 1964, when the maximum tritium releases occurred. The following process control improvements have led to the decrease of tritium releases:

- change from continuous purges of reactor area disassembly basins to periodic purges in the late 1960s, allowing longer holdup time for decay, some evaporation, and a larger inventory of tritium in the basins
- development of equipment and techniques to flush and contain tritium-bearing moderator present on fuel and target housings during discharge from the reactor
- diversion of periodic disassembly basin purges from streams to seepage basins in P and C Areas in 1978, allowing some radioactive decay of tritium before migration to streams via groundwater

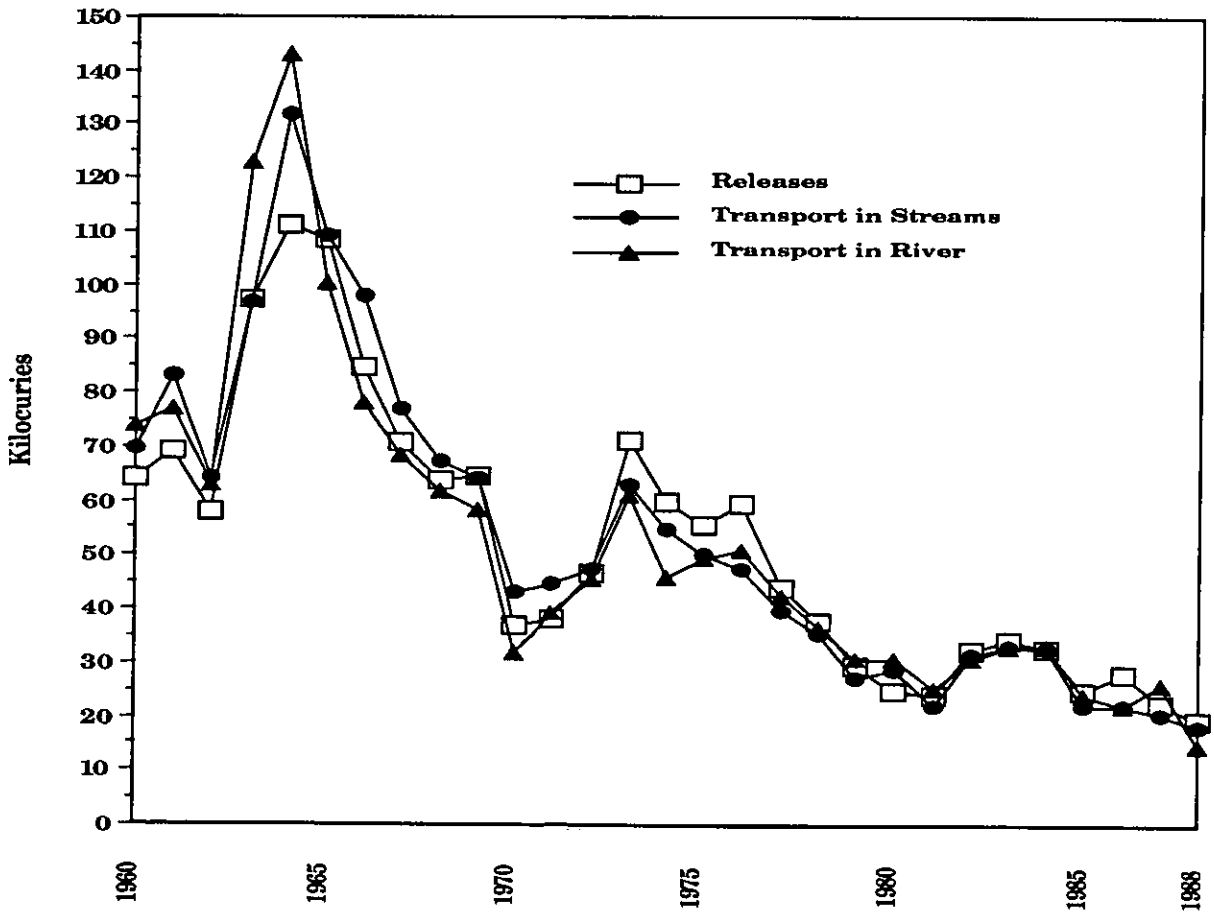


Figure 4-7. Tritium balance summary 1960-1988

In addition, releases were reduced by the shutdown of R- and L-Area reactors in 1964 and 1968, respectively.

Summary of 1988 Liquid Releases and Concentrations

Releases of radioactive materials to the Savannah River in 1988 are shown in Table 4-5 (Table 4-8, Vol. II). Tritium is the major radionuclide released to liquid effluents. The average concentrations of radioactive materials in water are shown at three locations, just below SRS after complete mixing, in Beaufort-Jasper drinking water, and in Port Wentworth drinking water (both drinking water plants are approximately 100 miles downriver from SRS).

The majority of the concentrations shown in Table 4-5 are calculated, rather than measured; the calculated values are based on dilution of radioactivity entering the Savannah River with a known flow rate of water. However, measured concentrations are shown in those cases where the radionuclides are measurable by conventional analytical techniques.

As shown in Table 4-5, the maximum concentrations occur in the Savannah River just below SRS. Tritium was the radionuclide having the highest offsite concentration.

Offsite Radiation Doses from Liquid Releases

Table 4-6 (Table 4-9, Vol. II) shows the maximum calculated offsite dose commitments to a hypothetical individual from SRS releases of radioactivity to the Savannah River. The *maximum individual* is described as a person who consumes a maximum amount of water and a maximum amount of fish from the river just below SRS. This person also spends many hours in shoreline activities, swimming, and boating. The highest potential dose commitment was 0.79 mrem (0.0079 mSv). This dose commitment is only 0.79% of the 100 mrem DOE Revised Interim Radiation Dose Limit from prolonged exposure and 0.3% of the annual dose commitment of 295 mrem (2.95 mSv) received from natural radiation sources.

Table 4-7, and Table 4-8 (Tables 4-10 and 4-11, Vol. II) show calculated dose commitments to individuals who consume 2 L of water from water supplied by the Beaufort-Jasper and Port Wentworth water treatment plants, respectively. The dose commitments for average water consumption were 0.07 mrem (0.0007 mSv) for Beaufort-Jasper and 0.06 mrem (0.0006 mSv) for Port Wentworth; the dose commitments for maximum water consumption rates for Beaufort-Jasper and Port Wentworth were 0.13 mrem (0.0013 mSv) and 0.12 mrem (0.0012 mSv), respectively. The maximum dose of 0.13 mrem is only 3.3% of the EPA standard of 4 mrem to the body or any organ from public water supplies. EPA standards are based on a maximized water consumption of 2 L per day.

Table 4-7. Individual Doses From Public Water Supplies at Beaufort-Jasper

Average Consumption

Radionuclide	Individual Dose, mrem[a]	% of Total Dose
H-3	6.00E-02	91.80
Sr-90	2.42E-03	3.70
I-129	3.04E-04	0.47
Cs-137	1.39E-03	2.13
Pm-147	9.22E-07	0.00
U-235,238	6.26E-05	0.10
Pu-239	1.18E-03	1.81
Total	6.54E-02	

Maximum Consumption

Radionuclide	Individual Dose, mrem[a]	% of Total Dose
H-3	1.18E-01	91.78
Sr-90	4.77E-03	3.71
I-129	6.00E-04	0.47
Cs-137	2.75E-03	2.14
Pm-147	1.82E-06	0.00
U-235,238	1.23E-04	0.10
Pu-239	2.32E-03	1.80
Total	1.29E-01	

[a] Committed effective dose equivalent.

Collective (population) dose commitments from liquid releases of radioactivity in 1988 are shown by exposure pathway in Table 4-9 (Table 4-12, Vol. II). Dose commitments from the water consumption pathway (Beaufort-Jasper and Port Wentworth) occur to discrete population groups; however, the dose commitments from other exposure pathways (i.e., fish and shellfish consumption and recreational activities) occur to a diffuse population that cannot be

described as being in a specific geographical location. As shown in Table 4-9, the collective dose commitment from liquid releases was 6.2 person-rem (0.062 person-Sv).

Radiation dose commitments are not routinely calculated for the irrigation exposure pathway because there is no known use of Savannah River water for farm irrigation downstream of SRS. But capability for calculating offsite dose from the irrigation-food pathways has been developed to provide potential dose from irrigation for information purposes. Potential doses from the irrigation pathway are shown above in Table 4-10 (Table 4-13, Vol. II).

The maximum individual dose commitment from the irrigation pathway was 0.31 mrem (0.0031 mSv). This dose value is 38% of the maximum individual dose of 0.79 mrem (0.0079 mSv) calculated for all other pathways (fish consumption, water consumption, and recreation).

Table 4-8. Individual Doses From Public Water Supplies at Port Wentworth

Average Consumption

Radionuclide	Individual Dose, mrem[a]	% of Total Dose
H-3	5.77E-02	91.80
Sr-90	2.33E-03	3.71
I-129	2.92E-04	0.46
Cs-137	1.34E-03	2.13
Pm-147	8.87E-07	0.00
U-235,238	6.02E-05	0.10
Pu-239	1.13E-03	1.80
Total	6.29E-02	

Maximum Consumption

Radionuclide	Individual Dose, mrem[a]	% of Total Dose
H-3	1.14E-01	91.82
Sr-90	4.59E-03	3.70
I-129	5.77E-04	0.46
Cs-137	2.64E-03	2.13
Pm-147	1.75E-06	0.00
U-235,238	1.19E-04	0.10
Pu-239	2.23E-03	1.80
Total	1.24E-01	

[a]Committed effective dose equivalent.

Table 4-9. Collective Dose From Liquid Releases

By Pathway

Pathway	Collective Dose person-rem[a]	% of Total Dose
Sport fish	1.83E+00	29.51
Comml. fish	7.74E-02	1.25
Beaufort-Jasper	3.03E+00	48.86
Port Wentworth	1.26E+00	20.32
Salt Water invert.	1.77E-04	0.00
Recreation-river	3.88E-03	0.06
Total	6.20E+00	

By Radionuclide

Radionuclide	Collective Dose person-rem[a]	% of Total Dose
H-3	3.96E+00	63.81
Sr-90	1.82E-01	2.94
I-129	2.13E-02	0.34
Cs-137	1.95E+00	31.53
Pm-147	6.77E-05	0.00
U-235,238	4.15E-03	0.07
Pu-239	1.31E-01	2.12
Total	6.20E+00	

[a] Committed effective dose equivalent.

NONRADIOLOGICAL MONITORING

Surface water is monitored for nonradioactive materials at effluent outfalls from site facilities, at locations along the six site streams, and at three locations in the Savannah River. Operational effluents from SRS facilities discharge through 71 active SCDHEC-permitted outfalls. These outfalls are monitored to ensure applicable permit limits are met. SRS also maintains an extensive network of stormwater outfalls. The stream and river monitoring programs serve as a backup to outfall monitoring to ensure that materials that could adversely affect the environment are detected if released.

Liquid Effluent Monitoring (NPDES)

Description of Monitoring Program. Measurements of physical properties and concentrations of chemicals and metals in SRS effluents are regulated

Table 4-10. Potential Doses From Irrigation Pathway

Effective Dose Equivalent

Food Type[a]	Maximum Individual mrem	Collective person-rem
Vegetation	1.85E-01	2.87E+00
Leafy vegetables	2.28E-02	2.89E+00
Milk	7.65E-02	7.01E-01
Meat	2.44E-02	7.23E-03
Total	3.09E-01	6.47E+00

[a] Acreage for each food type assumed to be 1,000 acres.

by SCDHEC under the National Pollutant Discharge Elimination System (NPDES). The NPDES program at SRS included monitoring at 71 active outfalls in 1988.

Changes in 1988 Monitoring Program. Updates on existing NPDES permits included the following changes in 1988:

- Four new outfalls were added to the SRS NPDES program in 1988. The outfalls were located at F- and H-Area ETF and at the TNX ETP, which became operational in 1988.
- Four outfalls, which no longer discharge because operational changes were dropped from the program.
- Quarterly monitoring for priority pollutants was discontinued at the influent to the M-Area Groundwater Air Stripper.

NPDES outfall located on SRS

Applicable Standards. Standards applicable to nonradioactive materials and physical properties in SRS wastewater discharges are contained in SRS's NPDES permit administered by SCDHEC. Monitoring requirements and standards are listed in permit SC 0000175 [SCDHEC85].

Monitoring Results. NPDES outfall locations are listed in Table 4-14, Vol. II, and a summary of monitoring results is presented in Table 4-15, Vol. II. SRS had a 99.8% NPDES compliance rate in 1988, as compared to a 99.7% compliance rate in 1987. Only 14 of the 6,250 analyses performed exceeded permit limits. Listed in Table 4-11 is a summary of the 14 limits exceeded.

Table 4-11. Summary of NPDES Exceedances

Analysis	Number of Exceedances	Number of Outfalls
Total Nonfilterable Residue	2	2
Fecal Coliform	1	1
pH	6	5
Oil and Grease	1	1
Trichloroethylene	3	1
Nonfilterable Residue	1	1
Totals	14	11

Savannah River

Description of Monitoring Program. The Savannah River is extensively monitored for chemicals, metals, and physical and biological properties. Monitoring of the river above and below the site provides means of comparing SRS contribution of pollutants with the "background", which includes natural and upstream contaminants produced by industry sewage plants, etc. Measurements confirm that the impact of SRS operations is minimal. All indications show that SRS operations do not have a deleterious effect on the Savannah River aquatic environment. Special environmental surveys on the Savannah River conducted since 1951 by the National Academy of Natural Sciences of Philadelphia (ANSP) also reveal that site operations have had no harmful effects on the

environment (see Chapter 9). Evidence that the environment is not impacted is further supported by routine field measurements in the Savannah River for conductivity, dissolved oxygen, pH, and temperature. Laboratory measurements are conducted for the remaining water quality parameters.

Applicable Standards. Chemical and biological quality standards for the Savannah River are specified in the requirements of the State of South Carolina for Class B streams, which state: "Freshwaters suitable for secondary contact recreation and as a source for drinking water supply after conventional treatment in accordance with requirements of the Department (SCDHEC). Suitable for fishing, survival, and propagation of fish, and other fauna and flora. Suitable also for industrial and agricultural uses..."[SCDHEC81]. Specifications are summarized in Table 4-12.

Monitoring Results. A comparison of Savannah River water quality analyses upriver and downriver of SRS showed no significant differences except for fecal coliform. Fecal coliform levels were higher upriver of SRS than downriver. The average of the monthly geometric mean of fecal coliform measurements was 393 colonies/100 mL upriver and 141 colonies/100 mL downriver of SRS. Savannah River water quality data are presented in Tables 4-16 and 4-17, Vol. II. Sampling locations are shown in Figure 4-8 (Figure 4-7, Vol. II).

SRS Streams

Description of Monitoring Program. SRS streams are extensively monitored for chemicals, metals, and physical and biological properties. The stream monitoring program helps ensure that materials are not inadvertently released from sources other than routine release points. Five principal streams traverse the SRS site and a sixth stream, Beaver Dam Creek, contains water primarily from the D-Area Powerhouse. D Area also has heavy-water rework facilities and a process control laboratory. The streams receive varying amounts of wastewater and rainwater runoff from SRS facilities.

In addition to SRS monitoring, SCDHEC collects monthly samples from Tims Branch near Road C, Upper Three Runs Creek at Road A, Four Mile Creek at Road A-7, and Steel Creek at Road A. Duplicate samples are collected at these locations for analysis at SRS.

Applicable Standards. South Carolina water quality standards for Class B waters also apply to SRS streams as shown in Table 4-12.

Monitoring Results. Analyses of SRS stream samples and measurements in the streams indicate that, except for temperature in Pen Branch, the water quality is not adversely affected by SRS operations. Pen Branch receives heated water from K Area. The heated water from L and P Areas is cooled by L Lake and Par Pond, respectively. C Area, which formerly discharged heated water to Four Mile Creek, was out of service in 1986, 1987, and 1988.

During 1988, fecal coliform counts decreased in Pen Branch at Road A from 1987 but remained slightly elevated relative to other site streams. The maximum count was 1,600 colonies/100 mL compared to 14,000 colonies/100 mL in 1987. The geometric mean was 457 colonies/100 mL compared to 648 colonies/100 mL in 1987. In 1987 the laboratory that performs the fecal coliform analyses noticed a red overgrowth on the Pen Branch samples that interfered with the analysis. As a result, the analytical procedure was changed to an alternate EPA approved procedure.

Table 4-12. South Carolina Water Quality Standards (for Class B Waters)

Fecal Coliform. (The count is) not to exceed a geometric mean of 1000 colonies/100 mL based on five consecutive samples during any 30-day period; not to exceed 2000 colonies/100 mL in more than 20% of the samples examined during such period.

pH. Range between 6.0 and 8.5, except that specified waters may range from pH 5.0 to 8.5 due to natural conditions.

Temperature. Shall not exceed a weekly average temperature of 90 degrees F (32.2 degrees C) after adequate mixing as a result of heated liquids, nor shall a weekly average temperature rise of more than 5 degrees F (2.8 degrees C) above temperatures existing under natural conditions be allowed as a result of the discharge of heated liquids unless an appropriate temperature criterion or mixing zone has been established.

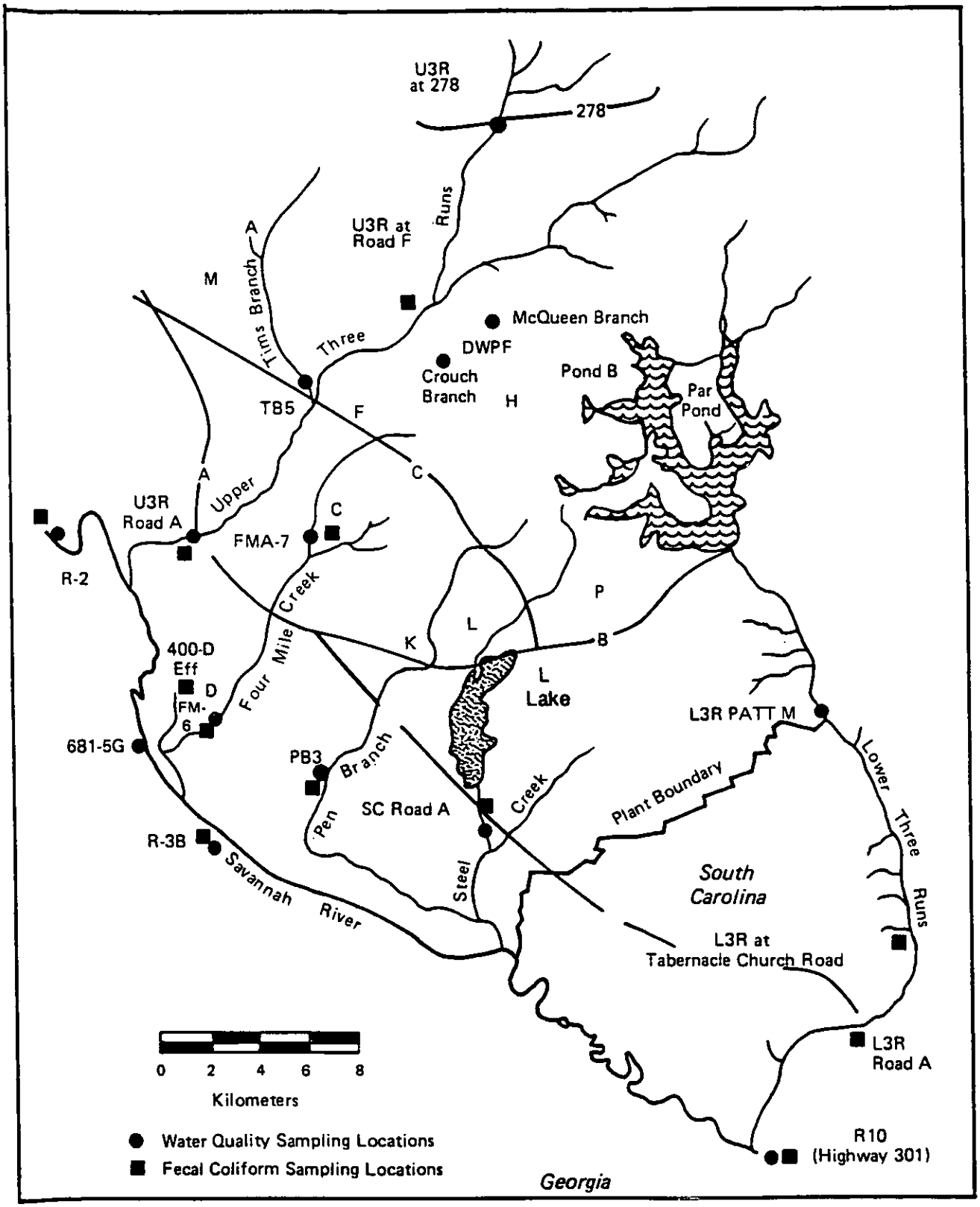


Figure 4-8. Water quality sampling locations for nonradiological monitoring

Temperature surveys are conducted on SRS streams

Except for temperature in Pen Branch, all stream analyses were within the South Carolina standards for a Class B stream. Stream water quality data are summarized in Tables 4-18 and 4-19 in Vol. II, and sampling locations are shown in Figure 4-8 (Figure 4-7 in Vol. II).

Monitoring for Pesticides, Herbicides, and Polychlorinated Biphenyls

Description of Monitoring Program. Water and sediment samples from seven site stream locations were analyzed for 30 pesticides, herbicides, and polychlorinated biphenyls (PCBs) during 1988. A listing of the 30 constituents and typical minimum detectable concentrations are shown in Table 4-20, Vol. II. This program has been conducted since 1976 to assess concentrations of these materials in streams and the Savannah River.

Monitoring Results. Concentrations of all parameters analyzed in river and stream water and sediment were less than the minimum detectable concentrations. Savannah River water, stream water, and sediment pesticide, herbicide, and PCB data are presented in Table 4-21, Vol. II and Table 4-22, Vol. II, respectively.

River and Stream Temperature Surveys

Description of Monitoring Program. Temperature profile surveys are conducted on the Savannah River and SRS streams as part of a comprehensive study of the thermal effects of SRS operations upon the waters of the State of South Carolina as stated in consent order 84-4-W between SCDHEC and DOE.

Measurements in the creek mouths are taken at 2-ft. intervals across the creeks. At each of these intervals, stream temperatures are measured at 1-ft. depth intervals from the surface to the bottom. River measurements are taken at 10-20 ft. intervals from the South Carolina bank to the Georgia bank. At each of these intervals, temperature measurements are taken at 1-ft. depth intervals from the surface to the bottom.

The reference ambient temperature for the river and SRS streams is determined from a temperature profile 100 yd. above the point where the first heated SRS effluent (Beaver Dam Creek) enters the river. In addition to the temperature profile surveys conducted by SRS, the USGS has established continuous monitoring stations for temperature measurements at the mouth of each SRS stream.

Monitoring Results. During the first quarter 1988, a temperature profile survey was made in the mouths and upriver of Beaver Dam Creek and Steel Creek. A survey was not made in the mouth and downriver of Four Mile Creek because C Reactor is no longer in operation. Temperature measurements in both Beaver Dam Creek and Steel Creek exceeded the ambient river temperatures but were within the consent order

Table 4-13. Temperature Data for March 1988

Month	Location	Maximum Temperature Above Ambient (°C)	Consent Order Daily Maximum Allowable Above Ambient (°C)
March	Steel Creek	3.9	16.6
	Beaver Dam Creek	8.0	17.5

limits shown in Table 4-13. Since the SRS reactors did not operate in the last three quarters of 1988, no other temperature profiles surveys were made.

Data from this survey, together with past data, indicated that subsurface river temperature measurements were significantly less than the limits set by consent order 84-4-W. This consent order states that "the temperature should not exceed 2.8 °C above ambient at the edge of 25% of the cross sectional area and over 33% of the surface area." Therefore, additional measurements for plume definition in the Savannah River were not necessary.

The elevated temperatures in Pen Branch mentioned previously are not reported in this survey. The mouth of Pen Branch is a poorly-defined swamp area and was not monitored under this program.

1988 HIGHLIGHTS

- In 1988, no measurable differences were detected between upriver and downriver alpha and beta concentrations in the Savannah River.
- Tritium measured in transport in the river was 14,600 Ci in 1988, compared to 26,145 Ci in 1987. The tritium concentrations in 1988 averaged 3.1 pCi/mL.
- A total of 3.3 Ci of ^{90}Sr was measured in transport in the river, and the average ^{90}Sr concentration was 0.72 pCi/L at the R-10 sampling location downriver of SRS compared to 0.32 pCi/L upriver of SRS.
- The maximum tritium concentration at Upper Three Runs (U3R) Creek was 14 pCi/mL due to the startup of the Effluent Treatment Facility in late 1988. The maximum tritium concentration in U3R Creek in 1987 was 3.3 pCi/mL.
- Measured migration of tritium in 1988 was 3,330 Ci from the F-Area Seepage Basins (18% increase from 1987), and 3,670 Ci from H-Area Seepage Basin 4 and the Solid Waste Storage Facility (41% decrease from 1987).
- The dose commitment to a hypothetical individual who could receive the highest offsite doses from releases of radioactivity from SRS to the Savannah river was 0.79 mrem (0.008 mSv), which is only 0.3% of the annual dose commitment of 295 mrem (2.95 mSv) received from natural radiation sources.
- SRS had a 99.8% NPDES compliance rate in 1988. Only 14 of the 6,250 analyses performed exceeded permit limits.

5
Groundwater Monitoring Program

SUMMARY—This chapter presents the results of the groundwater monitoring program for both radioactive and nonradioactive constituents at the Savannah River Site.

The chapter begins with a description of the monitoring programs, applicable standards, and hydrogeology at SRS, and then focuses on the monitoring results from sixteen major areas at the SRS: A Area, Radioactive Waste Burial Grounds, C Area, Central Shops Area, D Area, F Area, General Areas, H Area, K Area, L Area, M Area, P Area, R Area, S Area, TNX Area, and the Z Area.

The Environmental and Health Protection Department (EHP) radiological groundwater monitoring program at SRS is responsible for monitoring total radium, gross alpha, nonvolatile beta, and tritium at selected locations.

The nonradioactive groundwater monitoring program consists of quarterly field measurements of pH, temperature, alkalinity, conductivity, and water level at all wells. Metals and other nonradioactive constituents are measured periodically by contract laboratories that have been approved by the South Carolina Department of Health and Environmental Control (SCDHEC) to conduct the analyses.

In addition, the SRS Raw Materials Engineering and Technology Department monitored for volatile organics in A- and M Areas in the first quarter of 1988 and then transferred operation of its groundwater monitoring program to EHP.

Savannah River Laboratory Interim Waste Technology also monitors selected wells within the Radioactive Waste Burial Grounds. Wells within the sixteen areas that have chemical constituents and radioactivity levels above their respective drinking water standards are identified.

DESCRIPTION OF GROUNDWATER MONITORING PROGRAM

The Environmental Protection Program at the Savannah River Site (SRS) includes the Groundwater Monitoring Program, which gathers data to quantify any effect of SRS facilities on groundwater quality. Facilities monitored include waste disposal sites, chemical storage areas, tanks, sewers, spills, and certain process buildings. The program is designed to accomplish the following:

- assist SRS in complying with environmental regulations and DOE orders
- provide high-quality data to identify and monitor contaminants in the groundwater
- permit characterization of new facility sites to ensure the sites selected are well suited to house those facilities
- support basic research projects

The Groundwater Monitoring Program at SRS is performed by several organizations within Westinghouse Savannah River Company. Groups responsible for components of the program are the Groundwater Monitoring Group and the Environmental Monitoring Section (EMS-GW) of the Environmental and Health Protection Department (EHP), the Environmental Technology Section of the Savannah River Laboratory (SRL-ETD), and the operating departments of SRS. The Site Groundwater Coordinator (in the Environmental Protection Section (EPS)) is re-

sponsible for ensuring SRS compliance with applicable federal, state, and local regulations regarding groundwater. SRL-ETD provides technical support to EPS and the operating departments. The operating departments take the primary responsibility for compliance with environmental laws through preparation and submission of reports and data analyses and by initiating projects to obtain the data for these reports. The Groundwater Monitoring Group of the Environmental Monitoring Section provides services to assist the operating departments in meeting their responsibilities. These services include activities related to drilling, sampling, analysis, and reporting.

The Groundwater Monitoring Group of the Environmental Monitoring Section maintains contracts with subcontractors to provide field or laboratory services as needed and coordinates these work activities to meet the needs of the groundwater program. This centrally coordinated program ensures consistent adherence to SRS procedures and specifications as presented in DPSOP 254, Hydrogeologic Data Collection.

Representatives from the Groundwater Monitoring Group (EMS-GW), EPS, and SRL-ETD must review a program plan before well installations or other drilling activities can begin. The review ensures that plans are technically sound, practical and efficient in concept, and cost effective. After the review, contractors are selected to provide the drilling services and field technical oversight. Finally, the field work is scheduled and conducted at the earliest convenient time.

Groundwater sampling and analyses are conducted either in response to specific requests for analysis of one or more constituents or as part of the ongoing quarterly sampling program that provides the data for compliance with environmental regulations. Field measurements of pH, temperature, conductivity, alkalinity, and water level are taken quarterly at all wells. Other analyses are performed according to the sampling schedule, which is generated using criteria such as regulatory requirements, previous analytical results, potential contaminants, and ongoing research.

The current EHP groundwater monitoring program at SRS comprises radioactive and nonradioactive monitoring programs. The radioactive monitoring program began in the early 1950s and primarily monitors gross alpha, nonvolatile beta, and tritium at selected sites. Many of these analyses are conducted in the Environmental Monitoring (EM) Section's laboratories at SRS. Groundwater monitoring for nonradioactive constituents began in 1975 with four wells at the Sanitary Landfill. All samples collected for analysis of nonradioactive constituents and some collected for analysis of radioactive constituents are packaged appropriately and shipped to laboratories under contract to conduct the required analyses and certified by the South Carolina Department of Health and Environmental Control (SCDHEC). The laboratories submit the results of analyses on computer disks. These results are screened for entry into a computerized database. The screening involves a data review, error correction, and collation cycle. Error correction includes reviewing data that are inconsistent with previous results, but changes are made only when laboratories can certify that inaccurate data have been reported.

Once entered into the database, the groundwater data are prepared for formal periodic reports to regulatory agencies or for publication in the Annual Environmental Report. The database also allows for data to be extracted for specific studies.

In addition to the monitoring performed by EHP, the SRS Raw Materials Engineering and Technology Department monitored for volatile organics in A-and M Areas in the first quarter 1988, and the Interim Waste Technology Division of the Savannah River Laboratory (SRL) monitors selected wells within the Radioactive Waste Burial Grounds.

APPLICABLE MONITORING STANDARDS

Analytical results of groundwater monitoring from SRS monitoring wells are compared with federal primary drinking water standards (40 CFR 141-143) in this report. Although drinking water standards do not apply to monitoring wells, they are a convenient reference for comparison. Federal secondary drinking water standards are not addressed in this report because they are primarily aesthetic guidelines relating to public acceptance of drinking water (40 CFR 143.1). Primary drinking water standards for radioactive and nonradioactive constituents are given in Table 5-1. Wells sampled in 1988 that contained constituents above their respective drinking water standards are discussed in this chapter. Some constituents that do not have drinking water standards are also discussed when their values are of concern. Volume II contains summary tables for all monitored wells.

Table 5-1. EPA Primary Drinking Water Standards

Analyte	Level	Units	Reference[a]
Antimony-125	0.3	pCi/mL	EPA, 1977
Cesium-134	0.08	pCi/mL	CFR, 1986
Cesium-137	0.2	pCi/mL	EPA, 1977
Chromium-51	6	pCi/mL	EPA, 1977
Cobalt-60	0.1	pCi/mL	EPA, 1977
Gross Alpha	15	pCi/L	CFR, 1987
Iodine-131	0.003	pCi/mL	EPA, 1977
Radium-226	0.005	pCi/mL	CFR, 1987
Ruthenium-103	0.2	pCi/mL	EPA, 1977
Ruthenium-106	0.03	pCi/mL	EPA, 1977
Strontium-89/90*	8	pCi/L	EPA, 1977
Total Radium	5	pCi/L	CFR, 1987
Tritium	20	pCi/mL	CFR, 1987
Zirconium/Niobium-95*	0.2	pCi/mL	EPA, 1977
Arsenic	0.05	mg/L	CFR, 1987
Barium	1	mg/L	CFR, 1987
Cadmium	0.01	mg/L	CFR, 1987
Chromium	0.05	mg/L	CFR, 1987
Fluoride	4	mg/L	CFR, 1987
Lead	0.05	mg/L	CFR, 1987
Mercury	0.002	mg/L	CFR, 1987
Nitrate (as N)	10	mg/L	CFR, 1987
Selenium	0.01	mg/L	CFR, 1987
Silver	0.05	mg/L	CFR, 1987
Endrin	0.0002	mg/L	CFR, 1987
2,4-D	0.1	mg/L	CFR, 1987
Lindane	0.004	mg/L	CFR, 1987
Methoxychlor	0.1	mg/L	CFR, 1987
Silvex	0.01	mg/L	CFR, 1987
Toxaphene	0.005	mg/L	CFR, 1987
Benzene	0.005	mg/L	EPA, 1987
Chloroethene	0.002	mg/L	EPA, 1987
Carbon Tetrachloride	0.005	mg/L	EPA, 1987
1,2-Dichloroethane	0.005	mg/L	EPA, 1987
Trichloroethylene	0.005	mg/L	EPA, 1987
1,1-Dichloroethylene	0.005	mg/L	EPA, 1987
1,1,1-Trichloroethane	0.2	mg/L	EPA, 1987
1,4-Dichlorobenzene	0.075	mg/L	EPA, 1987
Chloroform**	0.1	mg/L	CFR, 1987

*The drinking water standard given is the lower of the two drinking water standards for the individual isotopes.
**The level for trihalomethanes is set at 100 ug/L. Because bromated methanes are rarely detected in SRS groundwater, EHP presumes that most of the trihalomethanes present in plant water are chloroform

[a]EPA (U.S. Environmental Protection Agency), 1977. *National Interim Primary Drinking Water Regulations*, EPA-570/9-76-003, U.S. Environmental Protection Agency, Washington, DC.
CFR (Code of Federal Regulations), 1986. *National Primary Drinking Water Regulations; Radionuclides (Proposed)*, 40 CFR 141.
CFR (Code of Federal Regulations), 1987. *National Primary Drinking Water Regulations*, 40 CFR 141.
EPA (U.S. Environmental Protection Agency), 1987. *National Primary Drinking Water Regulations; Volatile Synthetic Organic Chemicals, U.S. Environmental Protection Agency*, Federal Register, July 8, 1987, pp. 25690-25717.

CHANGES IN THE MONITORING PROGRAM DURING 1988

Three SRS locations had Resource Conservation and Recovery Act (RCRA) wells monitored for the first time in 1988. The BGO well series, consisting of 38 RCRA wells, was installed at the perimeter of Burial Ground 643-7G, which encompasses the Mixed Waste Management Facility (MWMF; 643-28G). Forty-two new RCRA point-of-compliance (POC) and plume assessment wells added to the FSB well series monitor the F-Area Seepage Basins. Seventy-four new RCRA POC and plume assessment wells added to the HSB well series monitor the H-Area Seepage Basins.

Twenty-four wells comprising seven new well series were monitored for the first time in 1988 at the following SRS locations: the F- and H-Area Effluent Treatment Facilities (four FET and four HET series wells, respectively); the H-Area Acid/Caustic Basin (four HAC series wells); the H-Area Auxiliary Pump Pit (two HAP series wells); the S-Area Low Point Pump Pit (two SLP series wells); the TNX Burying Ground (six TBG series wells); and the Z-Area Drain Tank (two ZDT series wells). Eight piezometer wells (SLW series) were installed to characterize the geohydrology of the proposed New Sanitary Landfill site. Fifteen wells (MWD series) were installed at the proposed site of the new Hazardous Waste/Mixed Waste Disposal Facility (HWMW). However, the proposed site of the facility has been changed, and these wells have not been sampled.

Thirteen wells were installed at the following sludge land application sites to replace the SSS series wells: F Area (four FSS series wells), H Area (three HSS series wells), K Area (three KSS series wells), and Par Pond (three PSS series wells). Twenty-four wells were added to existing well series at several sites: the Metallurgical Laboratory Basin (four AMB series wells); the SRL Seepage Basins (one ASB series well); the coal pile runoff containment basins in D Area (four DCB series wells) and in F Area (three FCB series wells); the acid/caustic basins in F Area (four FAC series wells), K Area (three KAC series wells), and P Area (two PAC series wells); and the Old TNX Seepage Basin (three XSB series wells).

The SRS Raw Materials Engineering and Technology Department (RMETD) transferred the responsibility for sampling and analysis of its groundwater monitoring wells (including monitoring of the plume definition and POC wells in A-and M Areas) to EHP at the end of the first quarter of 1988. RMETD maintains all other responsibility for the program (i.e, reporting the data to regulatory agencies, determining future well locations, additional corrective action measurements, etc.)

HYDROGEOLOGY AT SRS

SRS is located on the Upper Atlantic Coastal Plain, approximately 20 miles southeast of the Fall Line, which separates the Piedmont and Coastal Plain provinces. SRS is on the Aiken Plateau, a comparatively flat surface that slopes southeastward and is dissected by several tributaries to the Savannah River. The SRS stratigraphy comprises about 1,000 ft of unconsolidated sands, clayey sands, and sandy clays, which are underlain by dense crystalline metamorphic rock or consolidated red mudstone in the Dunbarton basin. The geologic terminology applicable to SRS (discussed from bottom to top) is as follows.

The **Cretaceous System** comprises the Cape Fear, Middendorf, and Black Creek Formations and the Steel Creek Member of the Peedee Formation (formerly collectively called the Tuscaloosa Formation). Sands in the lower and upper parts of this section are important water producers. The **Paleocene Series** comprises the Ellenton Member of the Rhems Formation, Williamsburg Formation, and unnamed formations. Very few clean sands occur in the Paleocene, which constitutes a regional aquitard. The **Lower Middle Eocene Stage** (or Congaree Formation) contains Lower Claibornian rocks that are generally sandy and capable of producing several hundred gallons of water per minute to wells. The **Upper Middle Eocene Stage** comprises the Upper Claibornian Lisbon or Santee Formation equivalents, which are generally marine formations of low permeability. Provisionally these units are assigned to the Santee Formation with a McBean sandy micritic member; a Warley Hill sandy, often glauconitic, member; and a basal Caw Caw glauconitic and/or lignitic shale member. The Caw Caw Member has been called the "green clay" in SRS hydrologic writings. The **Upper Eocene Stage** comprises nearshore sands, clays, and fossiliferous limestones in the Dry Branch Formation. A persistent clay in this formation is the "tan clay" of SRS hydrologic literature. The Irwinton Sand Member overlies the tan clay. The upper portion of the Upper Eocene section, the Tobacco Road Formation, is predominantly clayey sands with a few clean sands or clays. These two formations (the Dry Branch and the Tobacco Road) make up the Barnwell Group. In some SRS litera-

ture, the Jacksonian Dry Branch Formation has been included in the "McBean Formation." The **Post-Jacksonian Sediments** are gravels, clays, and arkosic sands of fluvial origin that cap many interfluvial areas of the SRS region and are included in an informal stratigraphic unit called the "Upland unit." These gravels, together with a reticulate-mottled B soil horizon, were mapped as the "Hawthorn Formation" in early SRS publications. The **Flood Plain Deposits** are numerous but generally occur along the Savannah River and its major tributaries.

A generalized view of these formations is shown in Figure 5-1 (Vol. II). The two aquifers in the Cretaceous formations are used separately and in combination to obtain yields of greater than 1,000 gal/min in wells. The lower middle Eocene section also contains sands that yield a few hundred gallons per minute in many locations. Apart from these aquifers, the Coastal Plain sediments transmit water on a local scale but do not yield water to wells in sufficient quantity to be classified as primary aquifers. A few excavated wells and some low-yield drilled wells exist in the Upper Middle Eocene and Upper Eocene Formations; thus, these formations could be marginally classified as aquifers. The confining beds retard the interchange of water between formations but do not totally prevent it.

The direction of groundwater movement is governed largely by the depths of incisions of the creeks that dissect the Aiken Plateau. Small creek valleys govern the groundwater flow directions in the shallow sediments. The valleys of major tributaries of the Savannah River govern flow direction in the sediments of intermediate depth, and the valley of the Savannah River governs the flow in the deep sediments. Groundwater in the Cretaceous formations flows toward the Savannah River, and that in the Lower Middle Eocene flows toward Upper Three Runs Creek or the Savannah River, depending on location. In several locations, dissection by creek valleys creates groundwater subunits or islands in some formations.

In the northwest part of SRS, groundwater head decreases with depth, providing the potential for recharge from the surface to penetrate to the deeper formations. However, in and near the valleys of Upper Three Runs Creek and the Savannah River, the water levels above the Paleocene confining units are drawn down by natural discharge more than those in the deeper formations. Thus, a head reversal in the central part of SRS causes the vertical groundwater gradients to be upward.

Water levels in wells sampling the Cretaceous sands do not respond quickly to rainfall; however, a long-term relationship probably exists between water level and recharge by rainfall. Decreases in water levels during the past several years cannot be completely accounted for by decreases in rainfall. Pumping for irrigation in Allendale and Barnwell Counties has increased greatly during this period. In addition, pumping at SRS has also increased. The head reversal near the central part of the plant has not disappeared because of the falling water levels, but it has decreased.

WASTE SITES COMMON TO SEVERAL AREAS

Acid/Caustic Basins

The acid/caustic basins in F, H, K, L, P, and R Areas are unlined earthen pits (approximately 50 ft by 50 ft by 7 ft deep) that received dilute sulfuric acid and sodium hydroxide solutions used to regenerate ion-exchange units in the water-purification processes at the Reactor and Separations Areas in the center of the plant. Other wastes discharged to the basins include water rinses from the ion-exchange units, steam condensate, and runoff from the spill containment enclosures for the storage tanks. The basins allowed mixing and neutralization of the dilute solutions before their discharge.

The basins were constructed between 1952 and 1954. The R-Area basin was abandoned in 1964; the L-Area basin was abandoned in 1968; the H-Area basin was abandoned in 1985. The other basins remained in service until new neutralization facilities became operational in 1982. The basins are uncovered and abandoned in place. Most of the basins are dry except during periods of prolonged precipitation.

Burning/Rubble Pits

From 1951 to 1973, burnable wastes such as paper, wood, plastics, rubber, oil, degreasers, and drummed solvents were received and incinerated monthly in the burning/rubble pits in A, C, Central Shops, D, F, K, L, P, and R Areas. Disposal of chemically contaminated oils was not permitted. In 1973, the burning of waste stopped, and the pits were covered with a layer of soil. Rubble wastes, including paper, wood, concrete, cans, and empty galvanized-steel drums, were then disposed of in the pits until they reached capac-

ity and were covered with soil. All burning/rubble pits were inactive by 1981, and all are covered except for the R-Area pit, which has not been backfilled.

Coal Pile Runoff Containment Basins

Electricity and steam at SRS are generated by burning coal, which is stored in open piles. The coal is generally moderate-to-low sulfur coal (1-2%) received by rail, placed on a hopper, sprayed with water to control dust, and loaded onto piles in A, C, D, F, H, K, L, P, and R Areas. The coal pile in R Area was removed in 1964, the L-Area coal pile was removed in 1968, and the coal piles in C and F Areas were removed in 1985.

The facilities generally contain a 90-day reserve of coal, which is not rotated, resulting in long-term exposure to the environment. This weathering results in the formation of sulfuric acid, which is caused by the oxidation of sulfur in the coal and bioactivity.

To achieve compliance with the National Pollutant Discharge Elimination System (NPDES) permit issued in 1977, coal pile runoff containment basins in A and D Areas were completed in October 1978, and basins in C, F, H, K, and P Areas were completed in March 1981.

Rainwater runoff from the coal piles flows into the coal pile runoff containment basins via gravity flow ditches and sewers. The basins allow for the passive equalization of the rainwater runoff and its seepage into the subsurface, where it can undergo natural renovation.

All of the basins are active except for those in C and F Areas. The C- and F-Area basins still collect runoff, but no coal remains at either site.

Disassembly Basins

The disassembly basins were constructed adjacent to each reactor at SRS to store irradiated assemblies prior to their shipment to the Separations Areas. The disassembly basins are concrete-lined tanks containing water. The irradiated assemblies are rinsed before being placed in the basins, but some radioactivity is transferred from the irradiated assemblies to the basin water. Sand filters are used to maintain the clarity of the disassembly basin water and to remove radioactive particulates. The basin water is circulated through deionizers. The deionizers are regenerated; then the basin water is purged through the deionizers and replaced with clean water. The basin water is purged periodically to the reactor seepage basins to reduce radiation exposure to operating personnel from the accumulation of tritium in the basin.

Reactor Seepage Basins

Since 1957, the reactor seepage basins have received low-level radioactive purge water from the disassembly basins. This water purge is necessary to keep the tritium concentration in the disassembly basin water within safe levels for working conditions. Although many radionuclides have been discharged to the basins, almost all of the radioactivity is due to tritium, ^{90}Sr, ^{137}Cs, and ^{60}Co. The radionuclides enter the disassembly basin water as a film of liquid on the irradiated components as they are discharged from the reactor tank to the disassembly basin, in the oxide corrosion film on the irradiated components, and, infrequently, from leaks in porous components.

Purge water was pumped directly into the seepage basins before the use of mixed-bed deionizers and sand filters began in the 1960s. From 1970 to 1978, the seepage basins were bypassed, and the deionized purge water was discharged directly into plant streams. However, in 1978, the basins were reactivated and are currently in use.

GROUNDWATER MONITORING RESULTS BY AREA

A AREA

A Area is located in the northwest part of SRS (Figure 5-1). Surface elevations across A Area range approximately from 350 to 380 ft mean sea level (msl). Surface drainage is toward Tims Branch, approximately 5,000 ft to the east, and toward valleys to the northwest and southwest that lead to the Savannah River.

The nearest plant boundary to A Area is approximately 0.5 miles to the northwest. A Area is on a water-table mound, with radial flow to the east toward Tims Branch, to the southwest toward the Savannah River, and to the north and west toward apparent drainage into lower zones. Monitoring of organic plumes in A Area indicates that most of the water-table water migrates downward into lower zones because the vertical gradient exceeds the horizontal gradient.

In 1988, groundwater was monitored at the following sites in A Area: the A-Area Background Well, the A-

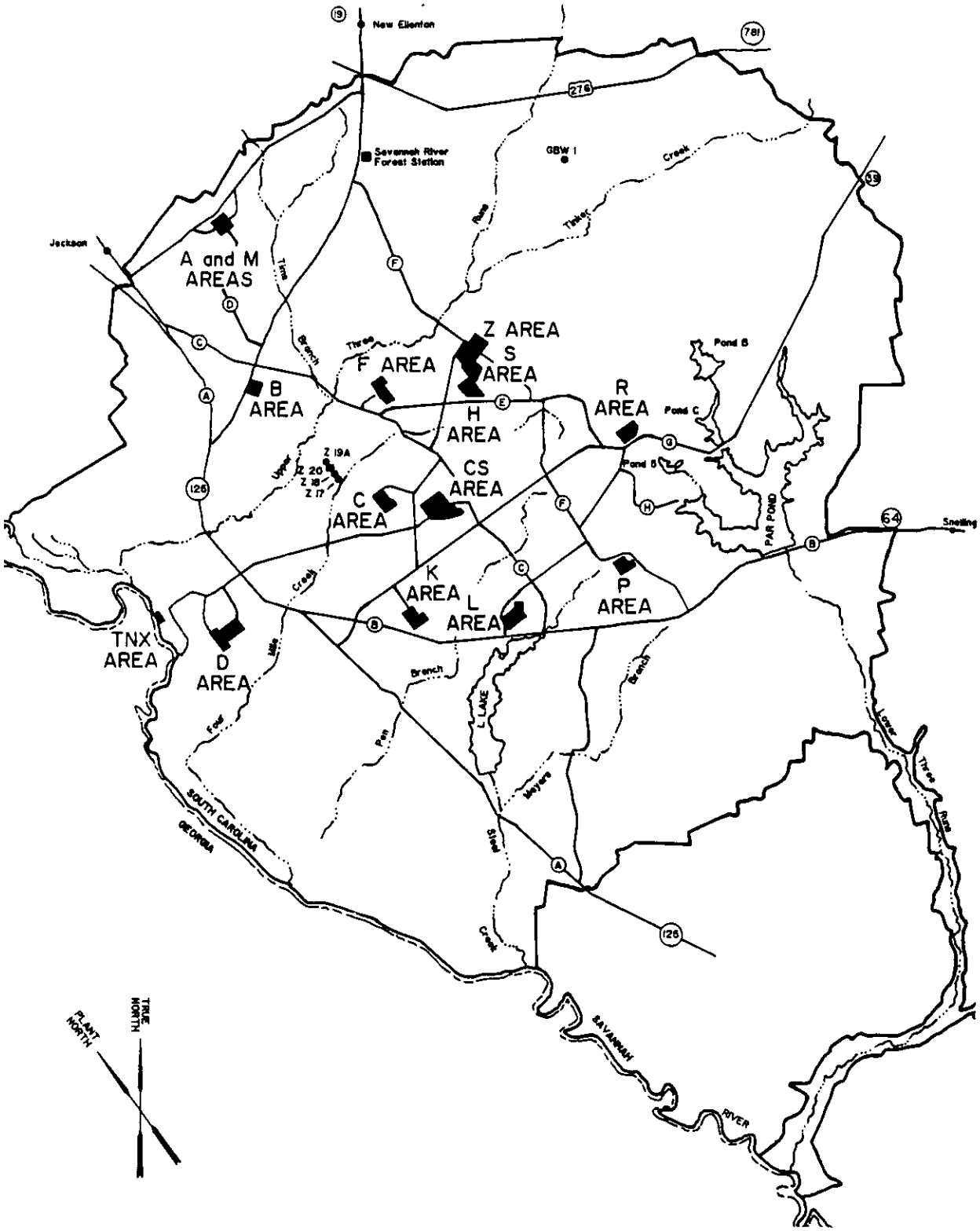
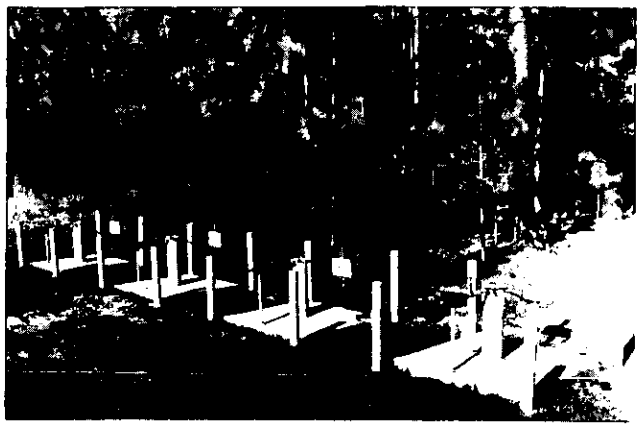


Figure 5-1. The Savannah River Site



Groundwater well cluster located in A Area

Area Burning/Rubble Pits (and A-Area Ash Pile 788-2A), the A-Area Coal Pile Runoff Containment Basin, the A-Area Metals Burning Pit, the Metallurgical Laboratory Seepage Basin, the Miscellaneous Chemical Basin, the Motor Shop Oil Basin, the Savannah River Laboratory (SRL) Seepage Basins, and the Silverton Road Waste Site (Figures 5-3 through 5-5, Vol. II). A summary of maximum groundwater monitoring results at these sites is given in Table 5-1 and Table 5-2 (Vol. II).

A-Area Background Well near the Firing Range

A-Area Background Well near the Firing Range (ABW 1) was installed as a background well for A Area and is approximately 2,300 ft east of the SRL Seepage Basins (Figure 5-3, Vol. II). The screen in this well was placed below the water table in the Congaree Formation. The well is downgradient of the SRL Seepage Basins and NPDES Outfall A-1 .

No radioactive constituents were detected above drinking water standards in well ABW 1 (Table 5-2, Vol. II).

No chemical constituents were detected above drinking water standards in this well (Table 5-2, Vol. II). Trichloroethylene concentrations reached the drinking water standard of 0.005 mg/L. Tetrachloroethylene was also detected in the ABW 1 well (up to 0.005 mg/L).

A-Area Burning/Rubble Pits

The A-Area Burning/Rubble Pits (731-A and 731-1A) are west of Road D and to the north of the A-Area Metals Burning Pit (Figure 5-3, Vol. II). Although the pits are backfilled and inactive, A-Area Ash Pile 788-2A, which is currently active, is near pit 731-A. See the beginning of this chapter for a discussion of SRS burning/rubble pits.

The site is monitored by the four wells of the ARP series (Table 5-3, Vol. II). Well ARP 3 is upgradient

Table 5-2. Selected Maximum Constituent Levels at A Area

Constituent	DWS	Units	ASB	SRW	AMB	MCB
Gross Alpha	15	pCi/L	**24.3**	7.3	13.9	2.1
Nonvolatile Beta	-	pCi/L	20.7	9.3	15.8	3.2
Total Radium	5	pCi/L	4.3	**6.8**	3.34	0.9
Tritium	20	pCi/mL	**24.9**	-	<0.7	2.4
Cadmium	0.01	mg/L	0.003	-	<0.002	<0.002
Lead	0.05	mg/L	0.018	**0.061**	0.009	<0.006
Mercury	0.002	mg/L	0.0008	-	0.0003	<0.0002
Nitrate (as N)	10	mg/L	2.03	3.68	0.36	0.45
Trichloroethylene	0.005	mg/L	**2.52**	**0.008**	**0.058**	**0.531**
Endrin	0.0002	mg/L	-	-	<0.0001	-

Note: Analytical results in bold are above drinking water standards.
DWS = EPA drinking water standards; refer to Table 5-1, Vol. I.
ASB = Savannah River Laboratory Seepage Basins and Plume Definition Wells
SRW = Silverton Road Waste Site Wells
AMB = Metallurgical Laboratory Seepage Basin Wells
MCB = Miscellaneous Chemical Basin Wells

of the pits, well ARP 1A is downgradient, and wells ARP 2 and 4 are sidegradient.

No radioactive constituents were detected above drinking water standards.

No chemical constituents were detected above drinking water standards except trichloroethylene (up to 0.213 mg/L) in wells ARP 1A and 3 and 1,1-dichloroethylene (at 0.0274 mg/L) in AOB 3. Tetrachloroethylene (up to 0.016 mg/L) and chloroform (up to 0.010 mg/L) were detected in some of the ARP wells.

A-Area Coal Pile Runoff Containment Basin

The A-Area Coal Pile Runoff Containment Basin (788-3A) is east of Road D (Figure 5-3, Vol. II) and approximately 535 ft southeast of the A-Area coal pile. See the beginning of this chapter for a discussion of SRS coal pile runoff containment basins.

The site is monitored by the four wells of the ACB series (Table 5-4, Vol. II). The horizontal gradients in the area are low, making the terms *upgradient* and *downgradient* inappropriate at this site.

Gross alpha (up to 29.7 pCi/L) and total radium (up to 9.7 pCi/L) were detected above their respective drinking water standards in wells ACB 3A and 4A. No other radioactive constituents were detected above drinking water standards. However, nonvolatile beta activity was elevated in wells ACB 3A and 4A, with a level of 12.8 pCi/L in both wells.

No chemical constituents were detected above drinking water standards in the ACB wells. However, conductivity (up to 231 μmhos/cm) was elevated in wells ACB 3A and 4A.

A-Area Metals Burning Pit

The A-Area Metals Burning Pit (731-4A), placed in service about 1952, is west of Road D and south of the A-Area Burning/Rubble Pits (Figure 5-3, Vol. II). Lithium-aluminum alloy, aluminum pieces, plastic pipe, metal drums, and other metal scraps were deposited in piles in the pit and burned periodically. In 1974, the solid materials remaining in the pit were covered with soil, and the site was regraded. The site is currently inactive.

The basin is monitored by the four wells of the ABP series (Table 5-5, Vol. II). Wells ABP 1A, 2A, and 4 are screened below the water table, making interpretation of the site hydrology difficult.

No radioactive constituents were detected above drinking water standards.

No chemical constituents were detected above drinking water standards except trichloroethylene (up to 0.072 mg/L) in wells ABP 2A, ABP 3, and ABP 4.

Metallurgical Laboratory Seepage Basin

The Metallurgical Laboratory Seepage Basin (904-110G) at the east edge of A Area (Figure 5-4, Vol. II) received wastewater effluent from the Metallurgical Laboratory Building (723-A) from 1956 until 1985. Wastewater released to the basin consisted of small quantities of laboratory wastes from metallographic sample preparation (degreasing, cleaning, etching) and corrosion testing of stainless steels and nickel-based alloys. The wastewater volume discharged from the laboratory was small (5 to 10 gal/day) and consisted mostly of rinsewater. Noncontact cooling water (approximately 900 gal/day) was also discharged. The basin is currently inactive and contains rainwater.

The basin is monitored by the wells of the AMB series (Table 5-6, Vol. II). In the third quarter of 1988, the three existing AMB series wells (AMB 1A, 2, and 3A) were abandoned, and four new wells (AMB 4 through 7) were installed. The water table in this area is flat, making the terms *upgradient* and *downgradient* inappropriate.

No radioactive constituents were detected above drinking water standards at this site.

No chemical constituents were detected above drinking water standards except trichloroethylene (up to 0.058 mg/L) in wells AMB 2, 4, 5, and 6. Elevated pH, conductivity, and alkalinity in well AMB 6 suggest that water from this well may be affected by the leaching of well grout.

Miscellaneous Chemical Basin

The Miscellaneous Chemical Basin (731-5A) is west of Road D near the A-Area Metals Burning Pit (Figure 5-3, Vol. II). The basin, in operation by 1956, was closed and the site graded in 1974. There are no records of the materials disposed of at this site. However, soil gas investigations revealed halogenated organics in the near-surface soils at the site.

Wells MCB 2, 4, 5, and 6 were installed to monitor the groundwater at the site (Table 5-7, Vol. II). The site is near the water-table divide between Tims Branch

and the Savannah River Swamp. The horizontal water-table gradients at the site are low, making interpretation of site hydrology difficult. Well MCB 6 appears to be sidegradient to downgradient of the basin; wells MCB 4 and 5 appear to be upgradient; and well MCB 2 appears to be sidegradient.

No radioactive constituents were detected above drinking water standards.

Trichloroethylene (up to 0.531 mg/L) was detected at or above the drinking water standard in the MCB wells. Carbon tetrachloride was detected above drinking water standards in Well MCB 5 at 0.007 mg/L. No other chemical constituents were detected above drinking water standards. However, tetrachloroethylene (up to 0.072 mg/L) was detected in some of the MCB wells.

Motor Shop Oil Basin

The Motor Shop Oil Basin (904-101G) is at the south edge of A Area, by the 716-A Motor Shop (Figure 5-3, Vol. II). This unlined basin was placed in service in 1977 to receive liquid waste from the Motor Shop. Effluent discharges from the Motor Shop included waste engine oil, grease, kerosene, ethylene glycol, and soapy water. All waste passed through an oil skimmer prior to discharge into the basin. In August 1983, all discharges to the oil basin were terminated. The site is currently inactive but collects rainwater during periods of heavy precipitation.

The basin is monitored by the two wells of the AOB series (Table 5-8, Vol. II). Horizontal groundwater gradients are low, making the terms *upgradient* and *downgradient* inappropriate. The basin is near NPDES Outfall A-14, a known source of halogenated organics.

No radioactive constituents were detected above drinking water standards.

No chemical constituents were detected above drinking water standards except trichloroethylene (up to 0.088 mg/L) and endrin (at 0.0005 mg/L) in well AOB 1. Tetrachloroethylene (up to 0.104 mg/L) was also detected in this well.

Savannah River Laboratory (SRL) Seepage Basins

Savannah River Laboratory (SRL) Seepage Basins (904-53G1, 904-53G2, 904-54G, and 904-55G) are southeast of Road 1-A across from SRL (Figure 5-3, Vol. II). These four basins, constructed between 1954 and 1960, received low-level radioactive wastewater through underground drains from laboratories in Buildings 735-A and 773-A.

Basins 1 (Building 904-53G1) and 2 (Building 904-53G2) were placed in operation in 1954. Basins 3 (Building 904-54G) and 4 (Building 904-55G) were added in 1958 and 1960, respectively, to provide additional holding capacity. Wastewater flowed sequentially from Basin 1 to Basin 4 (west to east) in cascade via overflow channels. Basin 4 has no overflow or outlet. When the basins were in operation, only wastewater with radioactivity less than 100 d/m/mL alpha and/or 50 d/m/mL beta-gamma was discharged to the basins. An exception to this practice was made in 1971 when 0.68 Ci of curium from a leaking separator pit in Building 776-A was disposed of to the basins. Approximately 34 million gal of wastewater were discharged to the basins during their operating life. The basins were taken out of service in October 1982.

The basins are monitored by seven wells of the ASB series (1A, 2A, 3A, 4, 5A, 6A, and 7) (Table 5-9, Vol. II). The groundwater gradients in this area are relatively flat, and changes in flow direction have occurred. Generally, wells ASB 2A and 3A are upgradient; wells ASB 4 and 6A are downgradient.

ASB well clusters 8 and 9 are not adjacent to the basins: well cluster ASB 8 is near NPDES Outfall A-1, a possible source of contaminants; wells ASB 9 and 9B are approximately 1,600 ft southeast of the seepage basins. Well clusters ASB 8 and ASB 9 are part of the M-Area Plume Definition program, and results for these wells are discussed in the M-Area Plume Definition section.

Gross alpha (at 19.0 pCi/L) was detected above the drinking water standard in well ASB 6A. No other radioactive constituents were detected above drinking water standards. However, elevated levels of nonvolatile beta activity (at 11.0 pCi/L) were detected in well ASB 6A.

No chemical constituents were detected above drinking water standards except trichloroethylene (at 0.022 mg/L) in well ASB 5A. Tetrachloroethylene (up to 0.153 mg/L) was detected in some ASB wells.

Silverton Road Waste Site

The Silverton Road Waste Site (731-3A), southwest of Road C-1.1 (Figure 5-5, Vol. II), was used for

disposal of metal shavings, construction debris, tires, drums, tanks, and miscellaneous items. The site was probably used before construction of SRS, but the startup date is unknown, and no records of waste disposal activities have been kept. The site was closed in 1974. The waste material is presently covered with soil and vegetation.

The site is monitored by the 30 wells of the SRW series (Table 5-10, Vol. II) The wells monitor the water table and deeper zones. Wells with an "A" or "B" after the well number monitor the lower zones. Wells SRW 1 through 6 are at the edge of the site, with well SRW 1 and well cluster SRW 2 upgradient, well SRW 4 sidegradient to downgradient, and wells SRW 5 and 6 downgradient. The remaining wells are farther from the site, with well cluster SRW 16 upgradient, clusters SRW 14 and 15 sidegradient, and the remaining wells downgradient.

Total radium activity was above the drinking water standard in well SRW 6 at 6.8 pCi/L. No other radioactive constituents were detected above drinking water standards.

Carbon tetrachloride (up to 0.007 mg/L) was detected above the drinking water standard in wells SRW 7, 8, and 11. Trichloroethylene (up to 0.014 mg/L) was detected above the drinking water standard in wells SRW 7, 8, 11, 13C, and 14A. Lead (at 0.61 mg/L) was detected above the drinking water standard in well SRW 15B. No other chemical constituents were detected above drinking water standards. However, conductivity (at 181 μmhos/cm) was elevated in well SRW 16A.

C AREA

C Area is located near the central part of SRS as shown in Figure 5-1. Surface elevations across the area range approximately from 250 to 290 ft msl. Surface drainage is predominantly to the west toward a tributary of Four Mile Creek.

The nearest plant boundary from C Area is approximately 5.6 miles to the west. Several incised tributaries and streams exist between C Area and the SRS boundary and are regions of water-table discharge.

In 1988, groundwater was monitored at the following sites in C Area: the C-Area Burning/Rubble Pit, the C-Area Coal Pile Runoff Containment Basin, the C-Area Disassembly Basin, and C-Area Reactor Seepage Basins (Figure 5-6, Vol. II). A summary of maximum groundwater monitoring results at these sites is given in Table 5-3 and also in Table 5-11, (Vol. II).

Table 5-3. Selected Maximum Constituent Levels at C Area

Constituent	DWS	Units	CRP	CDB	CSB	CCB
Gross Alpha	15	pCi/L	9	2.3	1.26	-
Nonvolatile Beta	-	pCi/L	<2	5.9	172	-
Total Radium	5	pCi/L	0.8	1.4	0.88	-
Tritium	20	pCi/mL	**259**	**433**	**861**	10.8
Cadmium	0.01	mg/L	-	-	<0.002	-
Lead	0.05	mg/L	**0.108**	**0.157**	**0.145**	-
Mercury	0.002	mg/L	-	-	<0.0002	-
Nitrate (as N)	10	mg/L	1.06	-	-	-
Trichloroethylene	0.005	mg/L	**13.7**	-	**3.44**	-

Note: Analytical results in bold are above drinking water standards.
DWS = EPA drinking water standards; refer to Table 5-1, Vol. I.
CRP = C-Area Burning/Rubble Pit Wells
CDB = C-Area Disassembly Basin Wells
CSB = C-Area Reactor Seepage Basins Wells
CCB = C-Area Coal Pile Runoff Containment Basin Wells

C-Area Burning/Rubble Pit

The C-Area Burning/Rubble Pit (131-C) is approximately 1,000 ft west of C Area (Figure 5-6, Vol. II) on a gentle, west-trending slope. See the beginning of this chapter for a discussion of SRS burning/rubble pits.

The site is monitored by the four wells of the CRP series (Table 5-12, Vol. II). Relative to the pit, well CRP 1 is upgradient, well CRP 3 is downgradient, and wells CRP 2 and 4 are sidegradient.

Tritium (up to 404 pCi/mL) was detected above the drinking water standard in wells CRP 1 and 2. No other radioactive constituents were detected above drinking water standards.

Trichloroethylene (up to 13.7 mg/L) was detected above the drinking water standard in wells CRP 1 and 3. Lead (up to 0.108 mg/L) and chromium (up to 0.101 mg/L) were detected above their respective drinking water standards in well CRP 3. No other chemical constituents were detected above drinking water standards. However, well CRP 3 exhibited elevated pH (up to 12.1), alkalinity (up to 430 mg/L), and conductivity (up to 2,400 μmhos/cm), suggesting that the water from the well may be affected by well grout.

C-Area Coal Pile Runoff Containment Basin

The C-Area Coal Pile Runoff Containment Basin (189-C) is southeast of C Area approximately 650 ft southeast of the former location of the C-Area coal pile (Figure 5-6, Vol. II). See the beginning of this chapter for a discussion of SRS coal pile runoff containment basins.

The site is monitored by the four wells of the CCB series (Table 5-13, Vol. II). Relative to the basin, well CCB 3 is sidegradient, and wells CCB 1 and 2 are sidegradient to downgradient.

No radioactive or chemical constituents were detected above drinking water standards at this site.

C-Area Disassembly Basin

The C-Area Disassembly Basin (105-C) is located in the center of C Area (Figure 5-6, Vol. II). See the beginning of this chapter for a discussion of SRS disassembly basins.

Wells CDB 1 and CDB 2 monitor the C-Area Disassembly Basin (Table 5-14, Vol. II). There is insufficient information to determine the horizontal groundwater gradient at this site.

Tritium (up to 433 pCi/mL) was detected above the drinking water standard in wells CDB 1 and 2. No other radioactive constituents were detected above drinking water standards.

No chemical constituents were detected above drinking water standards except lead (up to 0.157 mg/L), which was detected in both CDB wells.

C-Area Reactor Seepage Basins

The three C-Area Reactor Seepage Basins (Buildings 904-66G, 904-67G, and 904-68G), currently active and receiving purge water when the C-Area Reactor is operating, are about 650 ft west of the reactor building (Figure 5-6, Vol. II). The basins are connected in series, with water entering Basin 1 then moving to Basins 2 and 3. See the beginning of this chapter for a discussion of SRS reactor seepage basins.

The basins are monitored by the six wells in the CSB series (Table 5-15, Vol. II). Well CSB 1A is upgradient relative to the basins. Well CSB 6A is sidegradient, and wells CSB 2A, 3A, 4A, and 5A are downgradient.

Tritium (up to 86,100 pCi/mL) was detected above the drinking water standard in all of the CSB wells. Total radium and gross alpha were not detected above their respective drinking water standards. Nonvolatile beta activity was elevated (172 pCi/L) in well CSB 1A on one occasion.

Trichloroethylene (up to 3.44 mg/L) was detected above the drinking water standard in all of the CSB wells. Lead (up to 0.145 mg/L) was detected above the drinking water standard in wells CSB 1A, 2A, and 3A. Chromium (up to 0.089 mg/L) was detected above the drinking water standard in well CSB 1A. No other chemical constituents were detected above drinking water standards. The pH, conductivity, and alkalinity of water from wells CSB 1A and 5A were elevated, suggesting that water in these wells is being affected by well grout.

CENTRAL SHOPS AREA

Central Shops (CS) Area is located in the central part of SRS as shown in Figure 5-1. Surface elevations

Table 5-4. Selected Maximum Constituent Levels at Central Shops Areas

Constituent	DWS	Units	CSA	CSO	CSR
Gross Alpha	15	pCi/L	1.5	-	7.3
Nonvolatile Beta	-	pCi/L	2	-	9.6
Tritium	20	pCi/mL	-	-	**236**
Cadmium	0.01	mg/L	0.002	-	-
Lead	0.05	mg/L	0.006	0.021	0.01
Nitrate (as N)	10	mg/L	4.36	-	0.87

Note: Analytical results in bold are above drinking water standards.
DWS = EPA drinking water standards; refer to Table 5-1, Vol. I.
CSA = Central Shops Hydrofluoric Acid Spill Area Wells
CSO = Fire Department Training Facility Wells
CSR = Central Shops Burning/Rubble Pits Wells

across the area range approximately from 280 to 300 ft msl. Surface drainage is to tributaries of Four Mile Creek to the north, west, and south and to tributaries of Pen Branch to the east.

The nearest plant boundary to CS Area is approximately 5.5 miles to the west. Four Mile Creek, Upper Three Runs Creek, and several other incised creeks are located between CS Area and the plant boundary and are areas of groundwater discharge.

In 1988, groundwater was monitored at the following sites in CS Area: the Central Shops Burning/Rubble Pits, the Fire Department Training Facility, the Ford Building Seepage Basin, the Hazardous Waste Storage Facility, and the Hydrofluoric Acid Spill Area (Figure 5-7, Vol. II). A summary of maximum groundwater monitoring results for these sites is given in Table 5-4 and Table 5-16, (Vol. II).

Central Shops Burning/Rubble Pits

The Central Shops Burning/Rubble Pits (631-1G and 631-5G) are about 1,600 ft north of CS Area (Figure 5-7, Vol. II). The exact boundaries of the pits are unknown. See the beginning of this chapter for a discussion of SRS burning/rubble pits.

This site is monitored by the four wells of the CSR series (Table 5-17, Vol. II). Available information indicates that wells CSR 1 through 4 are located either upgradient or sidegradient relative to pits 631-1G and 631-5G.

No radioactive constituents were detected above drinking water standards except tritium (at 236 pCi/mL) in well CSR 4.

No chemical constituents were detected above drinking water standards in the CSR wells.

Fire Department Training Facility

The Fire Department Training Facility (904-113G), also known as the Central Shops Burnable Oil Basin, is at the southeast end of CS Area (Figure 5-7, Vol. II), about 500 ft north of the Ford Building (690-G). The site, a shallow pit surrounded by an 18-in.-high asphalt dike, was used from 1979 to 1982 by the SRS Fire Department to train personnel to use firefighting equipment.

The site is monitored by the two wells of the CSO series (Table 5-18, Vol. II). There is not enough information to determine the water-table gradient at this site.

No radioactive or chemical constituents were detected above drinking water standards at this site.

Ford Building Seepage Basin

The Ford Building Seepage Basin (904-91G) (Figure 5-7, Vol. II) is approximately 100 ft east of the Ford Building (690-G). The basin received low-level radioactive wastewater from Ford Building opera-

tions (repairing heat exchangers) from 1964 to January 1984. The basin is currently inactive.

The basin is monitored by the three wells of the HXB series (Table 5-19, Vol. II). All of the HXB wells are screened below the water table. Relative to the basin, wells HXB 2 and 3 are upgradient, and well HXB 1 is sidegradient.

Samples were not analyzed for radioactive constituents at this site, and no chemical constituents were detected above drinking water standards.

Hazardous Waste Storage Facility

The Hazardous Waste Storage Facility (709-G) is west of CS Area (Figure 5-7, Vol. II). Since November 1983, wastes have been stored inside the building in drums placed on diked concrete floors designed to contain liquid spills. The facility, which is currently active, is inspected routinely for container leakage.

The site is monitored by the two wells of the HWS series (Table 5-20, Vol. II). Relative to the building, well HWS 2 is upgradient, and well HWS 1A is sidegradient.

Samples were tested for pH, conductivity, and alkalinity, none of which were elevated in either well.

Hydrofluoric Acid Spill Area

The Hydrofluoric Acid Spill Area (631-4G) is at the south end of CS Area, just north of the rail line to C Area (Figure 5-7, Vol. II). It is uncertain whether a spill occurred at this site or if contaminated soil or containers are buried here. The spill or burial occurred prior to 1970, and an identification sign is the only evidence that material was released at this site.

This site is monitored by the four wells of the CSA series (Table 5-21, Vol. II). Relative to the site, well CSA 2 is upgradient, wells CSA 1 and 3 are sidegradient, and well CSA 4 is downgradient.

No radioactive or chemical constituents were detected above drinking water standards at this site.

D AREA

D Area is located in the southwest part of SRS as shown in Figure 5-1. Surface elevations across D Area range approximately from 100 to 150 ft msl, decreasing to the west-southwest toward the Savannah River. The nearest plant boundary to D Area is the Savannah River, approximately 0.75 miles to the west. Natural discharge of the water table is to the Savannah River and to the nearby swamp.

In 1988, groundwater was monitored at the following sites in D Area: the D-Area Burning/Rubble Pits, the D-Area Coal Pile Runoff Containment Basin and Ash Basins, and the D-Area Oil Disposal Basin (Figures 5-8 and 5-9, Vol. II). A summary of the maximum groundwater monitoring results for these sites is presented in Tables 5-5 and 5-22 (Vol. II).

D-Area Burning/Rubble Pits

The D-Area Burning/Rubble Pits (431-D and 431-1D) are approximately 1,000 ft west of D Area (Figure 5-8, Vol. II). See the beginning of this chapter for a discussion of SRS burning/rubble pits.

The site is monitored by the four wells of the DBP series (Table 5-23, Vol. II). Relative to the pits, wells DBP 1 and 3 are upgradient, well DBP 4 is sidegradient, and well DBP 2 is downgradient.

No radioactive or chemical constituents were detected above drinking water standards. However, elevated conductivity (up to 260 μmhos/cm) and sulfate (up to 51.0 mg/L) concentrations were detected in wells DBP 2 and 4.

D-Area Coal Pile Runoff Containment Basin and Ash Basins

The D-Area Coal Pile Runoff Containment Basin (489-D) is south of D Area (Figure 5-8, Vol. II). See the beginning of this chapter for a discussion of SRS coal pile runoff containment basins. The D-Area Ash Basins (Buildings 488-D, 488-1D, and 488-2D) are southwest of the D-Area perimeter fence on a northwest-trending slope. Ash sluice water from the D-Area powerhouse has been discharged to the D-Area Ash Basins since plant startup in 1951. The annual ash disposal rate into the D-Area Ash Basins was approximately 50,000 yd^3/yr until 1983 and has been approximately 65,000 yd^3/yr since 1983.

The D-Area Coal Pile Runoff Containment Basin is monitored by the 16 wells of the DCB series (Table 5-24, Vol. II). Wells DCB 13 through 16 were installed in the third quarter of 1988. Relative to the basin, wells DCB 2A, 7, and 8 are upgradient, wells DCB 1A, 3A, 6, and 9 are sidegradient, and wells DCB 4A, 5A, and 10 are downgradient. Wells DCB 1A, 6, 7, 9, and 10 are downgradient of the coal pile. Well DCB 14 is sidegradient of the D-Area Ash Basins (488-D,

Table 5-5. Selected Maximum Constituent Levels at D Area

Constituent	DWS	Units	DBP	DCB	DOB
Gross Alpha	15	pCi/L	-	**191**	-
Nonvolatile Beta	-	pCi/L	-	**145**	-
Total Radium	6	pCi/L	-	**48.4**	-
Tritium	20	pCi/mL	-	**261**	-
Cadmium	0.01	mg/L	-	**0.042**	-
Lead	0.05	mg/L	0.006	**0.075**	-
Mercury	0.002	mg/L	-	0.001	-
Nitrate (as N)	10	mg/L	1.98	2.28	-
Trichloroethylene	0.005	mg/L	<0.001	**0.088**	**0.113**
Endrin	0.0002	mg/L	-	<0.0001	-

Note: Analytical results in bold are above drinking water standards.
DWS = EPA drinking water standards; refer to Table 5-1, Vol. I.
DBP = D-Area Burning/Rubble Pits Wells
DCB = D-Area Coal Pile Runoff Containment Basin Wells
DOB = D-Area Oil Disposal Basin Wells

488-1D, and 488-2D) and may be downgradient of the coal pile. Well DCB 11 is located in the northernmost ash basin and is probably sampling water from within the basin. Wells DCB 12, 15, and 16 are downgradient of the coal pile runoff containment basin and the ash basins. Well DCB 13 is upgradient of the ash basins and downgradient of the coal pile runoff containment basin.

Gross alpha (up to 191 pCi/L) was detected above the drinking water standard in wells DCB 1A, 6, 7, 9, and 10. Total radium (up to 48.4 pCi/L) was detected above the drinking water standard in wells DCB 1A, 6, 7, and 10. Tritium (up to 261 pCi/mL) was detected above the drinking water standard in wells DCB 12 and 14. Nonvolatile beta activity (up to 145 pCi/L) was elevated in wells DCB 1A, 6, 7, 10, 11, 14, and 16.

The DCB wells with the highest levels of chemical contamination are downgradient of the coal pile runoff containment basin and the coal pile (DCB 1A, 4A, 5A, 6, 7, 9, and 10) or within or downgradient of the ash basins (DCB 11, 12, 14, 15, and 16). The chemical contamination is characterized by low pH (down to 1.8) and high conductivity (up to 7,100 μmhos/cm), sulfate (up to 6,000 mg/L), and total dissolved solids (TDS) (up to 6,430 mg/L) levels. Cadmium (up to 0.042 mg/L), chromium (up to 0.854 mg/L), fluoride (up to 14.2 mg/L), lead (up to 0.071 mg/L), and trichloroethylene (up to 0.088 mg/L) were detected above their respective drinking water standards in many of these same wells. Lead (at 0.075 mg/L) was also detected above the drinking water standard in well DCB 2A. Selenium (up to 0.027 mg/L) was detected above the drinking water standard in wells DCB 1A and 10. Arsenic (up to 0.249 mg/L) was detected above the drinking water standard in wells DCB 6 and 10. No other chemical constituents were detected above drinking water standards. Tetrachloroethylene (up to 0.089 mg/L) was detected in wells DCB 6, 9, and 12.

The Savannah River Ecology Laboratory sampled the DCB wells monthly as part of an investigation of sources of contamination and the nature and fate of contaminants in D Area. Samples from the wells were analyzed for selected anions and cations.

D-Area Oil Disposal Basin

The D-Area Oil Disposal Basin (631-G) is north of D Area between Roads A-4.4 and A-4.5 (Figure 5-9, Vol. II). The basin was constructed in 1952 and began receiving waste oil products from D Area that were unacceptable for incineration in the powerhouse boilers. These waste oils may have contained hydrogen sulfide, chlorinated organics, or other chemicals. In 1975, the oil basin was removed from service and backfilled with soil.

The basin is monitored by the four wells of the DOB series (Table 5-25, Vol. II). The horizontal gradient in this area is low, and at least two major flow direction reversals have occurred since mid-1984. The flat water table and resultant fluctuations in flow direction make characterization of the hydrologic regime difficult.

No radioactive constituents were detected above drinking water standards at this site.

No chemical constituents were detected above drinking water standards except for trichloroethylene in well DOB 2 (at 0.113 mg/L). Tetrachloroethylene (up to 0.013 mg/L) was detected in wells DOB 1 and 2.

F AREA

F Area is located in the central part of SRS as shown in Figure 5-1. Surface elevations across F Area range approximately from 260 to 320 ft msl. F Area is incised by several tributaries of Upper Three Runs Creek, approximately 2,200 ft to the north and west, and of Four Mile Creek, approximately 2,000 ft to the south.

The nearest plant boundary to F Area is approximately 6 miles to the west. F Area is on a near-surface groundwater divide between Upper Three Runs Creek and an unnamed tributary of Four Mile Creek. The near-surface groundwater from the southern part of F Area discharges to an unnamed tributary of Four Mile Creek, approximately 2,000 ft to the south. The near-surface groundwater from the northern part of F Area discharges to one of many tributaries of Upper Three Runs Creek, approximately 1,500 ft to the north.

In 1988, groundwater was monitored at the following sites in F Area: the F-Area Acid/Caustic Basin, the F-Area A Line, the F-Area Burning/Rubble Pits, the F-Area Canyon Building, the F-Area Coal Pile Runoff Containment Basin, the F-Area Effluent Treatment Facility, the F-Area Seepage Basins, the F-Area Sludge Land Application Site, the F-Area Tank Farm, the Naval Fuel Material Facility Background Wells, and the Old F-Area Seepage Basin (Figures 5-10 through 5-14, Vol. II). A summary of the maximum groundwater monitoring results for these sites is presented in Table 5-6 and in Table 5-26, (Vol. II).

F-Area Acid/Caustic Basin

The F-Area Acid/Caustic Basin (904-74G) is east of F Area on a slope that leads to an unnamed tributary of Upper Three Runs Creek (Figure 5-11, Vol. II). See the beginning of this chapter for a discussion of SRS acid/caustic basins.

Table 5-6. Selected Maximum Constituent Levels at F Area

Constituent	DWS	Units	FAC	FCB	FNB	FSB
Gross Alpha	15	pCi/L	**39.9**	9.1	**71**	**2140**
Nonvolatile Beta	-	pCi/L	32.6	6.8	651	10900
Total Radium	5	pCi/L	**21.8**	4.3	**12.1**	**140**
Tritium	20	pCi/mL	<0.7	10.4	**515**	**65800**
Cadmium	0.01	mg/L	<0.002	<0.002	<0.002	**0.113**
Lead	0.05	mg/L	0.006	0.032	0.022	**3.6**
Mercury	0.002	mg/L	0.0003	<0.0002	0.0011	**0.0037**
Nitrate (as N)	10	mg/L	0.27	1.49	**30.7**	**545**
Trichloroethylene	0.005	mg/L	-	-	**0.075**	**0.019**
Endrin	0.0002	mg/L	<0.0001	<0.0001	-	<0.0001

Note: Analytical results in bold are above drinking water standards.
DWS = EPA drinking water standards; refer to Table 5-1, Vol. I.
FAC = F-Area Acid/Caustic Basin Wells
FCB = F-Area Coal Pile Runoff Containment Basin Wells
FNB = Old F-Area Seepage Basin Wells
FSB = F-Area Seepage Basins Wells

The site is monitored by the wells of the FAC series (Table 5-27, Vol. II). Wells FAC 1 and 2 have been inactive since the fourth quarter of 1987; wells FAC 5 through 8 were installed in the third quarter of 1988. The screen zone elevations in the site wells vary, and a clear pattern of water elevations in the wells does not exist, making interpretation of the water-table flow direction difficult.

Gross alpha (up to 39.9 pCi/L) and total radium (up to 21.8 pCi/L) were detected above their respective drinking water standards in wells FAC 3 and 4. Tritium was not detected above the drinking water standard. Nonvolatile beta activity (up to 32.6 pCi/L) was elevated in wells FAC 3, 4, and 7.

No chemical constituents were detected above drinking water standards. Well FAC 3 has elevated pH and conductivity, suggesting that it may be influenced by well grout. Conductivity (up to 130 μmhos/cm) was also elevated in wells FAC 4, 5, and 7.

F-Area A Line and F-Area Canyon Building

The F-Area Canyon Building (221-F) is in the center of F Area (Figures 5-11 and 5-12, Vol. II). The A-Line Uranium Recovery Facility (221-1F) is east of the south end of the Canyon Building (Figure 5-11 and 5-12, Vol. II). At the A-Line building, uranium is processed in the form of uranyl nitrate. At the Canyon Building, target rods from the reactors are dissolved using nitric acid, and the desired radionuclides are separated from the other fission products.

The groundwater at these buildings is monitored by the two wells of the FAL series and the five well clusters of the FCA series (Table 5-28, Vol. II). Eight other shallow wells of the FCA series, which are usually dry, monitor the canyon building base slab. These buildings are near the groundwater divide between Upper Three Runs Creek and Four Mile Creek. Horizontal gradients in the water table are low, making it difficult to determine which wells are upgradient or downgradient. Wells FAL 1, FAL 2, and FCA 2D are between the southeast end of the canyon building and the A-Line building.

Gross alpha (up to 238 pCi/L) was detected above the drinking water standard in wells FCA 2D, 9D, 10A, and 16D. Total radium (up to 11.8 pCi/L) was detected above the drinking water standard in wells FCA 2D, 9D, 10A, 16A, and 16D. Tritium (up to 452 pCi/mL) was detected above the drinking water standard in wells FCA 2D and 16D. Nonvolatile beta activity (up to 833 pCi/L) was elevated in wells FCA 2D, 9D, 10A, 10D, 16A, and 16D.

Nitrate (up to 31.2 mg/L) was detected above the drinking water standard in wells FCA 2D, 10A, and 16D. Trichloroethylene (up to 0.435 mg/L) was detected above the drinking water standard in wells FAL 1 and 2 and in wells FCA 2D and 16D. No other chemical constituents were detected above drinking water standards. However, conductivity (up to 425 μmhos/cm) was elevated in wells FAL 1 and FCA 2D, 9D, 10D, and 16D; pH (at 3.8) was low in well FCA 2D.

F-Area Burning/Rubble Pits

The F-Area Burning/Rubble Pits (231-F and 231-1F) are north of the intersection of Road C and the F-Area entrance road (Figure 5-11, Vol. II). See the beginning of this chapter for a discussion of SRS burning/rubble pits.

The site is monitored by the four wells of the FBP series (Table 5-29, Vol. II). The tops of the screens in the FBP wells are below the water table, making interpretation of the groundwater gradient difficult. Well FBP 1A is downgradient of the old pipeline to the F-Area Seepage Basins and may be affected by it.

No radioactive constituents were detected above drinking water standards. However, nonvolatile beta activity (up to 88.1 pCi/L) was elevated in well FBP 1A.

Trichloroethylene (up to 0.076 mg/L) was detected above the drinking water standard in wells FBP 1A and 2A. Carbon tetrachloride (up to 0.012 mg/L) was detected above the drinking water standard in well FBP 2A. No other chemical constituents were detected above drinking water standards. However, conductivity (up to 120 μmhos/cm) was elevated in well FBP 1A, and tetrachloroethylene (up to 0.060 mg/L) were detected in well FBP 2A.

F-Area Coal Pile Runoff Containment Basin

The F-Area Coal Pile Runoff Containment Basin (289-F) is southeast of F Area (Figure 5-11, Vol. II). See the beginning of this chapter for a discussion of SRS coal pile runoff containment basins.

The basin is monitored by the wells of the FCB series (Table 5-30, Vol. II). Well FCB 1 was abandoned in the third quarter of 1988 because of its anomalously

high pH. Wells FCB 5 through 7 were added to the monitoring network in the third quarter of 1988. Relative to the basin, wells FCB 1, 2, and 7 are upgradient, well FCB 4 is sidegradient to downgradient, and wells FCB 3, 5, and 6 are downgradient.

No radioactive or chemical constituents were detected above drinking water standards. Elevated conductivity, pH, and alkalinity indicate that water from well FCB 1 and possibly well FCB 6 is being influenced by well grout.

F-Area Effluent Treatment Retention Basin

The F-Area Effluent Treatment Retention Basin is located in the southwest portion of F Area (Figure 5-11, Vol. II). The basin serves the F/H Effluent Treatment Facility (ETF), which was placed in service in 1988 to treat the effluent formerly sent to the F- and H-Area Seepage Basins.

The basin is monitored by the four FET series wells (Table 5-31, Vol. II), which were installed in the third quarter of 1988. The horizontal groundwater gradient is low at this site, making interpretation of the horizontal flow direction difficult. In general, well FET 1D appears to be upgradient, and wells FET 2D, 3D, and 4D appear to be downgradient.

No radioactive or chemical constituents were detected above drinking water standards in the FET wells.

F-Area Seepage Basins

The F-Area Seepage Basins (904-41G, 904-42G, and 904-43G) are on both sides of Road C-4, southwest of Road C (Figure 5-13, Vol. II). Beginning in 1955, the basins received wastewater from F Area containing low-level radioactivity and chemicals, including nitric acid, mercury, and sodium hydroxide. In 1988, the basins operated under RCRA interim status until they were taken out of service in the fourth quarter of 1988.

Two water tables exist beneath the F-Area Seepage Basins: a perched groundwater table 10 to 26 ft below the ground surface and the normal water table, which is 60 to 65 ft below the ground surface. Both water tables discharge into Four Mile Creek, about 1,650 ft to the southeast.

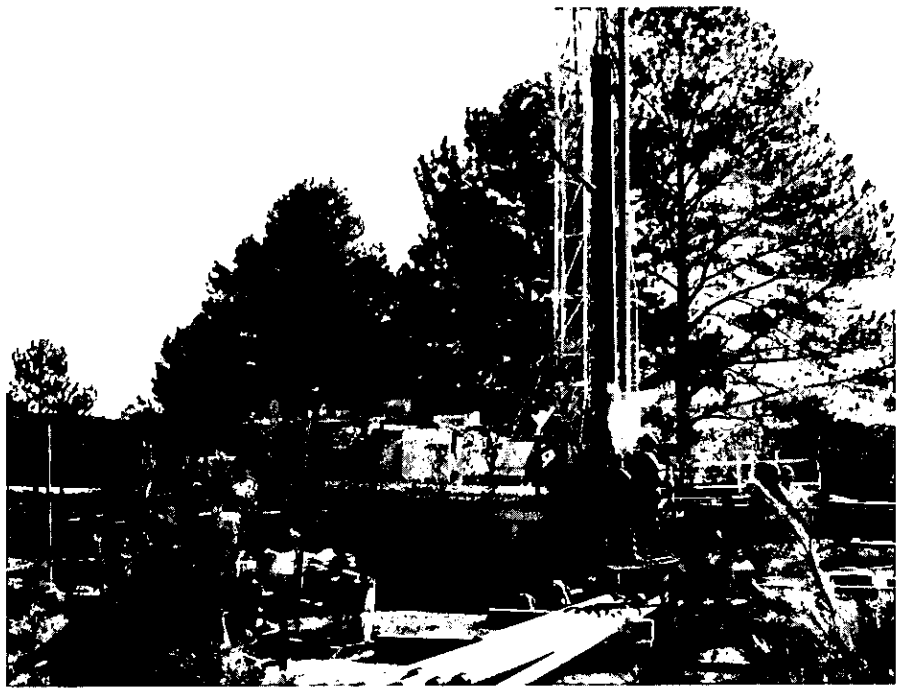
Three other water-bearing zones are monitored under the F-Area Seepage Basins. The Dry Branch and Santee Formations are monitored between 130 and 165 ft msl, the upper part of the Congaree Formation is monitored between 80 and 115 ft msl, and the lower part of the Congaree Formation is monitored between 25 and 60 ft msl. The vertical groundwater gradient is downward from the water table to the upper part of the Congaree Formation. The vertical gradient is upward to neutral between the upper and lower parts of the Congaree Formation. Groundwater in the Dry Branch and Santee Formations flows south toward Four Mile Creek. The groundwater in the Congaree Formation flows west toward Upper Three Runs Creek.

The F-Area Seepage Basins are monitored by the F and the FSB series wells (Table 5-32, Vol. II). Forty-two RCRA POC and plume assessment wells were added to the FSB monitoring network during the fourth quarter of 1987 and the first quarter of 1988. Water-table wells FSB 76, 108D, and 109D and F 24 are upgradient of the basins. The other water-table wells are downgradient to sidegradient of the basins.

At least one radioactive constituent was detected above drinking water standards in all water-table wells except FSB 108D and FSB 111D. Tritium (up to 65,800 pCi/mL), gross alpha (up to 2,140 pCi/L), and total radium (up to 140 pCi/L) activities were highest in the wells south and southwest of the basins. Strontium-89/90 was elevated above the drinking water standard in well F 10 at 173 pCi/L. Nonvolatile beta activity (up to 10,900 pCi/L) was elevated in the same area.

All of the wells screened in the Dry Branch and Santee Formations had tritium activities (up to 14,500 pCi/mL) above the drinking water standard except well FSB 76C. Gross alpha (up to 1,250 pCi/L) and total radium (up to 111 pCi/L) were detected above their respective drinking water standards in many of the same wells, particularly near Basin 3 (904-43G). Nonvolatile beta activities (up to 5,390 pCi/L) were elevated in most of the wells that contained elevated tritium activity.

All the wells monitoring the upper portion of the Congaree Formation had tritium activities (up to 556 pCi/mL) above the drinking water standard except wells FSB 76B, 79B, 96A, and 101A. Gross alpha (up to 140 pCi/L) was detected above the drinking water standard in wells FSB 96A and 98A. Total radium (up to 10.9 pCi/L) was detected above the drinking water standard in well FSB 98A. Nonvolatile beta activities (up to 262 pCi/L) were elevated in wells FSB 78B, 96A, 97A, 98A, and 100A.



Installation of surface casing during well construction in F Area

Tritium (up to 23.6 pCi/mL) in wells FSB 78A and FSB 87A was the only radioactive constituent detected above drinking water standards in the wells monitoring the lower portion of the Congaree Formation.

The chemical constituents above drinking water standards in the FSB wells occur in the same general pattern as the radioactive constituents. The contaminated groundwater is characterized by low pH (as low as 2.7) and high conductivity (up to 5,180 μmhos/cm), nitrate (up to 545 mg/L), and total dissolved solids (TDS; up to 2,320 mg/L) levels. Arsenic (up to 0.130 mg/L) was detected above the drinking water standard in wells FSB 91D, 92D, 94D, 95D, 104D, 105D, and 110D. Barium (up to 2.16 mg/L) was detected above the drinking water standard in wells FSB 90D, 92D, 98A, 98D, and 105D. Cadmium (up to 0.113 mg/L) was detected above the drinking water standard in wells FSB 78, 78C, 79C, 87D, 88D, 90D, 91C, 91D, 92D, 94D, 95D, 98C, 98D, 105C, 105D, 106C, and 107D. Chromium (up to 0.146 mg/L) was detected above the drinking water standard in wells FSB 76C, 79A, 91D, 94D, and 95D. Fluoride (up to 15.5 mg/L) was detected above the drinking water standard in wells FSB 92D, 93D, 94C, 105C, and 105D. Lead (up to 3.60 mg/L) was detected above the drinking water standard in wells FSB 88D, 90D, 91D, 92D, 93D, 94D, 95D, 98D, 105D, and 110D. Mercury (up to 0.0037 mg/L) was detected above the drinking water standard in well FSB 107D. Selenium (up to 0.034 mg/L) was detected above the drinking water standard in FSB wells 91D, 92D, 94D, 95D, and 110D. Trichloroethylene was detected above the drinking water standard in well FSB 109D at 0.019 mg/L. Benzene (up to 0.019 mg/L) was detected above the drinking water standard in wells FSB 91D and 109D. No other chemical constituents were detected above drinking water standards in the FSB wells. Copper was elevated in well FSB 95D at 2.04 mg/L. Samples from the F series wells were not tested for chemical constituents.

High values for pH (up to 12.7), conductivity, and alkalinity indicate that water from FSB 91C, 94C, 95C, 96A, 97C, 98A, 98D, and 100A is possibly being influenced by well grout.

F-Area Sludge Land Application Site

See the Sludge Land Application Sites section under **General Areas**.

F-Area Tank Farm

The F-Area Tank Farm (241-F), at the southwest edge of F Area (Figures 5-11 and 5-14, Vol. II), comprises 22 subsurface tanks containing aqueous radioactive wastes. These wastes consist of sludges, supernatant liquid of varying salt concentrations, and salt cake. The sludges are primarily a mixture of oxides and hydroxides of manganese, iron, and aluminum and a small amount of uranium, plutonium, and mercury, with almost all of the fission products originally in the irradiated fuel except cesium. The supernate is primarily a solution of sodium nitrate, sodium nitrite, sodium hydroxide, sodium aluminate, and most of the soluble fission products including the major cesium isotopes. The solution volume is reduced in the tank farm evaporators, then stored in tanks to precipitate the sodium nitrate and sodium nitrite. This precipitate forms the salt cake. In 1961, Tank 8 was overfilled, causing soil contamination and subsequent groundwater contamination.

The site is monitored by the 27 wells of the FTF series (Table 5-33, Vol. II). The wells surround tank groups and monitor for leaks from the adjacent tanks. The tank farm is on a groundwater divide between Upper Three Runs Creek and Four Mile Creek. Groundwater flow is generally to the south. Gradients are low, particularly in the northern part of the site, making interpretation of the horizontal groundwater flow direction difficult.

Gross alpha (up to 114 pCi/L) was detected above the drinking water standard in wells FTF 5, 6, 7, 9, and 27. Total radium (up to 52.3 pCi/L) was detected above the drinking water standard in wells FTF 2, 3, 4, 6, 7, 9, 10, 11, 15, 16, 17, 18, 20, 22, 23, 24A, 25A, 26, and 27. Tritium (up to 257 pCi/mL) was detected above the drinking water standard in wells FTF 5, 6, 11, 12, 24A, and 27. Nonvolatile beta activity (up to 43,900 pCi/L) was elevated in wells FTF 4, 5, 6, 7, 9, 10, 11, 12, 15, 21, 25A, 26, and 27.

No chemical constituents were detected above the drinking water standard except for nitrate (up to 324 mg/L) in wells FTF 3, 4, and 6. Elevated pH and conductivity in wells FTF 12, 13, and 21 suggest that water from these wells may be influenced by well grout. Conductivity (up to 576 μmhos/cm) was also elevated in wells FTF 3, 4, 5, 6, 9, 10, 24A, 25A, 26, and 27.

Naval Fuel Material Facility Background Wells

The Naval Fuel Material Facility (247-F), in the northern part of F Area (Figures 5-11 and 5-12, Vol. II), began startup operations in 1986.

The five wells of the NBG series wells (Table 5-34, Vol. II) were installed between the Naval Fuel Material Facility and the other facilities in F Area to determine the groundwater quality prior to startup of the Naval Fuel Material Facility. Because the wells are almost in a line, it is difficult to interpret the local groundwater flow direction, but flow appears to be toward the east, which would place the wells sidegradient to the Naval Fuel Material Facility. Since the elevated levels of constituents which were observed in samples taken from the NBG wells were present prior to the startup of the Naval Fuel Material Facility, it is concluded that the elevated levels originated elsewhere and this facility is an unlikely source of any elevated levels observed in samples taken in the area.

Tritium (up to 955 pCi/mL) was detected above the drinking water standard in wells NBG 1 and 2. No other radioactive constituents were detected above drinking water standards. However, nonvolatile beta activity (up to 31.6 pCi/L) was elevated in wells NBG 1 and 2.

Nitrate (up to 34.0 mg/L) was detected above the drinking water standard in wells NBG 1 and 2. Trichloroethylene (up to 0.132 mg/L) was detected at or above the drinking water standard in all of the NBG wells. No other chemical constituents were detected above drinking water standards. However, conductivity (up to 486 μmhos/cm) was elevated in wells NBG 1, 2, and 3.

Old F-Area Seepage Basin

The Old F-Area Seepage Basin (904-49G) is north of the F-Area perimeter security fence and the Canyon Building (221-F) (Figure 5-11, Vol. II). The first seepage basin constructed in the area, it was used for disposal of wastewater from the Canyon Building from November 1954 until mid-May 1955, when it was abandoned in place. During operation, the seepage basin received a variety of wastewaters, including evaporator overheads, laundry wastewater, and an unknown amount of chemicals. Currently the basin is open and contains some rainwater.

The basin is monitored by the four wells of the FNB series (Table 5-35, Vol. II). Well FNB 4 is upgradient of the basin, wells FNB 3 and FNB 1 are sidegradient, and well FNB 2 is downgradient.

Gross alpha (up to 71.7 pCi/L) and total radium (up to 12.1 pCi/L) were detected above their respective drinking water standards in wells FNB 2 and 3. Tritium (up to 515 pCi/mL) was detected above the drinking water standard in wells FNB 1, 2, and 3. Nonvolatile beta activity (up to 651 pCi/L) was elevated in wells FNB 1, 2, and 3.

Trichloroethylene (up to 0.075 mg/L) was detected above the drinking water standard in wells FNB 1 and 2. Nitrate (up to 30.7 mg/L) was detected above the drinking water standard in wells FNB 2 and 3. No other chemical constituents were detected above drinking water standards. However, pH (down to 3.7) was low in well FNB 2, and conductivity (up to 321 μmhos/cm) was elevated in wells FNB 2 and 3.

GENERAL AREAS

The General Areas are those sections of SRS outside areas designated for specific purposes. In 1988, groundwater was monitored at the following sites in

Table 5-7. Selected Maximum Constituent Levels at the General Areas

Constituent	DWS	Units	BRD	CMP	LFW	PSS
Gross Alpha	15	pCi/L	6.3	5.9	**20.2**	2.6
Nonvolatile Beta	-	pCi/L	4.2	9.6	25	1.4
Total Radium	5	pCi/L	1.2	2.6	**7.7**	2.3
Tritium	20	pCi/mL	-	-	**99**	0.86
Cadmium	0.01	mg/L	-	-	<0.002	<0.002
Lead	0.05	mg/L	**0.135**	0.045	0.029	<0.006
Mercury	0.002	mg/L	-	-	0.0012	<0.0002
Nitrate (as N)	10	mg/L	1.72	-	1.06	0.62
Trichloroethylene	0.005	mg/L	-	**0.007**	**0.097**	-
Endrin	0.0002	mg/L	-	<0.0001	<0.0001	<0.0001

Note: Analytical results in bold are above drinking water standards.
DWS = EPA drinking water standards; refer to Table 5-1, Vol. I.
BRD = Road A Chemical Basin (Baxley Road) Wells
CMP = Chemicals, Metals, Pesticides Pits Wells
LFW = Sanitary Landfill Wells
PSS = P-Area Sludge Land Application Site Wells

the General Areas: the Background Well Near Hawthorne Fire Tower; the Chemicals, Metals, and Pesticides (CMP) Pits; the Road A Chemical Basin (Baxley Road); the Sanitary Landfills; the Sludge Land Application Sites; and in and around F and H Areas by the Z and ZW wells. Although three Sludge Land Application Sites (F, H, and K) are near specific areas, this research program and these sites are outside the objectives of these areas and their facilities. A summary of maximum groundwater monitoring results for these sites is presented in Table 5-7 and Table 5-36 (Vol. II).

Background Well Near Hawthorne Fire Tower

The Background Well near Hawthorne Fire Tower is in the north-central part of SRS between Upper Three Runs Creek and Tinker Creek (Figure 5-2, Vol. II). Well GBW 1 was installed at this site to provide background groundwater quality information (Table 5-37, Vol. II).

No radioactive or chemical constituents were detected above drinking water standards in the well GBW 1.

Chemicals, Metals, and Pesticides (CMP) Pits

The Chemicals, Metals, and Pesticides (CMP) Pits (080-17G, 080-17.1G, 080-18G, 080-18.1G, 080-18.2G, 080-18.3G, and 080-19G) are west of Road C (Figure 5-15, Vol. II) at the top of a hill near the head of Pen Branch. The CMP Pits were used to dispose of waste from 1971 through 1979. The waste consisted of drummed oil, organic solvents, and small amounts of pesticides and toxic metals. Detailed inventories of the wastes disposed of in each pit are not available. In 1984, the pits were excavated, backfilled, and capped. During excavation, much of the liquid waste was recovered in drums.

The site is monitored by the 21 wells of the CMP series (Table 5-38, Vol. II). Wells CMP 8, 10, 11, 12, 13, 14C, and 15C monitor the water table. Water-table wells CMP 9C and 16C were dry throughout 1988. The remaining wells monitor lower zones. The water table flows away from the pits on three sides so that all of the wells are downgradient except CMP 10, which is sidegradient or upgradient.

No radioactive constituents were detected above drinking water standards at this site.

No chemical constituents were detected above drinking water standards except for trichloroethylene (up to 0.007 mg/L) in well CMP 13. Tetrachloroethylene (up to 0.013 mg/L) was detected in wells CMP 12 and 13.

Road A Chemical Basin (Baxley Road)

The Road A Chemical Basin (Baxley Road) (904-111G) is approximately 2,600 ft west of the intersection of SRS Road A and SRS Road 6 (about 2 miles southeast of the D-Area Powerhouse) (Figure 5-16, Vol. II). The basin received miscellaneous radioactive and chemical aqueous waste, but no data on the wastes are available. The basin was closed and backfilled in 1973.

The basin is monitored by the four wells of the BRD series (Table 5-39, Vol. II). The top of the screen in well BRD 4 is below the water table, and the water level in BRD 3 was not measured during 1988, making interpretation of the site hydrology difficult.

No radioactive constituents were detected above drinking water standards at this site.

Lead (up to 0.135 mg/L) was detected above the drinking water standard in well BRD 3. No other chemical constituents were detected above drinking water standards.

Sanitary Landfills

The Sanitary Landfill (740-G) is southwest of Road C about midway down the slope from the Aiken Plateau to Upper Three Runs Creek (Figure 5-17, Vol. II). The site was opened in 1973. At the landfill, materials such as paper, plastics, rubber, wood, cardboard, and rags are placed in trenches, which are covered with soil daily. The landfill receives approximately 4,000 tons of waste per year. In addition to the waste already listed, the landfill receives pesticide bags, punctured and empty aerosol cans, food waste, and asbestos in bags. The landfill is operated under South Carolina Domestic Waste Permit No. 87A.

The water table at the landfill is monitored by the 31 wells of the LFW series (Table 5-40, Vol. II). The horizontal groundwater flow direction is to the southeast toward Upper Three Runs Creek. Wells LFW 29, 30, and 31 are upgradient. Wells LFW 37, 38, 39, 40, and 41 are downgradient. The remaining wells are within the landfill or are sidegradient.

Gross alpha was detected above the drinking water standard (at 20.2 pCi/L) in well LFW 7. Total radium (up to 7.7 pCi/L) was detected above the drinking water standard in wells LFW 7 and 8. Tritium (up to 99.0 pCi/mL) was detected above the drinking water standard in wells LFW 8, 18, and 21. Nonvolatile beta activity (up to 25.0 pCi/L) was elevated in wells LFW 7, 8, 19, 21, 25, and 37.

Trichloroethylene (up to 0.097 mg/L) was detected above the drinking water standard in wells LFW 21, 36, 37, and 38. Carbon tetrachloride was detected above the drinking water standard in well LFW 38 (at 0.008 mg/L). Benzene (up to 0.008 mg/L) was detected above the drinking water standard in wells LFW 7, 8, 21, and 36. 1,2-dichloroethane (up to 0.013 mg/L) was detected above the drinking water standard in wells LFW 7, 8, and 36. 1-1-dichloroethylene (at 0.019 mg/L) was detected above drinking water standards in well LFW 21. No other chemical constituents were detected above drinking water standards. However, conductivity (up to 752 μmhos/cm) was elevated in wells LFW 6, 7, 8, 17, 18, 21, and 36. Alkalinity (up to 330 mg/L) was elevated in wells LFW 6, 7, 8, 17, and 18. Tetrachloroethylene (up to 2.03 mg/L) was detected in wells LFW 16, 21, 23, 31, 37, 38, and 39.

The location of the New Sanitary Landfill has been proposed for east of Road 2 outside B Area. The SLW well series (eight piezometer wells) was installed in the second quarter of 1988 to characterize the hydrology of the area. The location of the landfill and landfill monitoring wells will depend on the piezometer information.

Sludge Land Application Sites

The Sludge Land Application Sites were the subject of a research program using domestic sewage sludge to reclaim borrow pits and to enhance forest productivity at SRS beginning in 1980. After sludge was applied to the sites, hardwoods and pines were planted to identify the amount of wood biomass that could be produced using the sludge as a fertilizer and soil conditioner. Eleven sites were permitted by SCDHEC for sludge application. The following nine sites had sludge applied in 1980: the 40-Acre Hardwood Site, the Par Pond Borrow Pit, the Kato Road Site, the Road F Site, the Sandy (Lucy) Site, the Orangeburg Site, the K-Area Borrow Pit, the Second Par Pond Borrow Pit, and the Lower Kato Road Site. In 1988, the Central Shops Sanitary Sewage Sludge Lagoon was closed, and the lagoon sludge was applied to the K-Area and Par Pond Borrow Pits. Sludge is currently disposed of at the F-Area Sludge Land Application Site. When this site becomes exhausted, sludge disposal will begin at the H-Area Sludge Land Application Site.

The Sludge Land Application Sites were monitored by the 33 SSS series wells, which were sampled before they were abandoned in 1988. Currently active sites had new well series installed in 1988, as outlined below. Monitoring results for both the active and abandoned wells are presented in Table 5-41 (Vol. II).

The F-Area Sludge Land Application Site covers 8 acres southeast of F Area, south of Road E (Figure 5-18, Vol. II). The site is monitored by the four wells of the FSS series, which were installed in the fourth quarter of 1988 to replace wells SSS 28, 29, and 30 at this site.

The H-Area Sludge Land Application Site covers 13 acres southeast of H Area, south of Road E (Figure 5-19, Vol. II). The site is monitored by the three HSS series wells, which were installed in the fourth quarter of 1988 and replaced wells SSS 31, 32, and 33 at the site.

The K-Area Sludge Land Application Site (formerly the K-Area Borrow Pit Site; 761-4G) covers 17 acres southeast of K Area on the west bank of Pen Branch above its confluence with Indian Grave Branch (Figure 5-20, Vol. II). Surface elevations at the site range approximately from 180 to 220 ft msl. The site is monitored by the three KSS series wells, which were installed in the fourth quarter of 1988 and replaced wells SSS 13, 14, and 15 at the site.

The Par Pond Sludge Land Application Site (formerly the Par Pond Borrow Pit Site; 761-5G) covers 22 acres south of Par Pond and approximately 1.3 miles north-northeast of the intersection of SRS Road B and F (Figure 5-21, Vol. II). Surface elevations at the site range approximately from 215 to 230 ft msl. The site is monitored by the three PSS wells, which were installed in the fourth quarter of 1988 to replace wells SSS 16, 17, and 18 at the site.

Gross alpha was detected above the drinking water standard in well SSS 27 at 23.7 pCi/L. Total radium (up to 20 pCi/L) was detected above the drinking water standard in wells SSS 5, 8, 9, 10, and 27. Nonvolatile beta activity (up to 15.4 pCi/L) was elevated in wells SSS 9 and 27. Tritium (up to 487 pCi/mL) was detected above the drinking water standard in wells FSS 2D and 3D.

No chemical constituents were detected above drinking water standards. However, conductivity (up to 110 µmhos/cm) was elevated in well KSS 1D. Conductivity, alkalinity, and pH were elevated in well FSS 1D, indicating that water from this well has been affected by leaching of the well grout column.

Z and ZW Wells

In 1951, the Z and ZW wells were installed in the Separations Areas as piezometer wells (Figures 5-2, 5-11, 5-13, 5-22, and 5-23, Vol. II). These wells, which range from 23 to 85 ft deep, measure water-table elevations. These wells also monitor for groundwater contamination that might exist within a large radius of F and H Areas. Monitoring results from these wells are presented in Table 5-42 (Vol. II).

Tritium (up to 387 pCi/mL) was detected above the drinking water standard in wells Z 3, 11, and 15 and ZW 2, 5, 6, 7, 8, 9, and 10. Gross alpha was detected above the drinking water standard in well Z 3 (32.2 pCi/L). No other radioactive constituents were detected above drinking water standards. However, nonvolatile beta activity (up to 321 pCi/mL) was elevated in wells Z 3 and 19A and ZW 7, 8, and 10.

Samples were not tested for chemical constituents. However, conductivity (up to 210 µmhos/cm) was elevated in wells Z 3, 8, 9, 11, 17, 18, 19A, and 20 and ZW 1A, 2, 4, 5, 6, 7, 8, 9, and 10.

H AREA

H Area is located in the central part of SRS as shown in Figure 5-1 and in Figure 5-10, (Vol. II). Surface elevations across H Area range approximately from 240 to 290 ft msl. H Area is flanked to the north by Upper Three Runs Creek and to the south by Four Mile Creek. Surface drainage from H Area is toward tributaries of these two streams.

The nearest plant boundary to H Area is approximately 8 miles to the west. H Area is located near a water-table divide between Upper Three Runs Creek and Four Mile Creek. Near-surface groundwater from the southern part of H Area discharges to an unnamed tributary of Four Mile Creek, approximately 1,000 ft south of H Area. Near-surface groundwater from the northern part of H Area discharges to one of two tributaries of Upper Three Runs Creek, which are approximately 1,500 and 4,000 ft north of H Area, respectively.

In 1988, groundwater was monitored at the following sites in H Area: the H-Area Acid/Caustic Basin, the H-Area Auxiliary Pump Pit, the H-Area Canyon

Building, the H-Area Coal Pile Runoff Containment Basin, the H-Area Effluent Treatment Facility, the H-Area Retention Basins, the H-Area Seepage Basins, the H-Area Sludge Land Application Site, and the H-Area Tank Farm (Figures 5-22 through 5-25, Vol. II). A summary of maximum groundwater monitoring results for these sites is given in Table 5-8 and also in Table 5-43 (Vol. II).

H-Area Acid/Caustic Basin

The H-Area Acid/Caustic Basin (904-75G) is west of H Area by the H-Area effluent stream that leads to Four Mile Creek (Figures 5-22 and 5-23, Vol. II). The basin was excavated in a relatively flat area at an elevation of approximately 285 ft msl. The basin received steam condensate from a hose box and drainage from a chemical pad until 1985 in addition to the acid/caustic solutions that were discontinued in 1982. See the beginning of this chapter for a discussion of SRS acid/caustic basins.

The basin is monitored by the four HAC series wells (Table 5-44, Vol. II), which were installed in the third quarter of 1988. Wells HAC 1 and 4 are upgradient, and wells HAC 2 and 3 are downgradient of the basin.

Tritium (up to 59.2 pCi/mL) was detected above the drinking water standard in wells HAC 1, 2, 3, and 4. No other radioactive constituents were detected above drinking water standards.

No chemical constituents were detected above drinking water standards. However, conductivity (up to 676 µmhos/cm) was elevated in wells HAC 1, 2, and 3.

H-Area Auxiliary Pump Pit

The H-Area Auxiliary Pump Pit (241-49H) is at the east end of H Area (Figure 5-22, Vol. II). The facility will pump a low-level radioactive salt solution from the H-Area Tank Farm to the S-Area Low Point Pump Pit. When the pumps are shut down, this facility will collect the solution in a temporary holding tank via gravity flow lines.

The pump pit is monitored by the HAP series wells (Table 5-45, Vol. II), which were installed in the fourth quarter of 1987 and first sampled in 1988. Well HAP 1 is upgradient and HAP 2 is sidegradient to downgradient of the pump pit.

Tritium (up to 31.0 pCi/mL) was detected above the drinking water standard in well HAP 1. No other radioactive constituents were detected above drinking water standards.

Table 5-8. Selected Maximum Constituent Levels at H Area

Constituent	DWS	Units	HCB	HAC	HET	HSB
Gross Alpha	15	pCi/L	**42.4**	2.8	1.2	**572**
Nonvolatile Beta	-	pCi/L	37	2.7	1.92	12800
Total Radium	5	pCi/L	**8.6**	1	<1	**107**
Tritium	20	pCi/mL	**38.6**	**59.2**	**38.5**	**98000**
Cadmium	0.01	mg/L	**0.016**	<0.002	<0.002	**0.011**
Lead	0.05	mg/L	**0.081**	0.024	0.008	**0.066**
Mercury	0.002	mg/L	<0.0002	0.0006	0.0005	**0.0193**
Nitrate (as N)	10	mg/L	-	2.02	1.64	**138**
Trichloroethylene	0.005	mg/L	-	-	-	**0.05**
Endrin	0.0002	mg/L	-	<0.0001	<0.0001	**0.0126**

Note: Analytical results in bold are above drinking water standards.
DWS = EPA drinking water standards; refer to Table 5-1, Vol. I.
HCB = H-Area Coal Pile Runoff Containment Basin Wells
HAC = H-Area Acid/Caustic Basin Wells
HET = H-Area Effluent Treatment Facility Wells

Lead was detected above drinking water standards in well HAP 1 (0.053 mg/L). No other chemical constituents were detected above drinking water standards. However, conductivity (up to 275 μmhos/cm) and alkalinity (at 104 mg/L) were elevated in well HAP 1.

H-Area Canyon Building

The H-Area Canyon Building (221-H) is in the northeast part of H Area (Figures 5-22 and 5-23, Vol. II). At the building, target rods from the reactors are dissolved using nitric acid, and the desired radionuclides are separated from waste products.

The groundwater is monitored by the four wells of the HCA series (Table 5-46, Vol. II). The horizontal groundwater gradient in this area is low, but well HCA 2 is slightly upgradient of the site compared to the other wells.

Tritium (up to 140 pCi/mL) was detected above the drinking water standard in all HCA wells. No other radioactive constituents were detected above drinking water standards. However, nonvolatile beta activity (at 15.6 pCi/L) was elevated in well HCA 2.

Lead (up to 0.102 mg/L) and trichloroethylene (up to 0.016 mg/L) were detected above their respective drinking water standards in well HCA 4. No other chemical constituents were detected above drinking water standards. However, conductivity (up to 195 μmhos/cm) was elevated in wells HCA 1 and 2. Tetrachloroethylene (at 0.024 mg/L) was detected in wells HCA 2 and 4.

H-Area Coal Pile Runoff Containment Basin

The H-Area Coal Pile Runoff Containment Basin (289-H) is east of H Area, approximately 1,000 ft east-northeast of the H-Area coal pile (Figure 5-22, Vol. II). See the beginning of this chapter for a discussion of SRS coal pile runoff containment basins.

The site is monitored by the four wells of the HCB series (Table 5-47, Vol. II). Wells HCB 1 and 3 are screened below the water table, making interpretation of the groundwater gradient difficult. Relative to the basin, wells HCB 2 and 3 appear to be upgradient; wells HCB 1 and 4 appear to be downgradient to sidegradient.

Gross alpha (up to 42.4 pCi/L) and total radium (up to 8.6 pCi/L) were detected above their respective drinking water standards in well HCB 2. Tritium (up to 38.6 pCi/mL) was detected above the drinking water standard in wells HCB 1, 2, 3, and 4. Nonvolatile beta activity (up to 37.0 pCi/L) was elevated in well HCB 2.

Cadmium (up to 0.016 mg/L), as well as lead (at 0.081 mg/L), were detected above their respective drinking water standards in well HCB 2. No other chemical constituents were detected above drinking water standards. However, pH (down to 2.6) was low in wells HCB 2 and HCB 3. Conductivity (up to 3,700 μmhos/cm), copper (up to 1.67 mg/L), and sulfate (up to 2,550 mg/L) levels were elevated in well HCB 2.

H-Area Effluent Treatment Retention Basin

The H-Area Effluent Treatment Retention Basin is southwest of H Area (Figures 5-22 and 5-24, Vol. II). The basin serves the F/H Effluent Treatment Facility (ETF), which was placed in service in 1988 to treat the effluent formerly sent to the F- and H-Area Seepage Basins.

The basin is monitored by the four wells of the HET series, which were installed in the third quarter of 1988 (Table 5-48, Vol. II). Relative to the facility, well HET 1D is upgradient, well HET 4D is sidegradient, and wells HET 2D and 3D are downgradient.

Tritium (up to 38.5 pCi/mL) was detected above the drinking water standard in wells HET 1D, 2D, 3D, and 4D. No other radioactive or chemical constituents were detected above drinking water standards.

H-Area Retention Basins

The H-Area Retention Basins (281-3H and 281-8H) are southeast of the intersection of Road 4 and Road E (Figure 5-22 and 5-24, Vol. II). A small, unlined earthen retention basin (281-3H) was used from 1955 to 1973 to provide temporary emergency storage for radioactively contaminated cooling water from the chemical separations process. The water contained radionuclides and possibly trace quantities of chemicals. A larger, rubber-lined retention basin (281-8H) replaced the original basin in 1973 and is still in use. The basins are adjacent, and any contaminants in the groundwater are probably due to the unlined 281-3H basin.

The basins are monitored by the six wells of the HR3 and HR8 series (Table 5-49, Vol. II). These wells are screened below the water table. Wells HR3 11 and 13 are upgradient of the basins; wells HR8 14 and 11 are

sidegradient of the new basin, but HR8 14 is downgradient of the old basin. Wells HR8 12 and 13 are downgradient of both basins.

Gross alpha (up to 27.8 pCi/L) and total radium (up to 11.1 pCi/L) were detected above the drinking water standards in well HR8 14. Tritium (up to 67.4 pCi/mL) was detected above the drinking water standard in wells HR3 11 and 13 and HR8 11, 12, and 13. Nonvolatile beta activity (up to 24.6 pCi/L) was elevated in wells HR8 12 and 14.

Nitrate (up to 29.7 mg/L) was detected above the drinking water standard in Well HR8 14. No other chemical constituents were detected above drinking water standards. However, pH (down to 3.9) was low in wells HR8 11 and 13. Conductivity (up to 305 μmhos/cm) was elevated in wells HR3 13 and HR8 14.

H-Area Seepage Basins

The H-Area Seepage Basins (904-44G, 904-45G, 904-46G, and 904-56G) are southwest of H Area, southwest of the intersection of Road E and Road 4 (Figure 5-25, Vol. II). Starting in 1955, the basins received wastewater from H Area containing low-level radioactivity and chemicals, including nitric acid, mercury, and sodium hydroxide. Basin 3 has been inactive since 1962. In 1988, Basins 1, 2, and 4 operated under RCRA interim status until taken out of service in the fourth quarter.

At the H-Area Seepage Basins, the water table is 16 to 50 ft below the ground surface and outcrops adjacent to Four Mile Creek 330 to 1,300 ft from the basins. Below the water table are the Dry Branch, Santee, and Congaree Formations. Vertical groundwater gradients are predominantly downward from the water table to the lower part of the Congaree Formation. Water in the Santee Formation flows south toward Four Mile Creek. The groundwater in the upper part of the Congaree Formation flows toward Upper Three Runs Creek to the west.

The H-Area Seepage Basins are monitored by the wells of the H and HSB series (Table 5-50, Vol. II). In the fourth quarter of 1987 and the first quarter of 1988, 74 RCRA POC and plume assessment wells were added to the HSB series to monitor the water table and the waters of the Dry Branch, Santee, and Congaree Formations. The H series wells and HSB series wells with no letter and with a "D" after the well cluster number are generally screened in the water table. Wells HSB 111E, 112E, 65C, 85C, and 86C are also water-table wells. The other wells with a "C" after the well cluster number monitor the lower part of the water table and the Dry Branch and Santee Formations. Wells with a "B" after the well cluster number are screened in the upper Congaree Formation; wells with an "A" after the well cluster number are screened in the lower Congaree Formation. Wells HSB 65 and 66 are upgradient of the basins. The other water-table wells are downgradient to sidegradient of the basins.

In all the sampled H series wells and all the HSB wells screened in the water table except HSB 66, 85C, 130D, and 131D, tritium was detected above the drinking water standard (up to 98,000 pCi/mL). Tritium activities observed were highest in wells along the edge and downgradient of the seepage basins. Gross alpha (up to 704 pCi/L), total radium (up to 107 pCi/L), and nonvolatile beta activities (up to 15,900 pCi/L) were also generally elevated downgradient from the basins, with the highest levels recorded adjacent to the basins. The highest gross alpha and nonvolatile beta activities were recorded in well H 6, which is at the edge of Basin 2 (904-45G). Strontium-89/90 (at 9.05 pCi/L) was elevated above the drinking water standard in well H 12.

At least one radioactive constituent was detected above drinking water standards in all the wells screened in the Dry Branch and Santee Formations except HSB 83C, 130C, and 132C. The areas with the highest activities of radioactive constituents in the water table generally recorded the highest activities in the Dry Branch and Santee Formations, but the activities are markedly lower than in the water table.

Tritium (up to 279 pCi/mL) was detected above the drinking water standard in the upper Congaree Formation in wells HSB 68B and 84B and in the lower Congaree Formation (up to 24,200 pCi/mL) in wells HSB 68A, 84A, 117A, 119A, 123A, and 139A. Gross alpha was detected above the drinking water standard in well HSB 84A at 516 pCi/L, and total radium (up to 42.8 pCi/L) was detected above the drinking water standard in wells HSB 84A and 124A. Nonvolatile beta activities (up to 18.3 pCi/L) were elevated in wells HSB 68B and 85B in the upper Congaree Formation. Wells HSB 68A, 84A, 119A, 121A, and 124A in the lower Congaree Formation had elevated nonvolatile beta activities (up to 6,560 pCi/L). The highest activities of all radioactive constituents in the lower Congaree Formation were recorded in well HSB 84A.

Samples from the H well series were not tested for chemical constituents. However, pH was low in well H 6 at 3.8, and conductivity (up to 1,115 µmhos/cm) was elevated in all the sampled wells except H 15, 16, 17, 18A, and 19.

The chemical constituents above drinking water standards in the HSB wells occur in the same general pattern as the radioactive constituents. The contaminated groundwater is characterized by high conductivity (up to 1,946 µmhos/cm) and nitrate (up to 138 mg/L) levels and to a lesser extent by low pH (as low as 3.5). Cadmium was detected above the drinking water standard in well HSB 105C at 0.011 mg/L. Chromium was detected above the drinking water standard in well HSB 133C at 0.081 mg/L. Lead (up to 0.066 mg/L) was detected above the drinking water standard in wells HSB 70, 71, and 102D. Mercury (up to 0.0193 mg/L) was detected above the drinking water standard at the central part of the site in wells HSB 67, 69, 101D, 103D, 104D, 105D, 106D, 107D, 108D, 118A, 126D, and 139D. Trichloroethylene was detected above the drinking water standard in well HSB 101D at 0.050 mg/L. Endrin (at 0.0126 mg/L) was detected above the drinking water standard in well HSB 106D. Elevated total dissolved solids (TDS) concentrations (up to 968 mg/L) were observed in wells HSB 71C, 101D, 102D, 111D, 115C, and 124A.

High values for pH (up to 11.9), conductivity, and alkalinity suggest that water from wells HSB 84C, 85B, 115C, 124A, and 133C may be influenced by well grout. Wells screened in the Santee and Congaree Formations generally had elevated alkalinity, conductivity, and pH; these elevated values may be a result of groundwater interaction with carbonate-rich portions of the Santee Formation.

H-Area Sludge Land Application Site

See the Sludge Land Application Sites section under **General Areas**.

H-Area Tank Farm

The H-Area Tank Farm (241-H), at the south end of H Area (Figures 5-22 and 5-23, Vol. II), comprises 29 subsurface tanks containing aqueous radioactive wastes. These wastes consist of sludges, supernatant liquid of varying salt concentrations, and salt cake. The sludges are primarily a mixture of oxides and hydroxides of manganese, iron, and aluminum and a small amount of uranium, plutonium, and mercury, with almost all of the fission products originally in the irradiated fuel except cesium. The supernate is primarily a solution of sodium nitrate, sodium nitrite, sodium hydroxide, sodium aluminate, and most of the fission products including the major cesium isotopes. The solution volume is reduced in the tank farm evaporators, then stored in tanks to precipitate the sodium nitrate and sodium nitrite. This precipitate forms the salt cake. Tank 16 leaked prior to the removal of the waste from that tank in 1972. A spill occurred at Tank 13 in 1983.

The site is monitored by the 32 wells of the HTF series and well 241-H, a 6-ft-deep well between Tanks 9 and 11 (Table 5-51, Vol. II). The site is on the groundwater divide between Upper Three Runs Creek and Four Mile Creek. Gradients for this site are low, and the horizontal groundwater flow direction is difficult to determine except in the western portion of the site where the flow is toward the west. The wells surround tank groups and monitor for leaks from the adjacent tanks.

Gross alpha was detected above the drinking water standard in well HTF 5 (27.4 pCi/L). Total radium (up to 21.2 pCi/L) was detected above the drinking water standard in wells HTF 13, 14, 15, 16, 17, 18, 20, and 26. Tritium (up to 721 pCi/mL) was detected above the drinking water standard in wells 241-H and all of the active HTF wells except 7, 27, 28, 31, and 32. Nonvolatile beta activity (up to 55.0 pCi/L) was elevated in wells 241-H and HTF 3, 5, 6, 9, and 20. Cesium-137 (at 0.301 pCi/mL) was above the drinking water standard in wells HTF 6, 7, and 8.

Nitrate (up to 349 mg/L) was detected above the drinking water standard in wells HTF 16 and 29. Samples were not tested for any other chemical constituents except sodium, which does not have a drinking water standard. However, pH (down to 2.6) was low in wells HTF 8, 11, 27, 29, and 32. Conductivity (up to 301 µmhos/cm) was elevated in wells HTF 1, 2, 3, 4, 7, 10, 22, and 23. Samples from well 241-H were not tested for chemical constituents.

K AREA

K Area is located in the south-central part of SRS as shown in Figure 5-2 (Vol. II). The ground surface elevation near the central part of K Area is approximately 260 ft msl and slopes gently to the west toward Indian Grave Branch and to the east toward Pen Branch.

The nearest plant boundary to K Area is approximately 5 miles to the west. The dissection of Pen Branch and Indian Grave Branch creates a southward extending groundwater tongue in the Dry Branch and Santee Formations. Horizontal groundwater flow in the Congaree Formation is toward the Savannah River.

In 1988, groundwater was monitored at the following sites in K Area: the K-Area Acid/Caustic Basin, the K-Area Ash Basin, the K-Area Burning/Rubble Pit, the K-Area Coal Pile Runoff Containment Basin, the K-Area Disassembly Basin, the K-Area Reactor Seepage Basin, the K-Area Retention Basin, and the K-Area Sludge Land Application Site (Figure 5-26, Vol. II). A summary of the maximum groundwater monitoring results for these sites is given in Tables 5-9 and 5-52 (Vol. II).

K-Area Acid/Caustic Basin

The K-Area Acid/Caustic Basin (904-80G) is on the east side of K Area (Figure 5-26, Vol. II) near a tributary of Pen Branch. See the beginning of this chapter for a discussion of SRS acid/caustic basins.

The basin is monitored by the seven wells of the KAC series (Table 5-53, Vol. II). Relative to the basin, wells KAC 3 and 5 are upgradient, wells KAC 2, 6, and 7 are sidegradient, and well KAC 1 is downgradient. Well KAC 4 is sidegradient of the basin and is screened below the water table.

Total radium (up to 5.1 pCi/L) was detected above the drinking water standard in well KAC 1. No other radioactive constituents were detected above drinking water standards.

No chemical constituents were detected above drinking water standards. However, elevated pH, conductivity, and alkalinity indicate that the water from well KAC 3 may be influenced by well grout. Conductivity (up to 2,410 μmhos/cm) was elevated in all of the wells except KAC 5. Alkalinity was elevated (up to 320 mg/L) in wells KAC 2 and 3. Sulfate concentrations (up to 1,200 mg/L) were elevated in well KAC 1.

K-Area Ash Basin

The K-Area Ash Basin (188-K) is southwest of K Area, about 330 ft south of the coal pile (Figure 5-26, Vol. II). The basin receives ash sluice water from the powerhouse in K Area and has been in service since 1951.

The site is monitored by the four wells of the KAB series (Table 5-54, Vol. II). Well KAB 2 is upgradient of the basin, wells KAB 1 and 3 are sidegradient, and well KAB 4 is downgradient. Wells KAB 1 and 4 are downgradient of the K-Area coal pile.

Gross alpha (up to 38.6 pCi/L) and total radium (up to 12.4 pCi/L) were detected above their respective drinking water standards in wells KAB 1, 3, and 4. Tritium was not detected above the drinking water standard. Nonvolatile beta activity (up to 48.4 pCi/L) was elevated in wells KAB 2, 3, and 4.

No chemical constituents were detected above drinking water standards. However, conductivity (up to 692 μmhos/cm) was elevated in wells KAB 1, 2, 3, and 4, and alkalinity (up to 249 mg/L) was elevated in wells KAB 2 and 4.

The K-Area Burning/Rubble Pit

The K-Area Burning/Rubble Pit (Building 131-K) is northeast of K Area (Figure 5-26, Vol. II). See the beginning of this chapter for a discussion of the SRS burning/rubble pits.

The pit is monitored by the four wells of the KRP series (Table 5-55, Vol. II). The site is near the water-table divide between Indian Grave Branch and Pen Branch. Horizontal groundwater gradients are low, and horizontal groundwater flow direction changes have occurred in the area.

Tritium was not detected above the drinking water standard. Samples were not tested for other radioactive constituents.

Trichloroethylene (up to 0.032 mg/L) was detected above the drinking water standard in well KRP 4. No other chemical constituents were detected above drinking water standards. However, tetrachloroethylene (up to 0.063 mg/L) was detected in well KRP 4.

K-Area Coal Pile Runoff Containment Basin

The K-Area Coal Pile Runoff Containment Basin (189-K) is west of K Area, between the ash basin and the reactor seepage basin (Figure 5-26, Vol. II). See the beginning of this chapter for a discussion of SRS coal pile runoff containment basins.

The site is monitored by the four wells of the KCB series (Table 5-56, Vol. II). Relative to the basin, wells KCB 1 and 4 are upgradient, well KCB 2 is

sidegradient to downgradient, and well KCB 3 is downgradient.

Tritium (up to 28.9 pCi/mL) was detected above the drinking water standard in samples from wells KCB 2 and 3. Gross alpha (up to 52.8 pCi/L) and total radium (up to 11.3 pCi/L) were reported above drinking water standards in well KCB 3. Wells KCB 1, 3, and 4 also had elevated levels of nonvolatile beta activity (up to 35.2 pCi/L).

No chemical constituents were detected above the drinking water standards, but samples from wells KCB 1, 3, and 4 had elevated conductivities (up to 640 μmhos/cm), and well KCB 3 had elevated sulfate concentrations (up to 291 mg/L).

K-Area Disassembly Basin

The K-Area Disassembly Basin (105-K) is located in the center of K Area (Figure 5-26, Vol. II). See the beginning of this chapter for a discussion of SRS disassembly basins.

Wells KDB 1, 2, and 3 monitor the K-Area Disassembly Basin (Table 5-57, Vol. II). Relative to the basin, well KDB 2 is downgradient, and wells KDB 1 and 3 are sidegradient.

Tritium (up to 2,430 pCi/mL) was detected above the drinking water standard in all of the KDB wells. Gross alpha and total radium were not detected above their respective drinking water standards. Nonvolatile beta activity (up to 18.1 pCi/L) was elevated in wells KDB 1 and 3.

Lead (up to 0.114 mg/L) was detected above the drinking water standard in well KDB 1. Trichloroethylene (up to 0.197 mg/L) was detected above the drinking water standard in wells KDB 2 and 3. No other chemical constituents were detected above drinking water standards. However, conductivity (up to 344 μmhos/cm) was elevated in wells KDB 1 and 3. Alkalinity (up to 215 mg/L) was elevated in well KDB 3.

K-Area Reactor Seepage Basin

The K-Area Reactor Seepage Basin (904-65G) is west of K Area (Figure 5-26, Vol. II). The basin was used until 1960. See the beginning of this chapter for a discussion of SRS reactor seepage basins.

The basin is monitored by the four wells of the KSB series (Table 5-58, Vol. II). The KSB wells are screened below the water table, making interpretation of the groundwater gradient difficult.

Table 5-9. Selected Maximum Constituent Levels at K Area

Constituent	DWS	Units	KAC	KCB	KDB	KRB
Gross Alpha	15	pCi/L	5.7	**52.8**	14.9	5.4
Nonvolatile Beta	-	pCi/L	7.3	35.2	18.1	126
Total Radium	5	pCi/L	**5.15**	**11.3**	4.9	3.6
Tritium	20	pCi/mL	9.8	**28.9**	**2430**	**136000**
Cadmium	0.01	mg/L	<0.002	-	-	**0.013**
Lead	0.05	mg/L	0.034	0.009	**0.114**	**0.259**
Mercury	0.002	mg/L	0.0002	-	0.0005	-
Nitrate (as N)	10	mg/L	0.29	-	3.65	-
Trichloroethylene	0.005	mg/L	<0.001	-	**0.197**	<0.001
Endrin	0.0002	mg/L	<0.0001	-	-	-

Note: Analytical results in bold are above drinking water standards.
DWS = EPA drinking water standards; refer to Table 5-1, Vol. I.
KAC = K-Area Acid/Caustic Basin Wells
KCB = K-Area Coal Pile Runoff Containment Basin Wells
KDB = K-Area Disassembly Basin Wells
KRB = K-Area Retention Basin Wells

Tritium was detected above the drinking water standard in all four KSB wells, with the highest activity in well KSB 4A at 327 pCi/mL.

No chemical constituents were detected above drinking water standards at this site.

K-Area Retention Basin

The K-Area Retention Basin (904-88G) is north of K Area, about 330 ft from the perimeter fence (Figure 5-26, Vol. II). The basin has been used since 1965 for disposal of purge water from the K-Area Disassembly Basin.

The basin is monitored by the five wells of the KRB series (Table 5-59, Vol. II). Well KRB 8 is upgradient of the basin, wells KRB 1 and 13 are sidegradient, and wells KRB 14 and 15 are downgradient.

Tritium was detected above the drinking water standard in all of the KRB wells, with the highest activity detected in well KRB 8 (136,000 pCi/mL). Elevated nonvolatile beta activity was reported in well KRB 15 (up to 126 pCi/L).

Lead concentrations (up to 0.259 mg/L) above the drinking water standard were reported from wells KRB 1, 8, 13, and 14.

K-Area Sludge Land Application Site

See the Sludge Land Application Sites section under **General Areas.**

L AREA

L Area is in the south-central part of SRS as shown in Figure 5-2 (Vol. II). Surface elevations across L Area range approximately from 230 to 260 ft msl and decrease toward Steel Creek, approximately 2,500 ft to the southeast. Several small tributaries of Steel Creek receive surface drainage from L Area.

The nearest plant boundary to L Area is approximately 5.5 miles to the southeast. Steel Creek represents a sink into which groundwater from the Dry Branch and Santee Formations discharges. The incision of the Aiken Plateau by Pen Branch to the northwest and by Steel Creek to the southeast creates a southward extending tongue of groundwater in the Dry Branch Formation.

In 1988, groundwater was monitored at the following sites in L Area: the L-Area Acid/Caustic Basin, the L-Area Burning/Rubble Pit, the L-Area Disassembly Basin, the L-Area Oil and Chemical Basin, and the L-Area Reactor Seepage Basin (Figure 5-27, Vol. II). A summary of maximum groundwater monitoring results for these sites is given in Table 5-10 and in Table 5-60 (Vol. II).

L-Area Acid/Caustic Basin

The L-Area Acid/Caustic Basin (904-79G) is south of L Area to the east of the L-Area Oil and Chemical Basin (904-83G) on a slope leading to Steel Creek (Figure 5-27, Vol. II). See the beginning of this chapter for a discussion of SRS acid/caustic basins.

The site is monitored by the four wells of the LAC series (Table 5-61, Vol. II). Wells LAC 1, 3, and 4 are downgradient of the basin, and well LAC 2 is upgradient of the basin, and LAC 3 is sidegradient of the basin.

No radioactive constituents were detected above drinking water standards.

Trichloroethylene was detected above the drinking water standard in wells LAC 2, 3, and 4, with the highest level (0.081 mg/L) reported in well LAC 2. Tetrachloroethylene was also detected in wells LAC 2, 3, and 4.

L-Area Burning/Rubble Pit

The L-Area Burning/Rubble Pit (131-L) is northwest of L Area, between Road 7-1 and the steam-line road (Figure 5-27, Vol. II). See the beginning of this chapter for a discussion of SRS burning/rubble pits.

The site is monitored by the four wells of the LRP series (Table 5-62, Vol. II). Relative to the pit, well LRP 2 is upgradient, well LRP 1 is sidegradient, and wells LRP 3 and 4 are downgradient.

Total radium was not detected above the drinking water standard. Samples from the LRP wells were not tested for other radioactive constituents.

Lead (up to 0.063 mg/L) was detected above the drinking water standard in well LRP 2. No other chemical constituents were detected above drinking water standards.

L-Area Disassembly Basin

The L-Area Disassembly Basin (105-L) is located in the center of L Area (Figure 5-27, Vol. II). See the

Table 5-10. Selected Maximum Constituent Levels at L Area

Constituent	DWS	Units	LCO	LDB	LRP	LSB
Gross Alpha	15	pCi/L	-	-	-	2.8
Nonvolatile Beta	-	pCi/L	25	2.6	-	4.1
Total Radium	5	pCi/L	**36**	-	1.4	-
Tritium	20	pCi/mL	**1140**	-	-	**3190**
Lead	0.05	mg/L	0.019	**0.078**	**0.063**	0.041
Mercury	0.002	mg/L	**0.0025**	<0.0002	-	-
Trichloroethylene	0.005	mg/L	**0.03**	**0.008**	0.002	-

Note: Analytical results in bold are above drinking water standards.
DWS = EPA drinking water standards; refer to Table 5-1, Vol. I.
LCO = L-Area Oil and Chemical Basin Wells
LDB = L-Area Disassembly Basin Wells
LRP = L-Area Burning/Rubble Pit Wells
LSB = L-Area Reactor Seepage Basin Wells

beginning of this chapter for a discussion of SRS disassembly basins.

The L-Area Disassembly Basin is monitored by wells LDB 1 and 2 (Table 5-63, Vol. II). There is insufficient information to determine the horizontal groundwater gradient at this site.

Samples were not tested for radioactive constituents with drinking water standards at this site.

Lead (up to 0.078 mg/L) and trichloroethylene (at 0.008 mg/L) were detected above their respective drinking water standards in well LDB 1. No other chemical constituents were detected above drinking water standards.

L-Area Oil and Chemical Basin

The L-Area Oil and Chemical Basin (904-83G) is southeast of L Area (Figure 5-27, Vol. II), between the reactor seepage basin (904-64G) and the acid/caustic basin (904-79G). From 1961 to 1979, the basin received small quantities of radioactive oil and chemical waste from throughout the plant that were not appropriate for discharge to effluent streams, regular seepage basins, or the 200-Areas waste management systems. The waste came primarily from the reactor areas. The basin has been inactive since 1979. The vegetation inside the basin perimeter fence is removed and the area kept bare.

The L-Area Oil and Chemical Basin is monitored by the four wells of the LCO series (Table 5-64, Vol. II). Relative to the basin, wells LCO 2 and 3 are upgradient, and wells LCO 1 and 4 are downgradient. Wells LCO 3 and 4 are downgradient of the nearby L-Area Acid/Caustic Basin and may be affected by constituents released there.

Total radium (up to 36.0 pCi/L) was detected above the drinking water standard in wells LCO 3 and 4. Tritium (up to 1,140 pCi/mL) was detected above the drinking water standard in wells LCO 1 and 4. Gross alpha was not detected above the drinking water standard. Nonvolatile beta activity (up to 25.0 pCi/L) was elevated in wells LCO 1 and 4.

Trichloroethylene (up to 0.030 mg/L) was detected above the drinking water standard in well LCO 3. Mercury was detected above the drinking water standard in well LCO 4 at 0.0025 mg/L. No other chemical constituents were detected above drinking water standards. However, pH (down to 3.8) was low in well LCO 2. Conductivity (up to 1,034 µmhos/cm) was elevated in wells LCO 3 and 4. Tetrachloroethylene (up to 0.048 mg/L) was detected in all four LCO wells. Alkalinity (up to 400 mg/L) was elevated in well LCO 3. Sulfate concentrations were elevated in well LCO 4 at 368 mg/L.

L-Area Reactor Seepage Basin

The L-Area Reactor Seepage Basin (904-64G) is southeast of L Area adjacent to the L-Area Oil and Chemical Basin (Figure 5-27, Vol. II). The L-Area Reactor Seepage Basin was used from 1958 until 1969 and from 1985 to the present. See the beginning

of this chapter for a discussion of SRS reactor seepage basins.

The basin is monitored by the four wells of the LSB series (Table 5-65, Vol. II). Relative to the basin, wells LSB 3 and 4 are upgradient, LSB 2 is sidegradient, and LSB 1 is downgradient.

Tritium (up to 3,190 pCi/mL) was detected above the drinking water standard in wells LSB 1, 3, and 4. No other radioactive constituents were detected above drinking water standards.

No chemical constituents were detected above drinking water standards. However, pH (down to 3.6) was low in wells LSB 2 and 3.

M AREA

M Area is located in the northwest part of SRS as shown in Figure 5-2 (Vol. II). Surface elevations across M Area range approximately from 350 to 380 ft msl. Surface drainage is toward Tims Branch, approximately 5,000 ft to the east, and toward valleys to the northwest and southwest that lead to the Savannah River.

The nearest plant boundary to M Area is approximately 0.5 miles to the northwest. M Area is on a water-table mound, with radial flow to the east toward Tims Branch, to the southwest toward the Savannah River, and to the north and west toward drainage into lower zones. Monitoring of organic plumes in M Area indicates that most of the water-table water migrates downward into lower zones.

In 1988, groundwater was monitored at the M-Area Hazardous Waste Management Facility (HWMF) (Figure 5-3, Vol. II). A summary of the maximum results of this monitoring is presented in Table 5-11 and in Table 5-66 (Vol. II).

Groundwater beneath A- and M Areas is contaminated with halogenated organics as a result of past operations. Since the discovery of the contamination in June 1981, significant progress has been made in assessing the extent of the contamination and in establishing a remediation program. The inventory of organics in the groundwater is estimated to be 450,000 lb with peak concentrations of 300 mg/L.

A Groundwater Remediation Program is under way to clean up the groundwater contamination. In February 1983, a 20 gal/min air stripper began operation. In January 1984, two recovery wells were installed along with a 50-gal/min air stripper. A full-scale recovery system, which replaced the previous air strippers in April 1985, consists of 11 recovery wells and a 400-gal/min air stripper. Through December 1988, 181,000 lb of organics have been removed from 682,000,000 gal of water.

M-Area Hazardous Waste Management Facility (HWMF)

The M-Area Hazardous Waste Management Facility (HWMF) consists of the M-Area Settling Basin (904-51G), which is south of M Area and west of Road D, and Lost Lake (904-112G) (Figure 5-28, Vol. II). The unlined basin received wastewater containing metal cleaning solvents, uranium, and other chemicals and metals from fuel fabrication processes in M Area. In operation from 1958 until 1985, water from the settling basin flowed through an overflow ditch to Lost Lake, a Carolina bay. A seepage area formed between the ditch and Lost Lake. The basin is currently uncovered, contains water, and is undergoing RCRA closure.

The following MSB wells have been designated as POC wells for the M-Area HWMF: MSB 1A, 2A, 3A, 4A, 5A, 6A, 7A, 8A, 13A, 13B, 13C, and 22 (Table 5-67, Vol. II). Well clusters MSB 29 and 43 are the designated background wells for the site. The horizontal water-table flow direction beneath the facility is mainly to the southwest. The pumping of water in the Groundwater Remediation Program has altered the water table near the HWMF, making determination of upgradient and downgradient wells inappropriate.

Gross alpha (up to 83 pCi/L) was detected above the drinking water standard in wells MSB 2A, 4A, 8A, 13C, 22, and 29D. Total radium (up to 22 pCi/L) was detected above the drinking water standard in wells MSB 1A, 2A, 4A, 8A, 22, and 29D. No other radioactive constituents were detected above drinking water standards. However, nonvolatile beta activity (up to 125 pCi/L) was elevated in wells MSB 2A, 3A, 4A, 5A, 8A, 13B, 13C, 22, and 29D.

Nitrate (up to 156 mg/L) was detected above the drinking water standard in wells MSB 2A, 3A, 4A, 5A, 7A, 8A, 13B, 13C, and 22. Trichloroethylene (up to 63 mg/L) was detected above the drinking water standard in wells MSB 1A, 2A, 3A, 4A, 5A, 7A, 8A, 13A, 13B, 13C, and 22. In well MSB 4A, carbon tetrachloride was detected above the drinking water

Table 5-11. Selected Maximum Constituent Levels at M Area

Constituent	DWS	Units	MSB	AC
Gross Alpha	15	pCi/L	**152**	-
Nonvolatile Beta	-	pCi/L	174	-
Total Radium	5	pCi/L	**108**	-
Tritium	20	pCi/mL	2.91	-
Cadmium	0.01	mg/L	**0.028**	-
Lead	0.05	mg/L	**0.138**	-
Mercury	0.002	mg/L	**0.0023**	-
Nitrate (as N)	10	mg/L	**156**	-
Trichloroethylene	0.005	mg/L	**128**	<0.001
Endrin	0.0002	mg/L	<0.0001	-

Note: Analytical results in bold are above drinking water standards.
DWS = EPA drinking water standards; refer to Table 5-1, Vol. I.
MSB = M-Area Hazardous Waste Management Facility and Plume Definition Wells
AC = A-Area Cluster Perimeter Plume Definition Wells

standard at 0.008 mg/L, and chloroform was detected above the drinking water standard at 0.394 mg/L. 1,1-dichloroethylene (up to 0.459 mg/L) was detected above the drinking water standard in wells MSB 4A, 5A, and 13C. No other chemical constituents were detected above drinking water standards.

However, the high pH, conductivity, total dissolved solids (TDS), and alkalinity in water from well MSB 13B indicate that it may be influenced by well grout. Alkalinity (up to 246 mg/L) was also elevated in wells MSB 3A and 4A. Total dissolved solids (TDS) concentrations (up to 1,300 mg/L) were elevated in wells MSB 3A, 4A, 13B, and 13C. Conductivity (up to 2,130 μmhos/cm) was elevated in wells MSB 3A, 4A, 5A, 8A, 13C, 22, and 29A. Tetrachloroethylene (up to 470 mg/L) was detected in wells 1A, 2A, 3A, 4A, 5A, 7A, 8A, 13B, 13C, and 22.

Plume Definition Wells

Besides the waste-site groundwater monitoring conducted in A- and M Areas (Figure 5-3, Vol. II), groundwater is also monitored for organics by approximately 200 M-Area plume definition wells, which include the MSB wells not under the waste-site monitoring program, the ASB 8 and 9 well clusters, and the AC well series (Table 5-68, Vol. II).

Several water-bearing zones are monitored within the contaminant plume. The water table in the area is relatively flat with drainage toward Tims Branch and the Savannah River. Upper and Lower Congaree sands drain to the southeast toward Upper Three Runs Creek. Water in Cretaceous sediments below the Ellenton Formation drains to the south toward the Savannah River.

Gross alpha (up to 152 pCi/L) was detected above the drinking water standard in well ASB 8 and in wells MSB 9C and 22. Radium-226 (at 1.52 pCi/mL) was detected above the drinking water standard in well ASB 8. Total radium (up to 108 pCi/L) was detected above the drinking water standard in wells MSB 9C, 11F, and 17B. Tritium was detected above the drinking water standard in well ASB 8C (at 24.9 pCi/mL). Nonvolatile beta activities (up to 174 pCi/L) were elevated in well ASB 8 and in wells MSB 9B, 9C, 10C, 12B, 12C, 14A, 17A, 17B, 18B, and 31C. No radioactive constituents were detected above drinking water standards in the AC well series.

No chemical constituents were detected above drinking water standards in the AC well series. However, in the MSB and ASB plume definition wells, nitrate (up to 35.4 mg/L) was detected above the drinking water standard in wells near the M-Area Settling Basin. Trichloroethylene (up to 128 mg/L) was detected above the drinking water standard in many of the wells, with the highest concentrations detected in the water table underlying M Area and the M-Area Settling Basin. Lead (up to 0.138 mg/L) was detected

above the drinking water standard in well MSB 40D. Carbon tetrachloride was detected above the drinking water standard in well MSB 31C at 0.007 mg/L. Cadmium (up to 0.028 mg/L) was detected above the drinking water standard in well MSB 39A. Mercury was detected above the drinking water standard in well MSB 40A at 0.0023 mg/L. 1,2-dichloroethane (up to 0.113 mg/L) was detected above the drinking water standard in wells MSB 9A, 11D, 12B, 12C, 14B, 19C, 20A, 31C, 36B, and 39B. 1-1-dichloroethylene (up to 0.0967 mg/L) was detected above the drinking water standard in wells MSB 9B, 12B, 12C, 14B, 17A, 17B, 27B, 31C, 33B, and 39B.

No other chemical constituents were detected above drinking water standards. However, high pH and conductivity in water from wells ASB 9B, AC 3B, and MSB 20C, 24, 46A, 48D, 52B, and 54C indicate that they may be influenced by well grout. pH (as low as 3.3) pH was low in wells MSB 9C, 11F, and 36B. Conductivity (up to 1,926 μmhos/cm) was elevated in many wells, generally those with elevated nitrate. Tetrachloroethylene concentrations (up to 988 mg/L) were elevated in many wells in the same general pattern as the trichloroethylene concentrations. Total dissolved solids (TDS) concentrations (up to 1,340 mg/L) were elevated in wells MSB 36C and 39A. Zinc levels were elevated in well MSB 9A at 5.36 mg/L.

P AREA

P Area is located in the south-central part of SRS as shown in Figure 5-2, (Vol. II). Surface elevations across P Area range approximately from 270 to 340 ft msl.

The nearest plant boundary to P Area is approximately 5 miles to the east on the opposite side of Lower Three Runs Creek. Lower Three Runs Creek (to the east), Steel Creek (to the southwest), and Meyers Branch (to the south and east) create a groundwater island in P Area. The hydraulic gradient varies across P Area and increases near a tributary to Par Pond, approximately 1,000 ft to the northeast. The hydraulic gradient also increases near a tributary to Steel Creek to the southwest.

In 1988, groundwater was monitored at the following sites in P Area: the P-Area Acid/Caustic Basin, the P-Area Burning/Rubble Pit, the P-Area Coal Pile Runoff Containment Basin, the P-Area Disassembly Basin, and the P-Area Reactor Seepage Basins (Figure 5-29, Vol. II). A summary of maximum groundwater monitoring results is presented in Table 5-12, and in Table 5-69 (Vol. II).

P-Area Acid/Caustic Basin

The P-Area Acid/Caustic Basin (904-78G) is northeast of P Area and Road F on a slope that leads to a tributary of Par Pond (Figure 5-29, Vol. II). See the beginning of this chapter for a discussion of SRS acid/caustic basins.

The site is monitored by the six wells of the PAC series (Table 5-70, Vol. II); wells PAC 5 and 6 were installed in the third quarter of 1988. Relative to the basin, wells PAC 1 and 4 are upgradient, PAC 2 is sidegradient to downgradient, and PAC 3, 5, and 6 are downgradient.

No radioactive or chemical constituents were detected above drinking water standards. However, conductivity (up to 630 μmhos/cm) was elevated in wells PAC 3, 4, 5, and 6. Alkalinity (up to 245 mg/L) was elevated in wells PAC 5 and 6.

P-Area Burning/Rubble Pit

The P-Area Burning/Rubble Pit (131-P) is west of P Area (Figure 5-29, Vol. II). See the beginning of this chapter for a discussion of SRS burning/rubble pits.

The site is monitored by the four wells of the PRP series (Table 5-71, Vol. II). Well PRP 4 is upgradient of the pit, wells PRP 2 and 3 are sidegradient, and well PRP 1A is downgradient.

Tritium (up to 37.6 pCi/mL) was detected above the drinking water standard in well PRP 1A. No other radioactive constituents were detected above drinking water standards.

Trichloroethylene (up to 0.095 mg/L), 1,1,1-trichloroethane (up to 0.428 mg/L), and lead (at 0.079 mg/L) were detected above their respective drinking water standards in well PRP 3. No other chemical constituents were detected above drinking water standards. However, tetrachloroethylene (up to 0.045 mg/L) was detected in well PRP 3.

P-Area Coal Pile Runoff Containment Basin

The P-Area Coal Pile Runoff Containment Basin (189-P) is southeast of the coal pile and south of P Area (Figure 5-29, Vol. II). See the beginning of this

chapter for a discussion of SRS coal pile runoff containment basins.

The site is monitored by the four wells of the PCB series (Table 5-72, Vol. II). Horizontal groundwater gradients in this area are low, making interpretation of groundwater flow direction difficult, but well PCB 1A appears to be upgradient, and the other wells are sidegradient or downgradient.

Tritium (up to 24.6 pCi/mL) was detected above the drinking water standard in wells PCB 1A and 4A. No other radioactive constituents were detected above drinking water standards.

Cadmium was detected above the drinking water standard in well PCB 3A at 0.016 mg/L. Lead (up to 0.073 mg/L) was detected above the drinking water standard in well PCB 4A. No other chemical constituents were detected above drinking water standards. However, pH (down to 3.3) was low in wells PCB 3A and 4A. Conductivity (up to 1,610 µmhos/cm) was elevated in wells PCB 1A, 3A, and 4A. Sulfate concentrations (up to 1,440 mg/L) were elevated in well PCB 3A.

P-Area Disassembly Basin

The P-Area Disassembly Basin (105-P) is located in the center of P Area (Figure 5-29, Vol. II). See the beginning of this chapter for a discussion of SRS disassembly basins.

The site is monitored by wells PDB 2 and 3 (Table 5-73, Vol. II). Both wells are screened below the water table, making interpretation of the water table flow direction difficult.

Tritium (up to 498 pCi/mL) was detected above the drinking water standard in wells PDB 2 and 3. No other radioactive constituents were detected above drinking water standards.

Lead (up to 0.072 mg/L) was detected above the drinking water standard in well PDB 3. No other chemical constituents were detected above drinking water standards.

P-Area Reactor Seepage Basins

The P-Area Reactor Seepage Basins (904-61G, 904-62G, and 904-63G) are southwest of the reactor

Table 5-12. Selected Maximum Constituent Levels at P Area

Constituent	DWS	Units	PAC	PCB	PRP	PSB
Gross Alpha	15	pCi/L	<3	-	1.4	1.9
Nonvolatile Beta	-	pCi/L	8	6.5	3	9.6
Total Radium	5	pCi/L	<1	2.1	-	-
Tritium	20	pCi/mL	13.4	**24.6**	**37.6**	**267000**
Cadmium	0.01	mg/L	<0.002	**0.016**	-	<0.002
Lead	0.05	mg/L	<0.006	**0.073**	**0.079**	**0.088**
Mercury	0.002	mg/L	0.0009	-	0.0002	<0.0002
Nitrate (as N)	10	mg/L	0.28	-	-	**32**
Trichloroethylene	0.005	mg/L	-	<0.005	**0.095**	-
Endrin	0.0002	mg/L	<0.0001	-	-	-

Note: Analytical results in bold are above drinking water standards.
DWS = EPA drinking water standards; refer to Table 5-1, Vol. I.
PAC = P-Area Acid/Caustic Basin Wells
PCB = P-Area Coal Pile Runoff Containment Basin Wells
PRP = P-Area Burning/Rubble Pit Wells
PSB = P-Area Reactor Seepage Basins Wells

building (Figure 5-29, Vol. II). The basins are connected in series, with water entering Basin 1 then flowing to Basins 2 and 3. See the beginning of this chapter for a discussion of SRS reactor seepage basins.

The basins are monitored by the seven wells of the PSB series (Table 5-74, Vol. II). Well PSB 5A is upgradient of Basin 3. Well PSB 6A is upgradient of Basin 2 but downgradient of Basin 1. Well PSB 7A is sidegradient to upgradient of Basin 1. Wells PSB 1A, 2A, and 3A are downgradient of the basins. Well PSB 4A is sidegradient of Basin 3.

Tritium (up to 267,000 pCi/mL) was detected above the drinking water standard in all of the site wells. No other radioactive constituents were detected above drinking water standards.

Lead (up to 0.088 mg/L) was detected above the drinking water standard in wells PSB 3A, 4A, and 5A. Nitrate (up to 32.0 mg/L) was detected above the drinking water standard in wells PSB 2A and 7A. No other chemical constituents were detected above drinking water standards. However, conductivity (up to 240 μmhos/cm) was elevated in well PSB 2A.

RADIOACTIVE WASTE BURIAL GROUNDS

The Radioactive Waste Burial Grounds are between F and H Areas (Figure 5-10, Vol. II) and are used for storage of radioactive solid waste produced at the plant and shipped from other U.S. Department of Energy facilities. The original area (643-G) began receiving waste in 1952 and was full by 1972. Operations then shifted to an adjacent site, the 643-7G Burial Ground. The Hazardous Waste/Mixed Waste Disposal Facility (HWMW; 643-28G), an area within 643-7G, was defined in 1986 (Figure 5-30, Vol. II). Plans call for the 643-G, 643-7G, and 643-28G sites to be closed and capped.

The Radioactive Waste Burial Grounds are used for disposal of transuranic (TRU) alpha waste, low-level alpha and beta-gamma waste, intermediate-level beta-gamma waste, and waste generated offsite. Until 1965, TRU waste was placed in plastic bags and cardboard boxes and buried in earthen trenches. Between 1965 and 1974, TRU waste was segregated into two categories. Waste containing less than 0.1 Ci per package was buried unencapsulated in trenches. Waste containing greater than 0.1 Ci per package was buried in retrievable concrete containers or encapsulated in concrete. Since 1974, TRU wastes contaminated with greater than 10 nCi TRU/g have been stored in water-tight containers that can be retrieved intact up to 20 years from the time of storage. Containers are stored on a concrete pad with a monitoring sump. Some bulky wastes are stored directly in shallow land burial trenches. Since mid-1984, newly generated low-level waste has been placed in metal boxes or metal drums and is currently stored in trenches and covered with soil shortly after emplacement.

Mixed wastes (low-level radioactive waste containing hazardous waste) stored within the Radioactive Waste Burial Grounds include lead (used for shielding), cadmium (from control rods, safety rods, and shielding), tritiated pump oil, and mercury. Some of the waste is contained in welded stainless steel containers or metal drums and stored within concrete cylinders. Newly generated mixed waste is stored in Building 643-29G, permitted by SCDHEC and operating under interim status. Degraded solvents and tritiated pump oil were stored in tanks installed in 1975. A program is under way to incinerate the degraded solvents and tritiated oil. The tritiated pump oil was removed from Tank S-32 and either incinerated or stored in Building 643-29G. Tank S-32 was formally closed under RCRA. In March 1986, disposal operations for radioactive waste containing lead or any other listed hazardous substance were discontinued. A plan was implemented to ensure that all other wastes were certified to be free of hazardous materials. A summary of the maximum groundwater monitoring results is presented in Tables 5-13 and also in 5-75 (Vol. II). Groundwater monitoring results for this site are given in Table 5-76 (Vol. II).

The BG series wells monitor the water table. Most of the BG perimeter wells surrounding Burial Ground 643-7G were abandoned in the first half of 1988. The 16 active BG perimeter wells border the west, south, and east sides of Burial Ground 643-G. Two SRL BG series wells, BG 222GR and BG 822GR, monitor the water table within Burial Ground 643-7G.

The MGA, MGC, MGE, MGG, and MGI series wells (grid wells) monitor the water table and perched water zones in Burial Ground 643-G. Of the 69 wells in these series, 15 are EHP monitoring wells, and 53 wells are SRL monitoring wells. One well, MGC 36, was sampled by both EHP and SRL.

In late 1987 and early 1988, 38 BGO series wells were installed as RCRA wells at the perimeter of Burial

Table 5-13. Selected Maximum Constituent Levels at the Radioactve Waste Burial Grounds

Constituent	DWS	Units	BGO	BG	MG
Gross Alpha	15	pCi/L	**32.3**	**73.2**	**40**
Nonvolatile Beta	-	pCi/L	424	1460	36.6
Total Radium	5	pCi/L	**11**	-	-
Tritium	20	pCi/mL	**3060**	**2920000**	**3480000**
Cadmium	0.01	mg/L	<0.002	-	-
Lead	0.05	mg/L	**0.052**	-	-
Mercury	0.002	mg/L	0.0004	-	-
Nitrate (as N)	10	mg/L	9.4	-	-
Trichloroethylene	0.005	mg/L	**0.076**	-	-
Endrin	0.0002	mg/L	<0.0001	-	-

Note: Analytical results in bold are above drinking water standards.
DWS = EPA drinking water standards; refer to Table 5-1, Vol. I.
BGO = Radioactive Waste Burial Grounds Perimeter Wells
BG = Radioactive Waste Burial Grounds Wells
MG = Monitoring Grid Wells for Radioactive Waste Burial Grounds

Ground 643-7G. BGO series wells with a "D" or no letter after the well cluster number are screened in the water table. The Dry Branch and Santee Formations are found between about 120 to 160 ft msl; BGO wells with a "C" after the well cluster number monitor the lower portion of the water table and the Dry Branch and Santee Formations. The Congaree Formation is found between about 0 to 120 ft msl and is monitored by BGO wells with an "A" after the well cluster number.

The nearest plant boundary to the Radioactive Waste Burial Grounds is approximately 7 miles to the west. The site is on a water-table divide, with groundwater from Burial Ground 643-G and the southwestern parts of Burial Ground 643-7G and the MWMF flowing to the southwest and groundwater from the northeastern part of Burial Ground 643-7G and the MWMF flowing to the northeast. Wells BG 27, 28, 29, 30, 31, and 32 and wells BGO 2D, 3D, 4D, and 5D are upgradient to sidegradient of Burial Ground 643-G. The remaining wells are downgradient to sidegradient of the site. Well BG 10 is adjacent to H-Area Seepage Basin 4 (904-56G).

Gross alpha in the water table (up to 73.2 pCi/L) was detected above the drinking water standard in well BG 40. Total radium was below the drinking water standard in all of the BGO wells. Nonvolatile beta activity in the water table (up to 424 pCi/L) was elevated in wells BG 40, 58, and 60 and wells BGO 2D, 6D, 9D, 13D, 16D, 20D, 21D, and 24D. Tritium in the water table was detected at or above the drinking water standard in all but six of the sampled BG wells and all but 12 of the BGO wells. Gross alpha (up to 36.2 pCi/L) and tritium (up to 33,700 pCi/mL) were detected above their respective drinking water standards in well BG 10. Elevated nonvolatile beta activity (up to 1,460 pCi/L) was also detected in this well.

Since 1978, high tritium levels have been found in two areas of the perimeter. One tritium plume has been migrating southwest from the southwest end of the original Burial Ground (643-G) toward Four Mile Creek. The elevated tritium activity had extended from well BG 53 through BG 58, but in 1988 it extended from wells BG 55 to 57. These wells are downgradient of the western third of Burial Ground 643-G. The tritium in these wells has varied widely from year to year, with the maximum value generally occurring in well BG 56 and occasionally in BG 54. In 1988, the highest tritium activity recorded for this plume (61,100 pCi/mL) was found in well BG 56. The 1988 tritium level in well BG 56 is similar to the 1986 and 1987 levels but is higher than the levels recorded from 1976 through 1985.

Another plume of tritium has been migrating northwest from the north end of the Burial Ground addi-

tion (643-7G) toward Upper Three Runs Creek. This area of elevated tritium activity is near perimeter wells BG 33 through 35 and BGO 5D through 9D and may extend to wells BGO 4D and BG 31. Wells BG 68 through 90 were installed north of the perimeter fence to monitor this plume. Most of these wells had elevated tritium activities, with a maximum of 21,100 pCi/mL detected in well BG 69. The tritium activities in most of these wells changed during 1987 and 1988, generally decreasing in wells to the south and generally increasing in wells to the north. High tritium activity was also found in wells along the western perimeter of the Burial Ground addition (643-7G). The tritium activities recorded in 1988 for wells BG 40 and 42 and BGO 15D and 16D were elevated, with a maximum activity of 1,710 pCi/mL for BGO 16D.

Within Burial Ground 643-G, tritium (up to 371,000 pCi/mL) was above the drinking water standard in wells MGA 36; MGC 9, 19, 32, and 36; MGE 9, 21, 30, and 34; and MGG 19, 23, 28, and 36. Gross alpha (at 15.6 pCi/L) was above the drinking water standard in well MGC 19. No other radioactive constituents were above drinking water standards. However, nonvolatile beta activity (up to 36.6 pCi/L) was elevated in wells MGC 19, MGE 34, and MGG 36.

The wells of the BG, MGA, MGC, MGE, MGG, and MGI series that are sampled under the SRL research project monitor the groundwater beneath the 643-G and 643-7G Burial Grounds for gross alpha, beta-gamma, and tritium. The maximum activity levels for gross alpha (40 pCi/L) were found in well MGG 17. The maximum activity levels for beta-gamma (337 pCi/L) were found in well MGC 30, but most wells recorded elevated activities. Elevated tritium activities were observed in all of these wells, with the highest values recorded for wells BG 822GR (2,920,000 pCi/mL), MGC 7 (1,840,000 pCi/mL), MGE 3 (2,810,000 pCi/mL), MGE 36 (1,430,000 pCi/mL), MGG 13 (2,680,000 pCi/mL), MGG 21B (2,020,000 pCi/mL), and MGG 21P (3,480,000 pCi/mL). SRL maintains tritium monitoring programs south of Burial Ground 643-G and north of Burial Ground 643-7G. Results from these programs are not included in this report.

Wells screened in the Dry Branch and Santee Formations had elevated nonvolatile beta and tritium activities. Nonvolatile beta activity (up to 52.4 pCi/L) was detected in wells BGO 5C, 8C, 12C, and 14C, and gross alpha was detected above the drinking water standard in well BGO 14C at 16.4 pCi/L. Tritium (up to 3,060 pCi/mL) was detected above the drinking water standard in wells BGO 5C and 6C.

Collection of a groundwater sample from a monitoring well outside the RWBG fences

In the Congaree Formation at least one radioactive constituent was detected above drinking water standards in all of the wells except wells BGO 6A, 12A, and 18A. Gross alpha (up to 32.3 pCi/L) was detected above the drinking water standard in wells BGO 8A, 14A, and 16A. Nonvolatile beta activity (up to 357 pCi/L) was elevated in wells BGO 8A, 10A, 14A, and 16A. Total radium was detected above the drinking water standard in well BGO 8A at 11.0 pCi/L.

Lead was detected above the drinking water standard once in well BGO 14A at 0.052 mg/L. Selenium was detected above the drinking water standard once in well BGO 10A at 0.019 mg/L. Silver was detected above the drinking water standard once in well BGO 13D at 0.066 mg/L. Trichloroethylene (at 0.076 mg/L) and benzene (at 0.007 mg/L) were detected above their respective drinking water standards in well BGO 7D. Mercury was detected once above the drinking water standard in well BGO 2D. No other chemical constituents were detected above drinking water standards. Samples from the BG wells were not tested for chemical constituents. However, pH was low in well BG 10 at 3.7. Conductivity (up to 557 μmhos/cm) was elevated in water-table wells BG 10, 43, 52, and 56 and BGO 6D, 10D, 12D, 13D, 17D, 20D, 21D, 23D, and 24D. Total dissolved solids (TDS) concentrations (up to 2,000 mg/L) were elevated in wells BGO 5D, 12C, 14A, 14C, 16A, and 20D. Water from wells BGO 5C, 8A, 10C, 12C, 12D, 14A, 14C, 16A, 16D, 21D, and 24D had elevated pH (up to 12.9),

conductivity, and alkalinity and may be affected by well grout. Wells screened in the Santee and Congaree Formations generally had elevated conductivity, alkalinity, and pH, suggesting groundwater in the lower formations is influenced by carbonates in the Santee Formation.

The MG series well samples were not analyzed for chemical constituents. However, conductivity (up to 348 µmhos/cm) was elevated in wells MGC 9, 19, 32, and 36; MGE 9, 21, 30, and 34; and MGG 19, 23, 28, and 36. Also, pH (at 3.7 pH) was low in well MGC 36.

R AREA

R Area, located in the east-central part of SRS as shown in Figure 5-2, Vol. II, is on a topographic divide where surface elevations range approximately from 280 to 300 ft msl. Surface drainage is to the northwest and northeast toward Mill Creek and Pond A and to the southeast and southwest toward tributaries of Pond 4 and Pond 2.

The nearest plant boundary to R Area is approximately 4.8 miles to the east. Incised tributaries, streams, and Par Pond separate R Area from the boundary. R Area is near a groundwater divide between Mill Creek and Par Pond. The groundwater just north of R Area naturally discharges to Mill Creek, approximately 1,000 ft to the northwest, and to the P-Area Canal of Pond A to the northeast. The groundwater from the southern part of R Area naturally discharges to a tributary of Pond 4, approximately 1,800 ft south of R Area.

In 1988, groundwater was monitored at the following sites in R Area: the R-Area Acid/Caustic Basin, the R-Area Burning/Rubble Pits, and the R-Area Reactor Seepage Basins (Figure 5-31, Vol. II). A summary of the groundwater monitoring results for these sites is given in Table 5-14 and in Table 5-77 (Vol. II).

R-Area Acid/Caustic Basin

The R-Area Acid/Caustic Basin (904-77G) is south of R Area, just south of Road G (Figure 5-31, Vol. II). See the beginning of this chapter for a discussion of SRS acid/caustic basins.

The site is monitored by the four wells of the RAC series (Table 5-78, Vol. II). Relative to the basin, well RAC 1 is upgradient, well RAC 3 is sidegradient to downgradient, and wells RAC 2 and RAC 4 are downgradient.

No radioactive constituents were detected above drinking water standards in the RAC wells.

No chemical constituents were detected above drinking water standards. However, conductivity (up to 120 µmhos/cm) was elevated in wells RAC 1 and 3.

Table 5-14. Selected Maximum Constituent Levels at R Area

Constituent	DWS	Units	RAC	RRP	RS
Gross Alpha	15	pCi/L	2.5	2.3	**20.5**
Nonvolatile Beta	-	pCi/L	3.1	-	5590
Total Radium	5	pCi/L	1.2	-	-
Tritium	20	pCi/mL	-	-	14.8
Lead	0.05	mg/L	0.028	0.01	-
Mercury	0.002	mg/L	<0.0002	-	-
Nitrate (as N)	10	mg/L	2.35	-	**30**

Note: Analytical results in bold are above drinking water standards.
DWS = EPA drinking water standards; refer to Table 5-1, Vol. I.
RAC = R-Area Acid/Caustic Basin Wells
RRP = R-Area Burning/Rubble Pits Wells
RS = R-Area Reactor Seepage Basins Wells

R-Area Burning/Rubble Pits

The R-Area Burning/Rubble Pits (131-R and 131-1R) are southeast of R Area and southeast of Road F-8 (Fig. 5-31, Vol. II). See the beginning of this chapter for a discussion of SRS burning/rubble pits.

The site is monitored by the four wells of the RRP series (Table 5-79, Vol. II). Relative to the pits, well RRP 1 is upgradient, well RRP 2 is sidegradient, and wells RRP 3 and 4 are downgradient.

No radioactive or chemical constituents were detected above drinking water standards in the RRP wells.

R-Area Reactor Seepage Basins

The six R-Area Reactor Seepage Basins (904-103G, 904-104G, and 904-57G through 904-60G) are just outside the perimeter fence northwest of R Area (Figure 5-32, Vol. II). The basins received purge water from the R-Area Disassembly Basin from 1957 until 1964. Overflow was sequential via overflow channels from Basin 1 to Basin 2, to Basin 3, to Basin 4. Basin 5 received water directly from the disassembly basin. Basin 6 received water pumped from Basins 2, 3, and 4 and then was used for receiving water from the disassembly basin.

On November 8, 1957, an experimental fuel element failed during a calorimeter test in the emergency section of the R-Area Disassembly Basin. Following this incident, the seepage basins received approximately 2,700 Ci of radionuclides, including 200 Ci of ^{90}Sr and 1,000 Ci of ^{137}Cs. About half of the ^{90}Sr and ^{137}Cs has decayed since the incident. Much of the released radioactivity was contained in Basin 1, which was backfilled in December 1957. Basins 2 through 6 were placed in operation in 1957 and 1958 after the incident to assist in containing the radioactivity.

In 1960, Basins 2 through 5 were closed and backfilled. The ground surface above Basins 1 through 5 was treated with herbicide and covered with asphalt. In addition, a kaolinite dike (down to a clay layer) was constructed around Basin 1 and the northwest end of Basin 3 to minimize lateral movement of the radioactive contamination. Basin 6, which was active until 1964, was backfilled in 1977.

The R-Area Reactor Seepage Basins are monitored by the wells of the RSA, RSB, RSC, RSD, RSE, and RSF series (Table 5-80, Vol. II). In 1975, a substantial increase in ^{90}Sr activity (3,400 pCi/L) occurred in groundwater monitoring well RSE 13 on the southeast side of Basin 1 outside the clay dike. Investigations revealed that the contamination was migrating through a sewer line that had been abandoned after completion of R-Reactor construction. Subsequently, eight groundwater monitoring wells (RSD 4 through RSD 11) were installed downgradient of well RSE 13 on three parallel lines, approximately 50, 150, and 300 ft south of well RSE 13.

In general, the water-table gradient beneath most of the site is to the north. To the south of Basin 1 and at the nearby abandoned sewer line, the water-table flow direction may be to the south.

Gross alpha (up to 31.9 pCi/L) was detected above the drinking water standard in wells RSD 1C and 2C and RSE 1B. No other radioactive constituents were detected above drinking water standards. However, nonvolatile beta activity (up to 5,590 pCi/L) was elevated in wells RSB 7 and 8; RSC 2 and 7; RSD 1, 2A, 2C, 4, 5, 6, 7, 8, 10, and 11; and RSE 1A, 1B, 1C, 2, 3A, 4A, 4C, 5, 11, 12, 13, and 19.

Nitrate was detected above the drinking water standard in well RSE 25 at 30.0 mg/L. No other chemical constituents were detected above drinking water standards. However, pH (down to 3.8) was low in wells RSA 8, 9, and 10 and RSE 9. Conductivity (up to 600 μmhos/cm) was elevated in wells RSA 7, 8, 9, and 10; RSB 7; RSC 3, 4, 5, 6, 7, 8, and 10; RSD 1, 9, 10, and 11; RSE 5, 9, 10, 11, 12, 18, and 19; and RSF 1. Alkalinity (at 111 mg/L) and pH (up to 10.6) were elevated in well RSF 1.

S AREA

S Area is located in the central part of SRS just north of H Area as shown in Figure 5-1 (Vol. I) and Figure 5-10 (Vol. II). Surface elevations across S Area range approximately from 300 to 320 ft msl. Surface drainage is to the east toward McQueen Branch and to the west toward Crouch Branch, both tributaries of Upper Three Runs Creek.

The nearest plant boundary to S Area is approximately 8 miles to the west. Near-surface groundwater flows toward McQueen Branch, approximately 4,000 ft to the northeast.

In 1988, groundwater was monitored at the following sites in S Area: the S-Area Background Wells and the

Table 5-15. Selected Maximum Constituent Levels at S Area

Constituent	DWS	Units	SBG	SLP
Gross Alpha	15	pCi/L	-	2.3
Nonvolatile Beta	-	pCi/L	4.6	3.9
Total Radium	5	pCi/L	-	0.5
Tritium	20	pCi/mL	**22.7**	12.6
Cadmium	0.01	mg/L	-	<0.002
Lead	0.05	mg/L	0.023	0.009
Mercury	0.002	mg/L	0.0007	0.0002
Nitrate (as N)	10	mg/L	-	0.81
Trichloroethylene	0.005	mg/L	**1.25**	-
Endrin	0.0002	mg/L	-	<0.0001

Note: Analytical results in bold are above drinking water standards.
DWS = EPA drinking water standards; refer to Table 5-1, Vol. I.
SBG = S-Area Background Wells
SLP = S-Area Low Point Pump Pit Wells

S-Area Low Point Pump Pit. A summary of the maximum groundwater results from S Area is presented in Table 5-15 and in Table 5-81 (Vol. II).

S-Area Background Wells

The six SBG series wells were installed as background wells in S Area (Figure 5-33, Vol. II) and are screened below the water table (Table 5-82, Vol. II). The groundwater flow direction appears to be to the north toward Upper Three Runs Creek. Wells SBG 2 and 3 appear to be downgradient, wells SBG 4, 5, and 6 appear to be upgradient, and well SBG 1 appears to be sidegradient of the monitoring area.

Tritium (up to 22.7 pCi/mL) was detected above the drinking water standard in wells SBG 1, 2, and 3. No other radioactive constituents were detected above drinking water standards.

Trichloroethylene (up to 1.25 mg/L) was detected above the drinking water standard in wells SBG 4 and 5. No other chemical constituents were detected above drinking water standards.

S-Area Low Point Pump Pit

The S-Area Low Point Pump Pit (511-S) is at the south end of S Area (Figure 5-33, Vol. II). The facility will pump high-level radioactive sludge from the H-Area Tank Farm to the Defense Waste Processing Facility (DWPF) Vitrification Building (221-S). When the pumps are shut down, the sludge remaining in the line will drain back to a temporary holding tank via gravity flow lines.

The S-Area Low Point Pump Pit is monitored by the two SLP series wells, which were installed in the fourth quarter of 1987 and first sampled in 1988 (Table 5-83, Vol. II). Well SLP 1 is sidegradient to downgradient of the site; well SLP 2 is downgradient of the site.

Tritium (at 20.4 pCi/mL) in well SLP 2 was the only radioactive constituent detected above the drinking water standard in the SLP wells.

No chemical constituents were detected above drinking water standards in these wells. However, elevated pH and conductivity in water from well SLP 2 indicate that this well may be influenced by well grout.

TNX AREA

TNX Area is located in the southwest part of SRS as shown in Figure 5-2 (Vol. II). Surface elevations across TNX range approximately from 100 to 150 ft msl, decreasing to the west-southwest toward the Savannah River.

The nearest plant boundary to TNX Area is the Savannah River, approximately 0.75 miles to the west. Natural discharge of the water table is to the Savannah River and to the nearby swamp.

In 1988, groundwater was monitored at the following sites in TNX Area: the New TNX Seepage Basin, the Old TNX Seepage Basin, and the TNX Burying Ground (Figure 5-34, Vol. II). A summary of the maximum groundwater monitoring results for these sites is given in Table 5-16 and in Table 5-84 (Vol. II).

New TNX Seepage Basin

The New TNX Seepage Basin (904-102T) has been in operation since 1980 and is in the east section of the TNX facility, across River Road from the TNX process area (Figure 5-34, Vol. II). The basin receives waste from pilot-scale tests conducted at TNX.

The basin is monitored by the four wells of the YSB series (Table 5-85, Vol. II). Well YSB 2A is upgradient, wells YSB 1A and 3A are sidegradient, and well YSB 4A is downgradient of the basin.

No radioactive or chemical constituents were detected above drinking water standards. However, alkalinity was elevated in well YSB 3A, at 106 mg/L, and conductivity (up to 317 μmhos/cm) was elevated in well YSB 3A.

Old TNX Seepage Basin

The Old TNX Seepage Basin (904-76T), in the southwest corner of the TNX facility (Figure 5-34, Vol. II), was in operation from 1958 to 1980 and received waste from pilot-scale tests conducted at TNX. In 1981, the west wall of the basin was breached to drain the impounded water, and the basin was backfilled with a sand and clay mixture and the top capped with clay.

The basin is monitored by the XSB series wells (Table 5-86, Vol. II). During the third quarter of 1988, wells XSB 1, 2, 4, and 5 were abandoned, and wells XSB 1D, 2D, and 4D were installed. The horizontal groundwater flow direction appears to be southwest toward the Savannah River Swamp. Wells XSB 1 and 3A are sidegradient, and the remaining wells are downgradient of the site.

Total radium (at 6.1 pCi/L) and gross alpha (at 17.5 pCi/L) were detected above their respective drinking water standards in well XSB 4. No other radioactive constituents were detected above drinking water standards. However, nonvolatile beta activity (up to 20.8 pCi/L) was elevated in wells XSB 1 and 4.

Lead was detected above the drinking water standard in well XSB 1 at 0.067 mg/L. Nitrate (up to 50.1 mg/L) was detected above the drinking water stan-

Table 5-16. Selected Maximum Constituent Levels at TNX Area

Constituent	DWS	Units	XSB	YSB	TBG
Gross Alpha	15	pCi/L	**17.5**	1.5	**83.7**
Nonvolatile Beta	-	pCi/L	20.8	2.8	68.9
Total Radium	5	pCi/L	**6.1**	0.9	**42.6**
Tritium	20	pCi/mL	12.5	3.22	2.42
Cadmium	0.01	mg/L	<0.002	<0.002	-
Lead	0.05	mg/L	**0.067**	<0.006	-
Mercury	0.002	mg/L	**0.0051**	<0.0002	0.0018
Nitrate (as N)	10	mg/L	**50.1**	8.84	-
Trichloroethylene	0.005	mg/L	**0.782**	0.002	-
Endrin	0.0002	mg/L	<0.0001	-	<0.0001

Note: Analytical results in bold are above drinking water standards.
DWS = EPA drinking water standards; refer to Table 5-1, Vol. I.
XSB = Old TNX Seepage Basin Wells
YSB = New TNX Seepage Basin Wells
TBG = TNX Burying Ground Wells

Table 5-17. Selected Maximum Consitiuent Levels at Z Area

Constituent	DWS	Units	ZBG	ZDT
Gross Alpha	15	pCi/L	1	3.3
Nonvolatile Beta	-	pCi/L	13.4	7.4
Total Radium	5	pCi/L	0.6	1.1
Tritium	20	pCi/mL	14	**35.1**
Cadmium	0.01	mg/L	<0.002	0.002
Lead	0.05	mg/L	0.011	0.008
Mercury	0.002	mg/L	0.0005	0.0005
Nitrate (as N)	10	mg/L	1.69	2.32
Trichloroethylene	0.005	mg/L	<0.005	-
Endrin	0.0002	mg/L	-	<0.0001

Note: Analytical results in bold are above drinking water standards.
DWS = EPA drinking water standards; refer to Table 5-1, Vol. I.
ZBG = Z-Area Background Wells
ZDT = Z-Area Low Point Drain Tank Wells

dard in wells XSB 1, 4, 4D, and 5A. Trichloroethylene (up to 0.782 mg/L) was detected above the drinking water standard in wells XSB 1, 1D, 2D, 3A, 4, 4D, and 5A. Carbon tetrachloride (up to 0.057 mg/L) was detected above the drinking water standard in wells XSB 1D, 2D, and 4. Mercury was detected above the drinking water standard in well XSB 4, up to 0.0051 mg/L. No other chemical constituents were detected above drinking water standards. However, conductivity (up to 1,040 μmhos/cm) was elevated in all of the XSB wells sampled.

TNX Burying Ground

The TNX Burying Ground (643-5T) was built within the TNX operating fence to dispose of debris from an experimental evaporator that exploded at TNX in 1953 (Figure 5-34, Vol. II). The buried material included contaminated conduit, tin, drums, and structural steel. Most of the buried material was excavated and sent to Radioactive Waste Burial Grounds between 1980 and 1984. An estimated 27 kg of uranyl nitrate remains buried at the site.

The TNX Burying Ground is monitored by the six TBG series wells (Table 5-87, Vol. II), which were installed in the third quarter of 1988. Well TBG 7 is upgradient of the site; the remaining wells are located within the site or downgradient of the site. Well TBG 2 has not been installed.

Gross alpha (up to 83.7 pCi/L) was detected above the drinking water standard in wells TBG 3 and 4. Total radium (up to 42.6 pCi/L) was detected above the drinking water standard in wells TBG 3, 4, and 6. No other radioactive constituents were detected above drinking water standards. However, nonvolatile beta activity (up to 68.9 pCi/L) was elevated in wells TBG 3, 4, and 6.

Trichloroethylene (up to 1.06 mg/L) was detected above the drinking water standard in wells TBG 1, 3, 4, 5, and 6. Nitrate (up to 43.5 mg/L) and carbon tetrachloride (up to 0.270 mg/L) were detected above their respective drinking water standard in wells TBG 3, 4, and 6. No other chemical constituents were detected above drinking water standards. However, tetrachloroethylene (up to 0.146 mg/L) was detected in wells TBG 3 and 4.

Z AREA

Z Area, located north of the intersection of Road F and Road 4 (Figure 5-35, Vol. II), is being developed for the disposal of saltstone. The saltstone will be made by mixing decontaminated supernate from the

Separations Areas Tank Farms with fly ash, cement, and pulverized blast furnace slag.

In 1988, groundwater was monitored at the following Z-Area sites: the Z-Area Background Wells and the Z-Area Low Point Drain Tank. A summary of the maximum groundwater monitoring results is presented in Table 5-17 and also in Table 5-88 (Vol. II).

Z-Area Background Wells

The ZBG wells were installed as background water-table wells in Z Area (Figure 5-35, Vol. II). Well ZBG 1 is upgradient of Z Area; well ZBG 2 is within the area.

No radioactive or chemical constituents were detected above drinking water standards (Table 5-89, Vol. II). However, nonvolatile beta activity (13.4 pCi/L) and conductivity (118 μmhos/cm) were elevated in well ZBG 1.

Z-Area Low Point Drain Tank

The Z-Area Low Point Drain Tank (551-Z) is southeast of S Area (Figure 5-33, Vol. II), north of the junction of the S access railroad. The facility will receive low-level radioactive salt solution from the H-Area Tank Farm and pump it to the DWPF Vitrification Building (221-S). When the H-Area pump is shut down, the low point drain tank will collect the solution still remaining in the lines via gravity flow.

This site is monitored by the two ZDT series wells (Table 5-90, Vol. II), which were installed in the fourth quarter of 1987 and first sampled in 1988. Well ZDT 1 is downgradient and ZDT 2 is sidegradient of the tank.

Tritium (up to 35.1 pCi/mL) was detected above the drinking water standard in wells ZDT 1 and 2. No other radioactive constituents were detected above drinking water standards.

No chemical constituents were detected above drinking water standards.

1988 HIGHLIGHTS

- Resource Conservation and Recovery Act (RCRA) point-of-compliance (POC) wells were monitored for the first time in 1988 at three SRS sites. These sites included the perimeter of Burial Ground 643-7G, the F-Area Seepage Basins, and the H-Area Seepage Basins.
- Twenty-four wells comprising seven new well series were monitored for the first time in 1988 at various locations within the F-, H-, S-, A- and TNX Areas.
- Since 1978, a tritium plume has been migrating from the original Burial Ground (643-G) toward Four Mile Creek. In 1988, the highest tritium concentration recorded for this plume was 61,100 pCi/mL in well BG 56, which is similar to the 1986 and 1987 activities.
- The C-Area Burning/Rubble Pit Area, which had the highest lead, chromium and trichloroethylene levels in 1987 had reduced levels of lead (0.108 mg/L), similar levels of chromium, and higher levels of trichloroethylene (up to 13.7 mg/L) in 1988.
- In the F-Area Seepage Basins, at least one radioactive constituent was detected above drinking water standards in all water-table wells except FSB 108D and FSB 111D. Maximum tritium (65,800 pCi/mL), gross alpha (2,140 pCi/L), and nonvolatile beta activities (10,900 pCi/L) were measured in wells to the south and southwest of the basins.

6
Food and Drinking Water Monitoring Programs

SUMMARY—The results of the radioactive monitoring of milk, food, and drinking water, and the monitoring of drinking water for chlorine, total coliform, chlorocarbons, and water quality parameters are presented in this chapter. Milk samples, routinely analyzed for ^{137}Cs, ^{131}I, tritium, and ^{90}Sr from dairies within a 25-mile radius of SRS and from locally-produced inventories of a major distributor, had concentrations of these radionuclides that were within ranges seen in previous years.

Farm products representing the food categories of leafy vegetables, fruit, grain, poultry, eggs, and meat were analyzed for gamma-emitting radionuclides, tritium, ^{90}Sr, U/Pu (nonspecific), ^{238}Pu, and ^{239}Pu. The radiation dose from eating foods with the levels of radioactivity measured is a small fraction of the dose from natural sources of radioactivity.

Drinking water from 30 onsite facilities and 14 surrounding towns were sampled and analyzed for gross alpha, nonvolatile beta, and tritium. Alpha and nonvolatile beta concentrations in drinking water collected onsite and from surrounding towns were within ranges attributed to naturally occurring radium and thorium. Small but measurable concentrations of tritium were detected occasionally in drinking water samples collected in operating areas at SRS.

The nonradioactive monitoring of drinking water indicated that residual chlorine concentrations were within acceptable ranges, and that drinking water supplies at SRS showed no confirmed chlorocarbons.

RADIOLOGICAL MONITORING

Milk

Description of Monitoring Program. Samples of milk are routinely collected from production at five dairies within a 25-mile radius of SRS and from locally-produced inventories of a major local distributor. Milk samples are analyzed for ^{137}Cs, ^{131}I, tritium, and ^{90}Sr. Sampling locations are shown in Figure 6-1, Vol. II.

Monitoring Results. Monitoring data for 1988 are presented in Table 6-1 of this chapter and also in Table 6-1, Vol. II. Tritium in milk is attributed to releases from SRS. During 1988, tritium concentrations in routine individual milk samples ranged from the lower limit of detection (LLD) to 4.0 pCi/mL with an average of 0.5 pCi/mL. These very small tritium concentrations in milk do not correspond to significant radiation doses. The 50-year dose commitment from drinking 0.5 L of milk per day for a year with a 1 pCi/mL tritium concentration is approximately 0.01 mrem (0.0001 mSv). This dose is 0.01% of the DOE Revised Interim Radiation Dose Limit from prolonged exposure and 0.003% of the average Central Savannah River Area (CSRA) individual's annual dose from naturally occurring radioactivity.

Concentrations of ^{90}Sr in milk ranged from less than the LLD to 9.1 pCi/L with an average concentration of 3.6 pCi/L, and were within ranges observed in previous years. All milk samples collected in 1988 showed an ^{131}I concentration of less than the LLD which is consistent with previous observations, except those from 1986. The maximum ^{131}I concentration of 11 pCi/L measured in milk in May 1986 reflected contribution from the Chernobyl incident. Because of its short physical half-life (eight days), ^{131}I is not generally detected, except shortly after tests of nuclear weapons or in the wake of events such as the Chernobyl incident. There were no announced atmospheric nuclear weapons tests or other major nuclear events in 1988.

Table 6-1. Milk Monitoring Data

Analysis	1986 Max	1986 Avg	1987 Max	1987 Avg	1988 Max	1988 Avg
Sr-90, pCi/L	6.3	3.0	11.0	7.0	9.1	3.6
Tritium, pCi/mL	3.4	0.7	4.0	0.6	4.0	0.5
Cs-137, pCi/L	9.4	1.0	8.1	2.1	7.5	1.7

Cesium-137 concentrations in milk ranged from less than the LLD to 7.5 pCi/L with an average concentration of 1.7 pCi/L, which is similar to data from previous years. Concentrations of ^{137}Cs in milk from the SRS area are within the ranges reported by the EPA for the southeastern United States and are attributed to worldwide fallout from weapons tests and occurrences such as the Chernobyl incident.

Food

Description of Monitoring Program. Farm products representing leafy vegetables, fruit, grain, poultry, eggs, and meat are collected at 14 localities in the six counties surrounding SRS. Six locations are near the plant perimeter and eight are approximately 25 miles from SRS. In addition, collards are collected from Columbia, SC as a control sample. Food samples are analyzed for gamma-emitting radionuclides, tritium, ^{90}Sr, U/Pu (non-specific), ^{238}Pu, and ^{239}Pu. Food sample locations are shown in Fig. 6-2, Vol. II.

Monitoring Results. Radioactivity in food monitoring data are presented in Table 6-2, Vol. II. Concentrations of gamma-emitting radionuclides in foods were generally near or less than the LLD. Concentrations of naturally occurring ^{40}K varied from less than detectable concentrations to 5.4 pCi/g and were within ranges normally observed in food and vegetation. Cesium-137 concentrations were near or below the LLD. The maximum ^{137}Cs concentration was 0.05 pCi/g in beef.

Strontium-90 concentrations were within the ranges observed in past years. The maximum in 1988 was 1.0 pCi/g in corn, compared to a maximum in 1987 of 0.63 pCi/g in pork. U/Pu maximum concentrations ranged from below the LLD to 0.38 pCi/g in a fruit sample. This is higher than the 1987 U/Pu concentrations which were less than the LLD. Maximum concentrations of ^{238}Pu in food ranged from 0.01 to 0.77 fCi/g. Plutonium-239 concentrations in food ranged from 0.02 to 1.1 fCi/g. All plutonium results were within ranges seen in previous years. Plutonium and ^{90}Sr in food result primarily from worldwide fallout that has accumulated in the soil.

Tritium concentrations in free water obtained from freeze-drying the food ranged from less than the LLD to a maximum concentration of 7.1 pCi/mL. The 1988 maximum tritium concentration was slightly higher than both the 1987 maximum of 4.3 pCi/mL and the 1986 maximum of 5.5 pCi/mL. The maximum concentration was observed in collards.

The radiation dose from eating foods with these levels of radioactivity is a small fraction of the dose from natural sources of radioactivity. If a person consumed collards at a maximum consumption rate of 64 kg/year (140 lb/yr), the 50-year whole body dose commitment would be 0.8 mrem (0.008 mSv) for ^{90}Sr (average 0.1 pCi/g) and 0.008 mrem (0.00008 mSv) for tritium (average 2 pCi/g). The sum is equal to 0.8% of the 100 mrem DOE Revised Interim Dose Limit from prolonged exposure, and 0.3% of the average CSRA individual's annual dose from naturally occurring radioactivity.

Drinking Water

Description of Monitoring Program. Drinking water from 30 onsite facilities and 14 surrounding towns are sampled and analyzed for gross alpha, nonvolatile beta, and tritium. Eight additional on-plant drinking water systems were put in service at SRS during late 1987 and 1988. Public drinking water locations are shown in Figure 6-3, Vol. II.

Two water treatment plants downriver from SRS supply treated Savannah River water to customers in Beaufort and Jasper Counties, SC, and Port Wentworth, GA (Figure 6-4, Vol. II). The Cherokee Hill Water Treatment Plant at Port Wentworth has been treating Savannah River water during the entire period of SRS operation. Treated water from this plant is used primarily for industrial and manufacturing purposes in an industrial complex near Savannah, GA, which has a consumer population of about 20,000 people who are primarily adults working in industrial facilities. The Beaufort-Jasper Water Treatment Plant near Hardeeville, SC, has been in operation since 1965. It serves a consumer population of approximately 50,000 people who live in Beaufort and Jasper Counties.

Raw and finished water treatment plant samples from these two plants and from a water treatment plant in North Augusta, SC, are collected daily by treatment plant personnel and composited for monthly analyses by SRS. The North Augusta Water Treatment Plant is upriver of SRS and provides a control for the analyses. These samples are analyzed for gross alpha, nonvolatile beta, and tritium concentrations.

Table 6-2. EPA Maximum Contaminant Levels for Radionuclides in Drinking Water

Gross Alpha[a]	15 pCi/L
Nonvolatile Beta	50 pCi/L
Tritium	20 pCi/mL
Strontium-90	8 pCi/L

[a] Excluding Radon and Uranium.

Note: Combination of all man-made radionuclides cannot result in a dose that exceeds 4 mrem assuming an intake of 2 L of water per day.

Monitoring Results. Drinking water radioactivity monitoring data for 1988 are presented in Table 6-3, Vol. II. Gross alpha and nonvolatile beta concentrations in drinking water collected onsite and from surrounding towns were within ranges attributed to naturally occurring radium and thorium. Studies conducted in South Carolina to determine levels of naturally occurring radionuclides in drinking water have indicated radium concentrations in some locations of over 20 pCi/L [Mi80]. Samples from SRS indicate lower levels. EPA maximum contaminant levels (MCL) are shown in Table 6-2.

Small but measurable concentrations of tritium were occasionally detected in drinking water samples collected in operating areas. The maximum onsite tritium concentration of 4 pCi/mL is 20% of the EPA drinking water standard (see Table 6-2). A special study conducted in 1987 indicated that trace levels of tritium detected in onsite drinking water samples are introduced after sample collection and do not reflect contamination in the aquifer.

Drinking water samples are collected in areas onsite and analyzed for radioactivity

The maximum tritium concentration observed in drinking water supplies from surrounding towns was 0.6 pCi/mL, which is 3% of the EPA drinking water standard. Tritium, when present in water supplies that use surface water, is attributed to SRS releases and global fallout. The measurable tritium concentrations in surface water result from the exchange of tritium from SRS atmospheric releases with hydrogen in rainwater and surface water. Analytical data from water treatment plants are shown in Table 6-3, Vol. II. Alpha concentrations at all three water treatment plants were less than the LLD of approximately 0.5 pCi/L. The maximum nonvolatile beta concentrations in finished water from the three plants ranged from 2.0 to 3.8 pCi/L. These concentrations were within the ranges observed in water from the Edisto River, which is approximately 20 miles from SRS and is negligibly influenced by SRS operations. The maximum nonvolatile beta concentration in water collected from the Edisto River during 1988 was 3.4 pCi/L (Chapter 3). These results for alpha and nonvolatile beta activity confirm that SRS operations have no significant impact on downriver concentrations. The only measurable SRS impact is from tritium. The maximum tritium concentration in finished water from the Beaufort-Jasper Water Treatment Plant in 1988 was 4.0 pCi/mL with an average concentration of 2.5 pCi/mL. The maximum tritium concentration in finished water from the Port Wentworth Water

Treatment Plant was 3.6 pCi/mL with an average concentration of 2.6 pCi/mL. The average concentration is 12.5% of the EPA drinking water standard for tritium.

NONRADIOLOGICAL MONITORING

Drinking Water

Description of Monitoring Program. Many of the 30 separate onplant drinking water systems are operated and monitored by the SRS Power Department. Most of the larger systems draw water from the Black Creek-Middendorf formations (also known as the Tuscaloosa aquifer). Most of the smaller systems utilize shallower wells which draw water from the Congaree or McBean formations. The domestic water system in D Area is supplied with surface treated water from the Savannah River. The drinking water is disinfected with chlorine to ensure that bacteriological concentrations are maintained below state and federal limits.

Samples from drinking water supplies are routinely analyzed for residual chlorine and total coliform. The sampling frequency depends upon the potential for contamination and the amount of use. In addition, the primary supplies are analyzed annually for a comprehensive list of chemicals and other water quality parameters.

Drinking water is also monitored for chlorocarbons. Groundwater in the vicinity of M Area was found to be contaminated with metal degreasing solvents in 1981. Follow-up sampling indicated that trichloroethylene and tetrachloroethylene (chlorocarbons) were present in Wells 20A and 53A in the A-Administration Area. These wells, which supplied both drinking water and process water for the A-Administration and M Areas, were shut down and drinking water was supplied from Well 82A, which was free of chlorocarbons. Use of drinking water from Well 31A, which served as a backup source of drinking water, was also discontinued in 1983 because of the occasional presence of low concentrations of chlorocarbons. The drinking water and process water systems were then separated, and water from Wells 20A and 53A was restricted to process water applications. A dense-bed activated charcoal filter system was installed on A-Administration/M Areas drinking water supplies in 1985. This action permitted the reactivation of Well 31A as a backup source of drinking water. In December 1986, the charcoal filter system was removed from service, and Well 31A is being converted to a process water well. New drinking water supply wells (112- and 113-G), approximately 1 and 0.5 miles east of the A-Administration Area, respectively, were placed in service in late 1986. No chlorocarbons have been detected in water from these wells. No chlorocarbons have ever been detected in SRS drinking water systems since February 1985.

Applicable Standards. SCDHEC maximum contaminant levels and recommended guidelines are used to ensure safe drinking water at SRS. The recommended guidelines call for a minimum of 0.2 part per million (ppm) (mg/L) chlorine at all locations of the water system. There are no maximum contaminant levels for chlorine. The maximum contaminant concentration limit for total coliform is a monthly average not greater than 1 colony/100 mL or an individual result not greater than 4 colonies/100 mL in two consecutive samples.

For total trihalomethanes, the standard is less than 100 μg/L for community drinking water supplies. Although SRS drinking water supplies are not classified as community drinking water supplies and are not required to meet this standard, SRS policy is to meet the requirement. For other constituents, the "National Interim Primary Drinking Water Regulations" apply [EPA76].

For chlorocarbons, the EPA drinking water standard for tetrachloroethylene is 10 μg/L. The proposed EPA standards for trichloroethylene of 5 μg/L (ppb) and 1,1,1-trichloroethane of 200 μg/L (ppb) have not yet been adopted. Table 6-3 summarizes the drinking water standards.

Monitoring Results. Monitoring data show that residual chlorine concentrations were above acceptable limits in 1988. Elevated total coliform counts were detected in a few domestic water samples collected in 1988. Enough chlorine was present in these samples to attribute the counts to sampling or procedure error. Analytical results are presented in Table 6-4, Vol. II.

Concentrations of chemicals, metals, and organics were generally within applicable recommended standards except for total iron, total manganese, turbidity, and color at a few locations. Twelve of the 16 samples had elevated total iron concentrations above the South Carolina drinking water standard of 0.3 mg/L. These elevated iron concentrations are attributed to natural sources. No health hazard exists from

drinking water with these levels of iron. Analysis results are summarized in Table 6-5, Vol. II.

No confirmed positive concentrations of tetrachloroethylene, trichloroethylene or 1,1,1-trichloroethane were detected in monthly analyses of drinking water for the A-Administration/M Areas in 1988. The new 112- and 113-G Wells have also shown no confirmed chlorocarbon concentrations. Semiannual analyses of other drinking water supplies at SRS showed no confirmed chlorocarbons.

Occasional low concentrations of trichloroethylene and tetrachloroethylene continued to be detected at the wellhead of Well 31A. The maximum concentrations for 1988 were 6.20 μg/L and 2.31 μg/L, respectively. The 6.20 mg/L of trichloroethylene measured at Well 31-A was reported by ECS/Normandeau, a subcontracted offsite laboratory. Duplicate analysis of the sample by the 320-M onsite laboratory measured 4.33 μg/L. Previously an A-Administration backup domestic water well, Well 31-A was removed from the domestic water line in November 1988. Process water wells 20A and 53A continued to show elevated chlorocarbon concentrations. The maximum concentration was 178 μg/L of trichloroethylene detected in well 20A in June 1988. Monitoring results are presented in Tables 6-6, 6-7, and 6-8, Vol. II. Well locations are shown in Figure 6-5, Vol. II.

Table 6-3. Drinking Water Standards for Nonradiological Contaminants[a,b]

Total coliform	either monthly average ≤1 colony/100 mL or ≤ 4 colonies/100 mL in 2 consecutive samples
Total trihalomethanes	< 100 μg/L
Tetrachloroethylene	< 10 μg/L[c]
Trichloroethylene	< 5 μg/L[c]
1,1,1-trichloroethane	< 200 μg/L[c]

[a]SCDHEC-recommended guidelines call for a minimum of 0.2 ppm chlorine at all parts of the water system. There are no maximum contaminant levels for chlorine.
[b]For constituents not shown, the "National Interim Primary Drinking Water Regulations" apply [EPA76]
[c]EPA standard or proposed EPA standard

1988 HIGHLIGHTS

- Strontium-90 concentrations in milk were slightly lower than in 1987,ranging from the lower limit of detection to 9.1 pCi/L with an average concentration of 3.6 pCi/L.
- Tritium concentrations in free water obtained from freeze-drying food ranged from less than the lower limit of detection to a maximum concentration of 7.1 pCi/mL, slightly higher than the1987 maximum of 4.3 pCi/mL and the 1986 maximum of 5.5 pCi/mL.
- Nine additional onplant drinking water systems were put into service at SRS during late 1987 and 1988.
- The maximum tritium concentration in drinking water supplies from surrounding towns was 0.6 pCi/mL, which is 3% of the EPA drinking water standard, while the maximum onsite tritium concentration of 4 pCi/mL was 20% of the EPA drinking water standard.
- The maximum nonvolatile beta concentrations in finished water from the three water treatment plants ranged from 2.0 to 3.8 pCi/L. These concentrations are within the ranges observed in water from the Edisto River, which is approximately 20 miles from SRS.
- Drinking water concentrations of chemicals, metals, and organics were within applicable standards except for total iron, total manganese, turbidity, color, and pH at a few locations, but no health hazard exists from drinking water with these levels.
- Occasional low concentrations of trichloroethylene and tetrachloroethylene continued to be detected at the well head of well 31A in the A-Administration Area. Well 31-A was removed from the domestic water line, November 1988.

7
Wildlife Monitoring Program

SUMMARY—This chapter presents the results of radioactive monitoring of fish and seafood, deer and hogs, furbearers, ducks and turtles, and the monitoring of fish for mercury. Savannah River fish, crabs and oysters, and fish collected from plant streams and ponds were analyzed for gamma-, alpha-, and beta-emitting radionuclides. Cesium-137 was the only man-made gamma-emitting radionuclide detected. The radiation dose from eating river fish (average 11.3 kg/year) with the maximum ^{137}Cs concentration (3.4 pCi/g) measured would be 1.9 mrem (0.019 mSv), which is 1.9% of the DOE Revised Interim Radiation Dose Limit.

The concentration of alpha- and nonvolatile beta-emitting radionuclides measured in 27 river fish were within ranges seen in previous years. Mercury concentrations were determined in randomly-selected, individual fish taken from onsite and offsite locations. It is assumed that the mercury comes principally from previous releases from industries upriver of SRS. The average mercury concentration of the Savannah River fish analyzed was 0.12 μg Hg/g compared to an FDA action level of 1.0 μg Hg/g for a daily intake of mercury in edible fish. Access to SRS streams and ponds is restricted, and no use of fish for food is allowed.

All deer and hog results were within ranges observed over the last several years. An adult consuming all edible meat (30 lbs) of the deer with the highest concentration of ^{137}Cs (60 pCi/g) would receive a 50-year radiation dose commitment of 40 mrem. This is 40% of the DOE Revised Interim Radiation Dose Limit from prolonged exposure and 13.6% of the annual dose commitment of 295 mrem received from natural radiation. This 50-year radiation dose commitment received from eating deer is dependent on the amount of meat consumed and the concentration of ^{137}Cs in the edible meat.

Furbearing animals such as foxes, raccoons, and opossums, as well as ducks and turtles were trapped and analyzed for gamma-emitting radionuclides.

INTRODUCTION

An abundance of wildlife finds refuge within the protected boundaries of the SRS. An objective of the environmental surveillance program is to collect and analyze a thorough representation of all wildlife on and in the vicinity of the site, and to determine the effects of SRS operations on the wildlife population.

RADIOLOGICAL MONITORING

Fish and Seafood

Description of Monitoring Program. Savannah River fish are routinely trapped upriver of SRS, adjacent to SRS, and downriver of SRS. Additional fish are caught in the mouth of the Savannah River (river miles 0-8). Fish are also collected from SRS plant streams and ponds and from Thurmond Lake (formerly Clarks Hill Lake). Thurmond Lake fish are used as controls because of its location above SRS. Seafoods (crabs and oysters) are collected from the mouth of the Savannah River near Savannah, GA, and analyzed for alpha-, beta-, and gamma-emitting radionuclides.

Monitoring Results. In 1988, a total of 210 individual fish from the Savannah River and Thurmond Lake were analyzed for gamma-emitting radionuclides. Cesium-137 was the only man-made gamma-emitting radionuclide detected. A total of 27 individual fish from the Savannah River were analyzed for alpha- and beta-emitting radionuclides. Table 7-1 summarizes the maximum concentrations of ^{137}Cs, alpha, and beta activity found in fish caught near and on the SRS, and in seafood caught near the mouth of the Savannah River. Savannah River sampling locations are shown in Figure 7-1, Vol. II. More comprehensive fish monitoring data for 1988 are presented in Table 7-1, Vol. II. Comparisons of ^{137}Cs data to those from previous years are presented in Table 7-2, Vol. II.

Table 7-1. Radioactivity in Fish and Seafood Caught On and Near SRS

Location	Maximum concentration (pCi/g) Gross Alpha	Nonvolatile Beta	^{137}Cs
Savannah River fish[a]	0.3 (27)	4.7 (27)	3.4[b] (210)
Crabs[c]	0.91 (17)	5.6 (17)	0.10 (20)
Fish from SRS streams ponds, and swamps	1.0 (114)	162 (114)	145[d] (423)

[a] Caught in the Savananah River, above, adjacent to and below the SRS.
[b] Caught at the Savannah River R-8 location adjacent to SRS. An individual eating 11.3 kg of fish (an average year's consumption) with this level of ^{137}Cs would receive 1.9 mrem (0.019 mSv) or 0.64% of the annual dose to an average CSRA resident from naturally occurring radioactivity.
[c] Caught at the mouth of the Savannah River.
[d] The maximum occurred in a bass taken from Pond B. Fish in Pond B and Par Pond are isolated from public access.
- Numbers in parentheses indicate number of samples analyzed.

Due to the greater uncertainties in some analyses results, uncertainty values are provided when appropriate. Of the 210 river fish and seafood analyzed for gamma-emitting radionuclides, 142 contained measurable concentrations of ^{137}Cs. Except for 14 fish, ^{137}Cs concentrations were less than 1 pCi/g. The maximum ^{137}Cs concentration, 3.4 ± 1.5 pCi/g was detected in an eel caught in the Savannah River adjacent to SRS at the R-8 sampling location. The radiation dose from eating fish having these ^{137}Cs concentrations is small. The 50-year dose commitment from eating fish for a year (11.3 kg/year average consumption) with the maximum ^{137}Cs concentration of 3.4 pCi/g would be 1.9 mrem (0.019 mSv). This represents 1.9% of the DOE Revised Interim Radiation Dose Limit from a prolonged period of exposure of 100 mrem and 0.64% of the average Central Savannah River Area (CSRA) individual's annual dose from naturally occurring radioactivity.

Of the 27 river fish analyzed for alpha- and beta-emitting radionuclides, nine contained measurable quantities of alpha and all 27 fish contained measurable quantities of nonvolatile beta. The average alpha concentrations in fish caught during 1988 were within ranges seen in previous years, while the nonvolatile beta concentrations were less than the average observed in 1987 but similar to that in 1986 averages. The maximum alpha concentration was 0.30 ± 0.11 pCi/g detected in a catfish from the Savannah River sampling location R-2 above SRS. The maximum concentration of nonvolatile beta was 4.7 ± 1.6 pCi/g detected in a bream from the Savannah River sampling location R-10 below SRS.

Crabs and oysters caught at the mouth of the Savannah River were analyzed for gamma-emitting radionuclides. Cesium-137 was detected in five of the 20 crabs collected with a maximum concentration of 0.10 ± 0.05 pCi/g. This maximum concentration is less than the 1987 maximum concentration of 0.17 pCi/g. Cesium-137 was not detected in the oysters. These data are consistent with analytical results from previous years.

Of the 17 crabs analyzed for alpha- and beta-emitting radionuclides, 11 had measurable quantities of alpha and all had measurable quantities of nonvolatile beta. The maximum concentrations of alpha and nonvolatile beta in the crabs were 0.91 ± 0.61 and 5.6 ± 1.3 pCi/g, while the average concentrations were 0.13 ± 0.51 and 3.4 ± 2.6 pCi/g, respectively. A maximum alpha concentration of 0.38 ± 0.46 pCi/g was measured in an oyster from the Savannah River mouth. A maximum beta concentration of 1.4 pCi/g was also measured in an oyster from the Savannah River mouth. These concentrations are greater than the maximum concentrations of less than the lower limit of detection (LLD) alpha and 0.16 pCi/g nonvolatile beta measured in oysters in 1987. Prior to

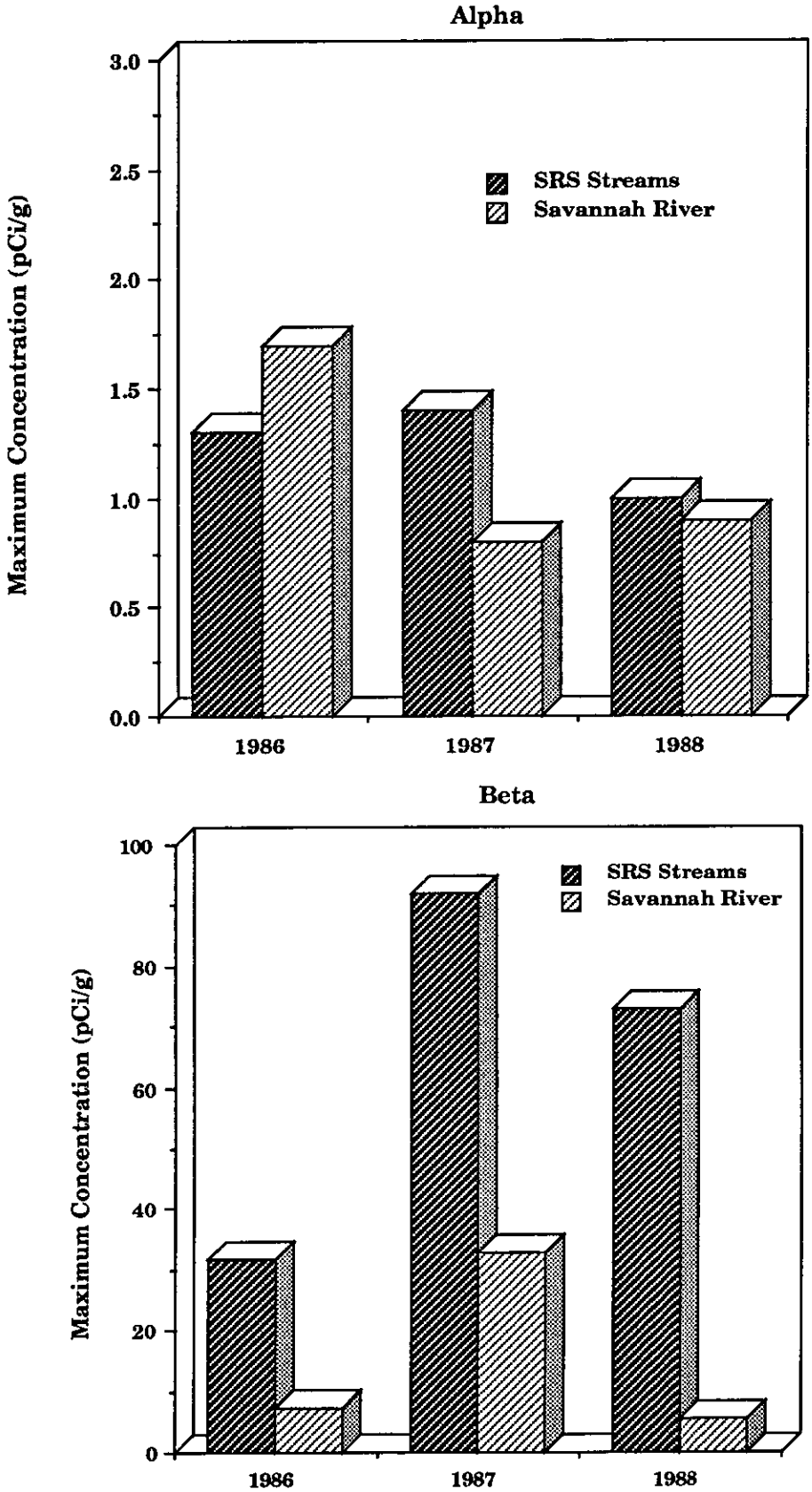


Figure 7-1. Alpha and beta concentrations in fish caught from SRS streams and the Savannah River over a three-year period

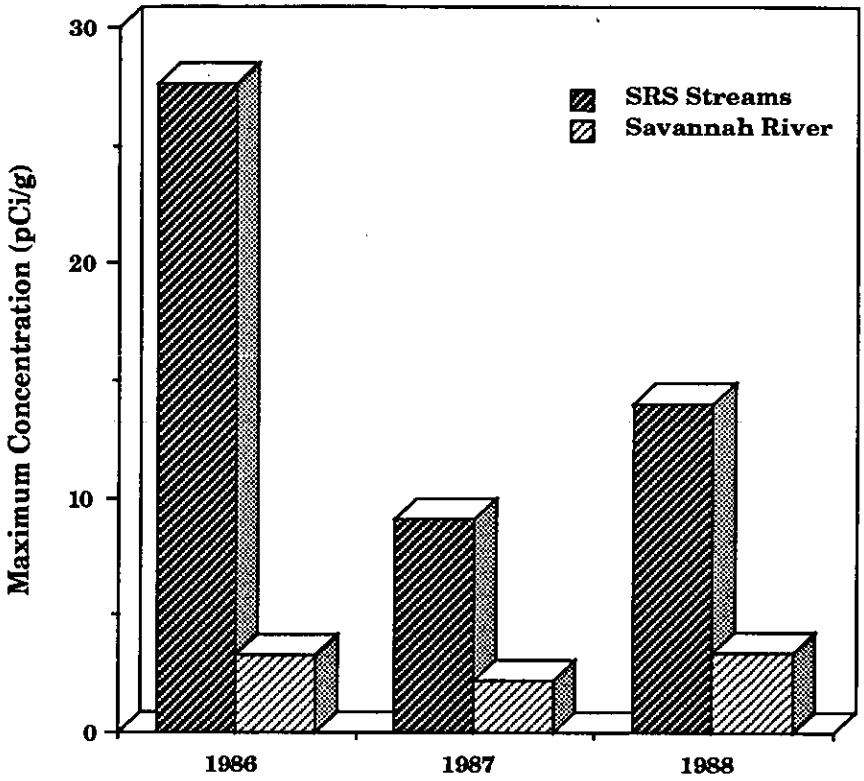


Figure 7-2. Cesium-137 concentrations in fish caught from SRS streams and the Savannah River over a three-year period

1987, crabs and oysters were not analyzed for alpha- and beta-emitting radionuclides.

A total of 423 fish were caught in SRS streams, ponds, and swamp areas. Cesium-137 was the only man-made gamma-emitting radionuclide detected in the fish. The maximum concentration of ^{137}Cs in a fish from an SRS stream was 14 ± 0.89 pCi/g in a sucker collected from Four Mile Creek.

The highest ^{137}Cs concentration in fish caught in SRS ponds was 145 ± 10 pCi/g detected in a bass from Pond B. Fish from Pond B had higher ^{137}Cs concentrations than fish from other onsite locations. Fish in Pond B averaged 73 pCi/g. Pond B is located along the effluent canal from R Area to Par Pond. The R-Reactor effluents were discharged through this canal from the late 1950s to 1964 when R-Reactor operation was permanently discontinued. During this time, releases from R Area were approximately 170 Ci of ^{137}Cs.

Cesium-137 concentrations in Par Pond fish were also elevated compared to previous years with a maximum concentration of 11 ± 0.28 pCi/g detected in a crappie. Par Pond receives reactor heat exchanger cooling water from P Area. However, releases of radioactivity from this source consist of only small amounts of tritium. No measurable ^{137}Cs is released via this route into Par Pond. Almost all of the ^{137}Cs in Par Pond was released from R Area before R Reactor was shut down in 1964. Access to SRS streams and ponds is restricted, and no use of fish for food is allowed. If a person was to illegally consume fish (11.3 kg/year average consumption) which was caught within SRS boundaries which contained the concentrations of 73 pCi/g of ^{137}Cs (average at Pond B), that person would receive a 50-year dose commitment of 41 mrem. This dose is 41% of the DOE Revised Interim Dose Limit from prolonged exposure, and 13.8% of the average Central Savannah River Area (CSRA) individual's annual dose from naturally occurring radioactivity.

Concentrations of ^{137}Cs generally decreased in plant stream and pond fish between 1971 and 1979. Since 1979, concentrations of ^{137}Cs in fish have remained fairly constant.

A total of 114 fish trapped in SRS streams and ponds were analyzed for gross alpha- and beta-emitters. Alpha concentrations ranged from less than the LLD

to a maximum of 1.0 ± 0.9 pCi/g. The beta concentration ranged from a minimum of 1.0 ± 0.94 pCi/g to a maximum of 162 pCi/g. The maximum alpha concentration was detected in a sucker caught in Upper Three Runs Creek, and the maximum beta concentration was detected in a bass from Pond B. Gross alpha and beta radioactivity data in fish are presented in Table 7-1, Vol. II.

Figures 7-1 and 7-2 show concentration relationships for alpha, beta, and ^{137}Cs of fish caught over a three-year period in SRS streams and the Savannah River.

Deer and Hogs

Description of Monitoring Program. Annual hunts are conducted at SRS to control the site deer and hog population in order to reduce animal-vehicle accidents. Field analyses for ^{137}Cs are performed on the deer and hogs at the hunt site using a portable 2x2 in. sodium iodide [Na(I)] detector. If the ^{137}Cs concentration in the monitored animal is less than 100 pCi/g, the animal is released to the hunter. Samples of flesh including thyroids, spleen, kidney, liver, and muscle are removed from 5-10% of the animals and ^{90}Sr, ^{137}Cs, and tritium analyses are performed. The 1988 hunts yielded 855 deer and 146 hogs, as compared with 606 deer and 123 hogs in 1987.

Monitoring Results. Due to the greater uncertainties in some laboratory analyses results, uncertainty values are provided when appropriate. In deer, the maximum ^{137}Cs field measurement was 60 pCi/g found in muscle tissue and the average concentration was 10.2 ± 11 pCi/g. Measurements in hogs were somewhat lower with a maximum ^{137}Cs concentration of 16 pCi/g and an average of 6 ± 7.4 pCi/g. The 1987 maximum ^{137}Cs concentrations in deer and hogs were 45 pCi/g and 5 pCi/g, respectively. Table 7-2 presents maximum concentrations of ^{137}Cs and ^{129}I found in deer and hogs taken in hunts on the SRS in 1988. A summary of ^{137}Cs monitoring data is presented in Table 7-3, Vol. II.

All deer and hog results were within ranges observed over the last several years and consumption of the meat from these animals presents no radiation hazard. The average ^{137}Cs concentration in SRS deer monitored in 1988 was 10.2 ± 11 pCi/g. It is important to measure ^{137}Cs in deer due to the prevalence of cesium onsite (from worldwide fallout and SRS operations). Since ^{137}Cs can be deposited in deer tissue, a large part of the radionuclide in the deer can be consumed by man resulting in a measurable dose. The 50-year dose commitment to an individual who consumed one 8 oz. steak of deer meat with this concentration would be 0.11 mrem. This dose is 0.11% of the DOE Revised Interim Dose Limit from prolonged exposure. The 50-year dose commitment received from consuming food with radioactive concentrations is directly proportional to the amount of food consumed and the concentration of radioactivity in the food. For instance, if the same person were to eat one 8 oz. steak which contained a concentration of 10.2 pCi/g ^{137}Cs every day for one year, he would receive a 50-year dose commitment of 41 mrem. This dose is 41% of the DOE Revised Interim Dose Limit from prolonged exposure and 14% of the average CSRA resident's average annual dose from naturally occurring radioactivity.

The deer with the highest concentration, 60 pCi/g, had edible meat which weighed approximately 13.6 kg. An adult consuming all of this meat would receive a 50-year radiation dose commitment of 40 mrem (0.40 mSv) or 40% of the DOE Revised Interim Radiation Dose Limit from a prolonged period of exposure. This dose would also be 13.6% of the average CSRA resident's annual dose from naturally occurring radioactivity.

Additional studies of ^{137}Cs levels in deer harvested onsite and in deer from the southeast United States are planned for 1989 in order to:

- gain a greater perspective on levels of ^{137}Cs in deer from site operations compared to worldwide fallout
- investigate the consumption habits of SRS deer by onsite hunters and the public (considering that more than one deer can be consumed by an individual in one year).

Each year SRS Environmental Monitoring collects deer samples from the 18,000 acre controlled hunting camp located on the South Carolina Coastal Plain (SCCP) about 65 miles east of SRS. During 1988 five deer were collected from the controlled camp on the SCCP. The average ^{137}Cs concentration was 6.9 ± 6.2 pCi/g, while the 855 deer collected on SRS had an average concentration of 10.2 ± 11.0 pCi/g. The SRS maximum concentration of 60 pCi/g was higher than the 11.8 pCi/g maximum detected in the deer from the controlled camp on the SCCP. The higher SRS maximum may reflect some uptake of ^{137}Cs from SRS

Table 7-2. Radioactivity in Deer and Hogs Killed in Hunts on SRS[a]

	Maximum concentration			
	^{137}Cs (pCi/g)	^{129}I (pCi/g)	Tritium (pCi/mL)	^{90}Sr (pCi/g)
Deer	60[b] (855)	21[c] (24)	-	-
Hogs	16 (146)	-	-	-

[a] Numbers in parentheses indicate number of specimen analyzed.
[b] Consumption of the meat of this deer would lead to a 50-year dose commitment of 40 mrem (0.40 mSv) from ^{137}Cs.
[c] Thyroid.
- No analysis performed.

operations and/or it may reflect differences in the diets of the deer. Additionally, since the number of deer collected onsite far exceeds those offsite (855 vs. 5), there exists a much greater potential to meaure higher ^{137}Cs concentrations in SRS deer compared to those offsite. A comparison of ^{137}Cs concentrations in SRS and SCCP deer since 1968 has shown significant year-to-year variations in both maximum and average concentrations, as shown in Table 7-4, Vol. II.

Tissue samples were collected from 67 deer and three hogs to verify field measurements and to determine whether other radionuclides were present. Statistical analysis of ^{137}Cs field and laboratory measurements, indicate good agreement between the two sets of data. Gamma analysis of the laboratory samples detected only ^{137}Cs and normal levels of naturally occurring ^{40}K. A comparison of field and laboratory ^{137}Cs measurements in deer and hogs is presented in Table 7-5, Vol. II. Cesium-137 concentrations in the tissue samples ranged from 0.88 pCi/g to 64 pCi/g. The 1988 maximum concentration was higher than the 1987 maximum concentration of 45 pCi/g. The 1988 average concentration of ^{137}Cs in deer tissue was 9.8 pCi/g compared to 7.4 pCi/g in 1987.

In addition to the ^{137}Cs laboratory analyses in deer and hog flesh, flesh samples from seven deer were analyzed for ^{131}I. All the flesh samples had less than detectable concentrations of ^{131}I. These data are presented in Table 7-6, Vol. II.

Tissue and thyroid samples were collected from 24 deer and sent to the Department of Physiology and Biophysics, University of Tennessee, Memphis, for analysis. The tissue samples were analyzed for ^{137}Cs, and the thyroids were analyzed for ^{129}I and ^{137}Cs. These analyses were consistent with SRS measurements. Concentrations of ^{137}Cs in the tissue samples ranged from 4.7 pCi/g to 16 pCi/g. Iodine-129 concentrations in the thyroids ranged from 0.1 pCi/g to 21 pCi/g, with an average of 2.9 pCi/g. These ^{129}I values for 1988 are similar to the average of 3.0 pCi/g and the range of 0.02 to 12 pCi/g detected in 1987. Concentrations of ^{137}Cs in the thyroids ranged from 0.7 to 18 pCi/g, with an average of 7 pCi/g. These data are presented in Table 7-7, Vol. II.

Furbearers

Description of Monitoring Program. The SRS is closed to outside hunters except for the controlled hunts for deer and hogs. Therefore, furbearers (referred to in previous reports as terrestrial animals) are not a likely source of food to the surrounding population. Furbearing animals such as foxes, raccoons, and opossums are trapped and analyzed for gamma-emitting radionuclides.

The U.S. Forest Service administers a SRS contract for trapping beavers in selected areas within the SRS perimeter. The purpose of the trapping is to reduce the beaver population in specific areas of SRS and thereby minimizing dam building activities that result in flood damage to timber stands, primary and secondary roads, and railroad beds. Beavers are monitored with a G-M detector (Thyac) and disposed of in the SRS sanitary landfill. In 1988, no trapped beavers were submitted for laboratory analysis.

Monitoring Results. During 1988, 32 furbearers (not including beavers) were trapped along 10 transects across the SRS and in the Savannah River

Swamp near Creek Plantation. The animals counted for gamma-emitting radionuclides indicated low concentrations of ^{137}Cs. The maximum concentration of ^{137}Cs was 6.3 pCi/g in an opossum from a location between Par Pond and Pond B. If this opossum left the SRS and was subsequently used for food, the 50-year radiation dose commitment to an individual who consumed all edible portions (total weight 2.4 kg) would be 0.76 mrem (0.0076 mSv) or 0.76% of the DOE Revised Interim Radiation Dose Limit of 100 mrem. This dose represents 0.26% of the average CSRA individual's annual dose from naturally occurring radioactivity. The average ^{137}Cs concentration in all furbearers was 1.8 pCi/g. Animal monitoring results are presented in Table 7-8, Vol. II.

Ducks

Description of Monitoring Program. Ducks are routinely trapped at Par Pond and Pond B and counted whole for gamma-emitting radionuclides.

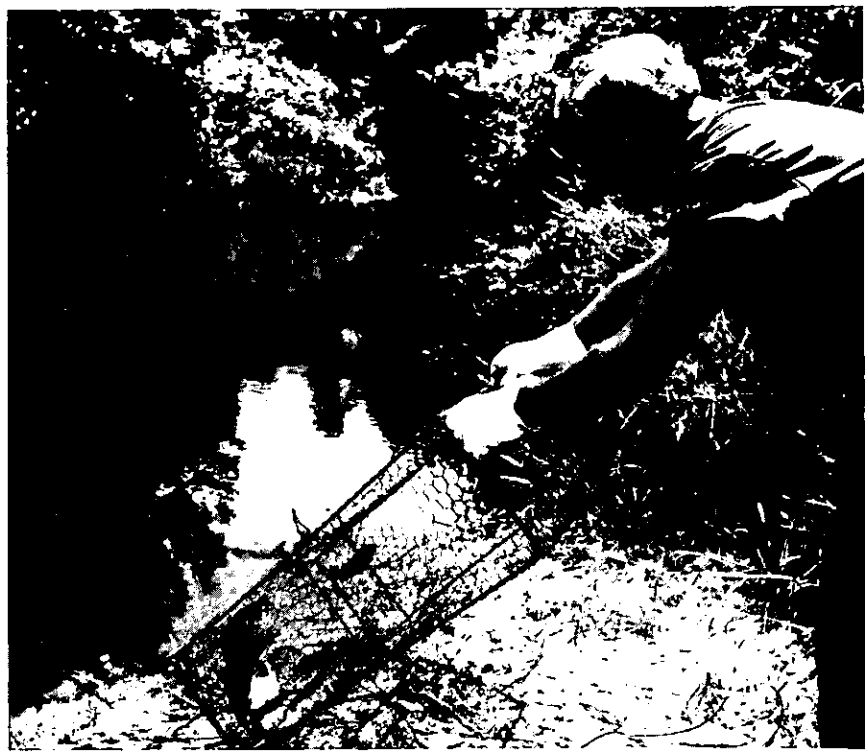
Monitoring Results. In 1988, a total of 29 ducks were trapped at SRS. During the fourth quarter 1987, 15 ducks were collected by the Savannah River Ecology Laboratory (SREL) from Par Pond and Pond B. Cesium-137 was the only gamma-emitting radionuclide detected in all ducks collected in 1988 and during the fourth quarter 1987. The maximum concentration of ^{137}Cs detected was 216 pCi/g in a coot from Pond B. Prior to 1988, the highest ^{137}Cs concentration detected was 170 pCi/g ^{137}Cs in 1972. The coot is not a preferred table fare of waterfowl hunters. However, if this coot left the SRS and if it was used for food, the 50-year radiation dose commitment to an individual who consumed the coot (total weight 347 g) would be 3.86 mrem (0.039 mSv) or 3.86% of the DOE Revised Interim Radiation Dose Limit of 100 mrem from a prolonged period of exposure. This dose would be 1.3% of the average CSRA resident's annual dose from naturally occurring radioactivity. Duck monitoring data for 1988 are presented in Table 7-9, Vol. II. Fourth quarter 1987 duck monitoring data are presented in Table 7-10, Vol. II.

Turtles

Description of Monitoring Program. Turtles are trapped on- and offsite as part of an ongoing study conducted by SREL to learn more about the animal's migratory behavior. Trapped turtles are then surveyed for radioactivity with a G-M detector (Thyac), aged, and sexed. Turtles collected from sites where no turtles had been previously collected, and those with field radiation measurements above levels previously detected in turtles from those locations are submitted for laboratory analysis to determine the origin of radioactivity.

Monitoring Results. A total of 1,287 turtles, mainly pondsliders and eastern mud turtles, were trapped in 1988. Only six of the turtles trapped had elevated radioactivity readings. All were pondsliders captured onsite; one was captured at Steel Creek, two were captured at the H-Area Seepage Basin, and three were captured from the R-Area Canal.

None of the turtles trapped offsite showed detectable levels of radioactivity. The offsite turtles used for analysis were taken from nearby private ponds in the Green Pond Church area, near the SRS boundary. No laboratory analyses were performed on turtles in 1988.



Fish are collected from SRS streams and analyzed for mercury

NONRADIOLOGICAL MONITORING

Fish

Description of Monitoring Program. Mercury (Hg) has been detected in river and stream fish since analyses began in 1971. Initially, individual fish flesh samples were analyzed. In 1972, fish samples were analyzed quarterly by composites of bass, bream, and catfish. Analyses by species composites continued from 1973 to 1975 but on a semiannual basis. Since 1975, analyses have been performed on individual fish.

The concentration of mercury is determined in the flesh of fish taken from onsite and offsite locations. The fish analyzed represent a random selection of fish caught in traps. These analyses are performed to assess the uptake of mercury that is assumed to come principally from previous industrial releases upriver of SRS. Much of the mercury concentrations detected in onsite fish reflect mercury in the Savannah River water that has been used as cooling water in site facilities and subsequently pumped into SRS streams and lakes.

Applicable Standards. The Food and Drug Administration (FDA) has established an action level of 1.0 μg Hg/g for a daily intake of mercury in edible fish. For this reason, it is appropriate to compare average concentrations to the action level rather than maximum concentrations.

Monitoring Results. In 1988, a total of 226 fish from SRS streams, ponds, the Savannah River, and offsite lakes were collected and analyzed for mercury. The maximum mercury concentration in fish from the Savannah River was 0.48 μg Hg/g, observed in a catfish caught at the mouth of the Savannah River. The average mercury concentration of the Savannah River fish analyzed was 0.12 μg Hg/g. The maximum mercury concentration from the control locations was 0.38 μg Hg/g in bass from Thurmond Lake. The maximum offsite concentrations were less than half of the FDA action level.

The onsite concentration of mercury ranged from the LLD of 0.10 μg Hg/g to 1.4 μg Hg/g analyzed in a bass from Par Pond. The average mercury concentration in fish in onsite surface waters was 0.30 μg Hg/g. The highest of the averaged mercury concentrations from a specific location was 0.60 μg Hg/g from Lower Three Runs Creek.

All on- and offsite average mercury concentrations were below the FDA action level. All mercury in fish monitoring data are presented in Table 7-11, Vol. II.

1988 HIGHLIGHTS

- Of the 210 river fish analyzed for gamma-emitting radionuclides, 142 contained measurable concentrations of ^{137}Cs; however, only 14 of these had levels greater than 1 pCi/g.
- The highest concentration of ^{137}Cs in fish caught in SRS ponds was 145 pCi/g detected in a bass from Pond B, which is located along the effluent canal from R Area to Par Pond.
- An adult consuming all edible meat from the deer harvested in 1988 with the highest ^{137}Cs concentration (60 pCi/g) would receive a 50-year radiation dose commitment of 40 mrem (0.40 mSv), which represents 13.6% of the average CSRA resident's annual dose from naturally occurring radioactivity. The 50-year dose commitment is directly proportional to the amount of food consumed and the radioactive concentration.
- A total of 1,287 turtles, mainly pondsliders and eastern mud turtles, were trapped in 1988. Only six of the 1,287 had elevated Thyac readings.
- In 1988, a total of 226 fish from SRS streams, ponds, the Savannah River, and offsite lakes were analyzed for mercury. The onsite concentration ranged from the lower limit of detection of 0.10 μg Hg/g to 1.4 μg Hg/g analyzed in a bass from Par Pond.

8
Monitoring of Rainwater, Soil, Vegetation, and Sediment

SUMMARY—This chapter discusses the radiological monitoring program results of rainwater, soil, vegetation, and sediments from the SRS and surrounding areas. Each section presents a description of the monitoring program, changes that occurred in 1988, and the monitoring data.

Routine monthly analyses of rainwater are performed at the H-Area onplant station, the Darkhorse and Barnwell gate plant perimeter stations, and at the Olar 25-mile-radius station. Measurable quantities of alpha, nonvolatile beta, $^{89,90}Sr$, ^{137}Cs, and naturally occurring ^{7}Be were detected in rainwater samples during the year. Soil samples are collected from each of the four quadrants around the two separation areas and at the SRS boundary.

Averaged concentrations of ^{90}Sr, ^{137}Cs, ^{238}Pu, and ^{239}Pu in multiple soil samples were calculated using soil density, sample volume, and the measured radionuclide concentration in soil. Vegetation samples are collected on the general plant site and at the plant perimeter, 25-mile radius, and 100-mile radius. Onsite samples are also collected around seepage and retention basins and in and around the Radioactive Waste Burial Ground (RWBG).

Alpha concentrations for vegetation collected at all sites were higher this year because a new method using a self-absorption factor was initiated. Beta-gamma and tritium concentrations were within ranges observed in previous years. Sediment samples, collected at locations where maximum accumulation of radioactivity in the river and stream beds is expected, were analyzed for gamma-emitting radionuclides, ^{90}Sr, ^{238}Pu, and ^{239}Pu.

INTRODUCTION

Radiological surveys of rainwater, soil, vegetation, and sediment comprise a significant fraction of the SRS Environmental Monitoring program. Rainwater, soil, and vegetation sample collection and analysis are crucial in quantifying the deposition of radioactive materials from routine and nonroutine atmospheric releases from SRS, as well as the deposition of worldwide fallout from atomic weapons testing and unusual occurrences such as the Chernobyl incident. In addition, data trends of migration and buildup of radioactivity in foliage and soil are supplied through these analyses. Sediment sample collection and analysis facilitate assessment of radioactive deposition in the streams and river bed due to effluent liquid releases of radioactivity.

RADIOLOGICAL MONITORING

Rainwater

Description of Monitoring Program. Small quantities of worldwide fallout that remain in the atmosphere are deposited on the earth in rainwater. The quantity deposited each year has decreased significantly since the 1960s and is now at or below detectable levels.

On occasions such as the Chernobyl incident or other unusual occurrences associated with radioactivity, the fallout in rainwater becomes more significant. Radionuclides in rainwater may provide a principal source of dose to persons through the grass-to-cow-to-milk-to-person pathway. Continuous measurements at selected monitoring stations are sufficient to identify these events when they occur. In 1986 the rainwater monitoring program was reduced because of decreased levels of worldwide fallout from previous nuclear weapons tests. A large number of stations is no longer considered necessary for adequate monitoring.

As a part of its monitoring program for worldwide fallout and emissions from the plant, SRS maintains a network of sampling stations for rainwater. Sampling locations, frequencies, and methods of analysis are described in Chapter 1.

Routine monthly analyses are performed on rainwater from the H-Area onplant station, the Darkhorse and Barnwell gate plant perimeter stations, and at the Olar 25-mile-radius station (see Figure 8-1, Vol. II). Quarterly analyses are also performed on samples from the four 100-mile-radius stations (at Columbia, SC; Greenville, SC; Macon, GA; and Savannah, GA). Additional rainwater samples from eight other locations are collected and retained until analyses from the primary locations are completed and reviewed.

Monitoring Results. Measurable quantities of alpha, nonvolatile beta, $^{89,90}Sr$, ^{137}Cs, and naturally occurring ^{7}Be were detected in rainwater samples during the year. Quantities of radioactivity deposited in rainwater are presented in Table 8-1, Vol. II.

Alpha activities measured in rainwater in 1988 were less than those in 1987, the maximum alpha deposition being 35 ± 16 pCi/m² at the Greenville, SC monitoring station. This deposition is attributed to worldwide fallout and not releases from SRS. Nonvolatile beta activities deposited in rainwater were also less than those depositions reported in 1987. The maximum beta depositions in rainwater from all rainwater collection stations ranged from 160 to 610 pCi/m²; in 1987 the range was 516 to 2,755 pCi/m². The maximum onplant nonvolatile beta deposition was 420 pCi/m² at the H-Area station, the maximum plant perimeter activity deposited was 410 pCi/m², and the maximum 100-mile-radius deposition was 610 pCi/m², observed at the Greenville, SC monitoring station.

The ^{137}Cs deposition in rainwater ranged from below the lower limit of detection (LLD) to 260 pCi/m². The maximum ^{137}Cs deposition was collected from the 100-mile-radius monitoring station at Columbia, SC.

The deposition of ^{238}Pu in rainwater ranged from less than the LLD to 1.5 pCi/m². Deposition of ^{239}Pu ranged from the LLD to 1.7 pCi/m². These values are slightly higher than the 1987 maximum ^{238}Pu and ^{239}Pu values of 1.1 pCi/m² and 1.3 pCi/m², respectively.

Maximum ^{7}Be concentrations ranged from 1,900 to 9,200 pCi/m². Maximum deposition of $^{89,90}Sr$ resulting from worldwide fallout ranged from 33 pCi/m² to 620 pCi/m². All ^{131}I results were below the LLD. Tritium concentrations in rainwater averaged 1.7 pCi/mL at the plant perimeter and 0.08 pCi/mL at the 100-mile radius. The maximum tritium concentration in rainwater was 6.7 pCi/mL at the plant perimeter.

Collection of soil samples at the site boundary

Soil

Description of Monitoring Program. Soil samples from uncultivated areas provide a measure of the quantity of radioactivity deposited from the atmosphere. Samples are collected from each of the four quadrants around F- and H Areas and at the SRS boundary. Two control locations approximately 100 miles from SRS are also sampled.

The concentrations of radionuclides in soil vary significantly among locations because of differences in rainfall patterns and in the mechanics of transport in different types of soil. Rates of migration in soil also vary significantly from one radionuclide to another. For example, strontium tends to migrate through soil more freely than cesium or plutonium.

The chemical separation of radionuclides in soil samples in the laboratory is complicated by the nonhomogeneity of the soil and by the difficulty in stripping ions from the soil. Therefore, individual measurements of radionuclides in soil samples may not be representative of large areas. Averaged concentrations of multiple samples provide a better measure of soil radionuclide concentrations.

Monitoring Results. Measurements of radioactive concentrations in soil for 1988 are presented in Table 8-2, Vol. II. The deposition of radioactivity in soil, calculated in mCi/km^2 from the sample concentrations in Table 8-2, Vol. II, is presented in Table 8-3, Vol. II. A yearly summary of deposition values is shown in Table 8-4, Vol. II.

Strontium-90 concentrations in soil ranged from less than the lower limit of detection to 0.06 pCi/g around F and H Areas, to 0.03 pCi/g at the plant boundary, and to 0.05 pCi/g at the 100-mile radius. These ^{90}Sr concentrations are similar to concentrations observed over the last several years and result primarily from worldwide fallout from nuclear weapons tests.

Cesium-137 concentrations ranged from 0.14 to 1.1 pCi/g around F Area and from 0.18 to 0.95 pCi/g around H Area. The F-Area soil concentration range is similar to the 1987 range of 0.12 to 1.0 pCi/g. The H-Area range, however, is considerably less than the 1987 range of 0.48 to 2.0 pCi/g. Concentrations of ^{137}Cs at the plant perimeter and at the 100-mile radius ranged from below the lower limit of detection to 0.81 pCi/g. Offsite data are consistent with previous years and are within the concentrations observed from worldwide fallout.

Plutonium concentrations in soil samples around the separations areas were somewhat greater than those detected at the plant perimeter, reflecting F- and H-Area releases. Cumulative atmospheric plutonium releases from the separations areas, since 1955, have totaled 0.7 Ci ^{238}Pu and 3.0 Ci ^{239}Pu through 1988. The majority of these releases occurred in earlier years of SRS operation. Releases for 1988 were 0.6 mCi of ^{238}Pu and 0.33 mCi of ^{239}Pu. Ranges of ^{238}Pu concentrations in soil were 0.005 to 0.29 pCi/g in F Area, 0.019 to 0.027 pCi/g in H Area, and from 0.002 to 0.007 pCi/g at the plant perimeter. For ^{239}Pu, the ranges were 0.005 to 0.23 pCi/g in F Area, 0.003 to 0.081 pCi/g in H Area, and 0.013 to 0.018 pCi/g at the plant perimeter. A maximum concentration of 0.012 pCi/g ^{239}Pu was reported at a 100-mile-radius station. Most concentrations of ^{238}Pu and ^{239}Pu measured in soil at the SRS boundary and at the 100-mile-radius sampling locations were near or below the lower limit of detection, and all concentrations at those locations were within the ranges observed in previous years.

The quantities of ^{90}Sr, ^{137}Cs, ^{238}Pu and ^{239}Pu deposited in soil were calculated using soil density, sample volume, and the measured radionuclide concentration in soil. Results in 1988 are similar to results reported in 1987, with the exception of ^{238}Pu and ^{239}Pu concentrations in F Area. The maximum ^{238}Pu and ^{239}Pu concentrations in the 1988 F-Area results were 34 and 28 mCi/km^2, respectively, compared to the 1987 concentrations of 8.8 and 11 mCi/km^2, respectively.

Vegetation

Description of Monitoring Program. Radioactive contamination of growing plants may result from sorption of radioactive materials from the soil or from radioactivity deposited from the atmosphere. Grass is analyzed routinely for radioactivity; Bermuda grass is used if available because of its importance as a pasture grass for dairy herds and year-round availability. Grass also provides an early indication of fallout because of the relatively large surface area of the grass blades exposed to the air.

Vegetation samples are collected on the general plant site and at the plant perimeter, 25-mile radius, and 100-mile radius. Onsite samples are also collected around seepage and retention basins and in and around the Radioactive Waste Burial Ground (RWBG) formerly the Solid Waste Storage Facility (Burial Ground).

Monitoring Results. Measurements of the radioactivity in vegetation are presented in Table 8-5, Vol. II. Gross alpha concentrations in vegetation collected at the onplant, plant perimeter, 25-, and 100-mile-radius locations were higher in 1988 than in previous years. The primary reason for this increase is a new method for calculating concentration using a self-absorption factor. The new method was implemented during the fourth quarter 1988.

The maximum gross alpha concentration detected in vegetation was 3.9 pCi/g in a sample from the Langley, SC station. Additional sampling locations with elevated alpha concentrations observed in 1988 were 3.1 pCi/g at the Green Pond plant perimeter station, 1.8 pCi/g at an F-Area sampling location, 1.3 pCi/g at the Allendale plant perimeter station, 1.3 pCi/g at the Waynesboro 25-mile-radius location, and 1.1 pCi/g at the Highway 39 plant perimeter location. Maximum beta concentrations ranged from 14 to 21 pCi/g at the F- and H-Area locations, 9.5 to 32 pCi/g at the plant perimeter, 16 to 29 pCi/g at the 25-mile-radius locations, and 16 to 38 pCi/g at the 100-mile-radius locations. These beta concentrations are comparable

Collection of onsite vegetation samples

with previous year's ranges, differences being attributed to variations in worldwide fallout patterns.

Naturally occurring ^{7}Be and ^{40}K were the major contributors to the beta-gamma activities in vegetation. Maximum concentrations of ^{137}Cs detected at the onplant, plant perimeter, 25-, and 100-mile radius locations were 1.6, 0.63, 1.1, and 0.21 pCi/g, respectively. A maximum $^{89,90}Sr$ concentration of 0.96 pCi/g was detected at the 25-mile-radius locations. The maximum "general" onsite $^{89,90}Sr$ concentration was 0.94 pCi/g. These values are within ranges observed in previous years.

The average of the tritium concentrations in the free water obtained from freeze-drying vegetation collected at the onplant sample locations at F- and H Areas was 42 pCi/mL compared to 4.8 pCi/mL at the plant perimeter stations, 3.2 pCi/mL at 25-mile-radius stations and 0.65 pCi/mL at 100-mile-radius stations. Maximum tritium concentrations ranged from 160 pCi/mL at an H-Area onplant location, 32 pCi/mL at a plant perimeter location, 11 pCi/mL at a 25-mile-radius location, and 4.6 pCi/mL at the Greenville, SC 100-mile-radius sample location. Maximum and average concentrations for 1988 are similar to those seen in 1987.

Only tritium concentrations in the vegetation samples collected at the F- and H-Area sampling locations show considerable differences when compared to plant perimeter, 25-, and 100-mile-radius locations. Figure 8-1 compares the average maximum and average onplant, plant perimeter, 25-, and 100-mile-radius concentrations.

In addition to the locations mentioned previously, vegetation samples were collected around seepage and retention basins located near the reactor and separations areas. Samples from four to eight locations outside the fence of each basin were composited for measurements of alpha, nonvolatile beta, and $^{89,90}Sr$ concentrations. The alpha and nonvolatile beta concentrations were near the levels observed offsite with maximums of 0.21 and 41 pCi/g, respectively. The maximum seepage basin vegetation concentration of $^{89,90}Sr$ was 17 pCi/g at the H-Area Seepage Basin. These data indicate general confinement of radioactivity within the basins. Seepage and retention basin vegetation monitoring results are presented in Table 8-6, Vol. II.

Vegetation samples were also collected inside the RWBG to determine whether significant uptake of radioactivity by vegetation from buried waste had occurred. Vegetation was collected from a relatively large area at 51 locations inside the RWBG and analyzed individually for annual analyses. This collection method provides coverage of a large part of the facility, yet keeps the number of samples to a minimum. Sample locations are shown in Figure 8-2, Vol. II; data are presented in Table 8-7, Vol. II.

The RWBG samples were analyzed for alpha-, nonvolatile beta-, and gamma-emitting radionuclides. Vegetation samples from RWBG sampling locations 9A, 10, and 24 contained radioactive concentrations which were above ambient levels. The elevated levels at locations 9A and 10 were nonvolatile beta concentrations of 328 pCi/g and 99 pCi/g, respectively. The ^{137}Cs concentration at location 9A was 4.5 pCi/g, which was higher than normally reported levels. The maximum concentrations observed at location 24 were 2.6 pCi/g alpha, 4,097 pCi/g nonvolatile beta, and 4 pCi/g of ^{137}Cs. Locations 9 and 10 have a history of contaminated vegetation. In 1965, contaminated vegetation with concentrations of up to 7.4×10^{6} pCi/g of $^{89,90}Sr$ was found near locations 9 and 10. Soil core samples at that time indicated up to 7.7×10^{7} pCi/g of nonvolatile beta (primarily $^{89,90}Sr$) within 2 ft of the surface of the ground. The area has been cleared of vegetation and treated with a herbicide several times. This removal considerably decreased the radioactive concentrations at these locations as the 1988 concentration levels indicate.

Vegetation samples were also collected quarterly outside of RWBG fences. Vegetation sampling loca-

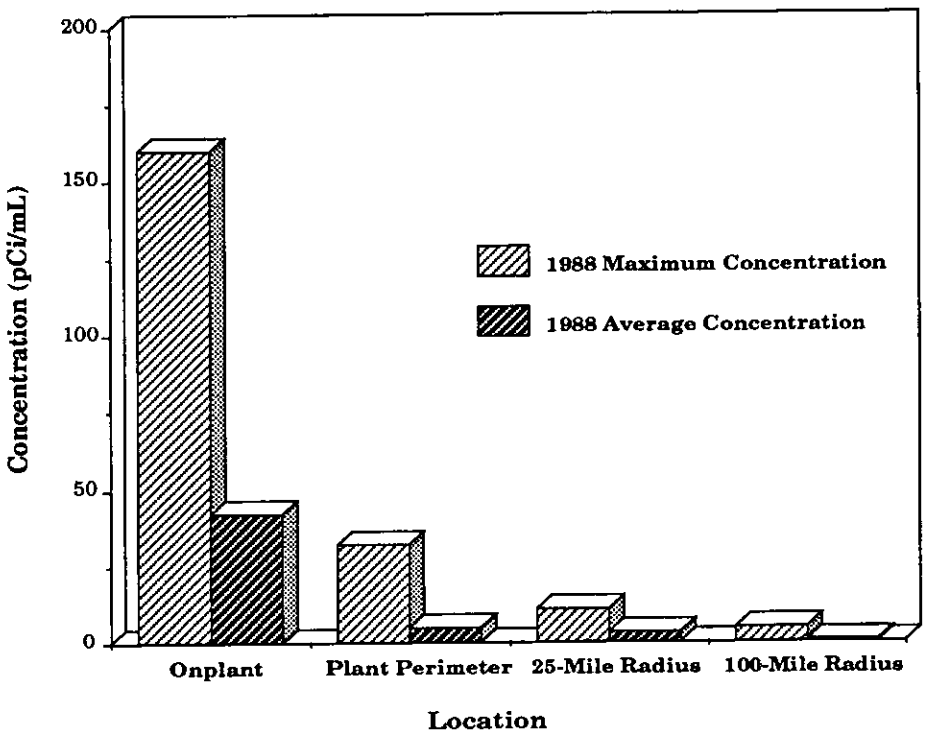


Figure 8-1. Comparison of 1988 tritium concentrations in vegetation at various locations on-and offsite

tions outside the RWBG are shown in Figure 8-3, Vol. II. The average alpha and nonvolatile beta concentrations were 0.40 and 16 pCi/g, respectively. These concentrations are higher than the 1987 average concentrations of 0.10 and 11 pCi/g, respectively. The higher average alpha concentration is attributed to the analysis correction for self-absorption. A maximum ^{137}Cs concentration of 13 pCi/g was detected at the BG 12 sampling location. In addition to ^{137}Cs, $^{141,144}Ce$ was the other gamma-emitting nuclide concentration in vegetation above the lower limit of detection analyzed from the BG 12 station. Both ^{7}Be and ^{40}K (naturally occurring radionuclides) were also detected. These surveys indicate control practices at the RWBG have been generally effective in preventing the spread of contamination from the facility. The surveys also indicate that vegetation sampling is an effective method of detecting the release of small quantities of radioactivity. Monitoring data are presented in Table 8-8, Vol. II.

Sediment

Description of Monitoring Program. Sediment samples have been collected annually at six locations in the Savannah River above, adjacent to, and below SRS since 1975 and at nine plant stream locations since 1977. The samples are collected at locations where maximum accumulation of radioactivity in the river and stream beds is expected. Collection techniques are designed to obtain samples from the top 8 cm of sediment in areas where fine sediment has accumulated. As a result, the samples are not representative of the entire stream bed. Sediment is analyzed for gamma-emitting radionuclides, ^{90}Sr, ^{238}Pu, and ^{239}Pu.

Monitoring Results. The analytical results for 1988 and a summary of results from 1975 to 1989 for both river and stream sediment samples are presented in Table 8-9, Vol. II. Concentrations of radioactivity in river sediment were within the ranges detected from worldwide fallout. Potassium-40, a naturally occurring radionuclide, and ^{137}Cs were the only gamma-emitting radionuclides routinely detected in river sediment. The maximum 1988 ^{137}Cs concentration detected in the river sediment was 0.74 pCi/g; the 1987 maximum was 0.62 pCi/g. Concentrations of naturally occurring ^{40}K were within ranges observed in previous years with a maximum of 21 pCi/g.

The maximum ^{90}Sr concentration in river sediment for 1988 was 0.25 pCi/g, as compared to a maximum of 0.06 pCi/g in 1987. The maximum sediment concentration of ^{239}Pu in 1988 was 0.009 pCi/g. Plutonium-238 concentrations were significantly higher in river sediment during 1988 than in 1987. The 1988 maximum concentration of 0.060 pCi/g was reported in a sediment sample taken in the Savannah River near the Highway 301 crossing. This concentration is greater than the maximum concentration of 0.002 pCi/g reported in 1987. The remaining radionuclide concentrations of river sediment are similar to those reported in 1987.

Results of stream sediment reflect contributions of radioactivity from SRS liquid releases. The maximum concentrations detected in stream sediment during 1988 were 18 pCi/g of ^{40}K, 262 pCi/g of ^{137}Cs, 6.3 pCi/g of ^{60}Co, 3.0 pCi/g of ^{90}Sr, 2.5 pCi/g of ^{238}Pu, and 0.76 pCi/g of ^{239}Pu. Two stream sediment loca-

tions had higher ^{238}Pu concentrations than those seen in previous years. The ^{238}Pu concentration of the Four Mile Creek A-7A (in Beaver Pond) sediment sample was 2.49 pCi/g, compared to 0.66 pCi/g in 1987. The concentration found in the Lower Three Runs mouth sediment was 0.264 pCi/g compared to 0.02 pCi/g in 1987. Three additional radionuclide concentrations, higher than those seen in previous years, were found in sediment from the Four Mile Creek A-7A location. Higher concentrations of ^{60}Co, ^{137}Cs, and ^{239}Pu were measured in 1988 sediment samples. The 1988 average concentrations were 6.3 pCi/g of ^{60}Co, compared to the average 0.9 pCi/g of ^{60}Co from 1977 to 1985; 18 pCi/g of ^{137}Cs, compared to 7.6 pCi/g in 1987; and 0.150 pCi/g of ^{239}Pu, compared to 0.046 pCi/g in 1987. The concentrations of alpha and novolatile beta in stream water collected near these locations were within concentrations seen in previous years. Concentrations in sediment may vary from year to year since the exact point at which a sample is collected in the stream may vary. The shifting of sediment, thus contaminants, may also cause variations in radionuclide concentrations.

1988 HIGHLIGHTS

- Nonvolatile beta deposition in rainwater was less than reported in 1987, with the maximum deposition ranging from 160 to 610 pCi/m^2, compared to the 1987 range of 516 to 2,755 pCi/m^2. The maximum deposition of 610 pCi/m^2 was observed at the 100-mile-radius station in Greenville, SC.
- In rainwater, alpha concentrations were less than 1987 concentrations and all ^{131}I results were less than the minimum detectable levels.
- Concentrations of ^{137}Cs and ^{90}Sr in soil at the plant perimeter and 100-mile radius are consistent with previous years and within concentrations observed from worldwide fallout.
- Soil plutonium concentrations detected at the SRS boundary and 100-mile-radius locations were near or less than the lower limit of detection. The maximum ^{238}Pu and ^{239}Pu soil concentrations in 1988 of 34 and 28 mCi/km^2 were detected in F Area, and are higher than the 1987 maximum concentrations of 8.8 and 11 mCi/km^2, respectively.
- In vegetation, naturally occurring ^{7}Be and ^{40}K were the major contributors to the beta-gamma activity, while the concentrations of ^{137}Cs and ^{90}Sr were within ranges observed in previous years.
- The average alpha and nonvolatile beta concentration in vegetation samples outside the RWBG fences were 0.40 and 16 pCi/g, respectively, and are higher than in previous years. The higher average alpha concentration is attributed to the self-absorption factor in the analysis.
- Concentrations of radioactivity in Savannah River sediment were within the ranges expected from worldwide fallout, while two stream sediment locations had higher ^{238}Pu, ^{239}Pu, ^{60}Co, and ^{137}Cs concentrations than those seen in previous years.

9
Special Surveys/Nonroutine Occurrences

SUMMARY—This chapter focuses on the sampling and analytical measures taken in the event of accidental releases of radioactive material at SRS, and on the special surveys and studies conducted to monitor the effects of the SRS effluents on the environment. In addition, the chapter describes oil and chemical spills that have occurred in 1988.

A short description of tritium biochemistry opens the chapter since routine and nonroutine atmospheric releases of tritium are responsible for 67% of the radiation dose to the maximally exposed individual at the plant perimeter. The nonroutine releases of radioactivity in 1988 include four incidents of atmospheric tritium release and four occasions of liquid tritium release, as well as eight incidents involving other radionuclides. All releases had no adverse impact on the general public or the environment.

The chapter also describes radiological surveys of Upper Three Runs Creek by the SRS Environmental Monitoring Section to document baseline data prior to the November 1988 startup of the Effluent Treatment Facility in H Area, surveys of the Savannah River Swamp, Lower Three Runs Creek, and R Area that have been done periodically because of contamination of these areas in previous years, and surveys by the Academy of Natural Sciences of Philadelphia of algae, macrophyte, insect, and fish communities of the Savannah River in the vicinity of the SRS conducted during 1988 which were continuations of long-term biomonitoring studies that have been conducted on the river since 1951.

Other special studies reported in the chapter include an ambient air study at Aiken Airport, measurements of ^{129}I in groundwater and surface water, and surveys of dry monitoring wells in F- and H-Area waste management facilities.

An environmental data exchange has been instituted by representatives from the South Carolina Department of Health and Environmental Control, the Georgia Department of Natural Resources, the Georgia Power Company, the Department of Energy, the Savannah River Laboratory, and the Savannah River Site.

RADIOLOGICAL SURVEYS

Atmospheric and liquid releases of radioactivity to the environment from SRS operations during 1988 have resulted in a dose of 0.46 and 0.79 mrem, respectively, to the maximum exposed individual. The exposure calculation is derived from the measured amounts of routine and nonroutine releases of radioactivity from the production and research facilities. This section discusses the sampling and analytical measures taken in the event of a nonroutine radioactive release as well as the special surveys (long term and short term) conducted to monitor the effects of the SRS effluents on the environment.

During nonroutine releases of radioactivity, special environmental surveys are performed to determine any potential risk to the public. Special surveys of process air, process water, vegetation, stream and river water, soil, and ambient air are conducted. These special samples are placed into the analysis system as priority samples. Estimates of the magnitude of all nonroutine releases are then evaluated based on the analytical results.

In addition to routine sampling and special sampling due to nonroutine environmental releases, the SRS Environmental Monitoring Section performed three major on- and offsite surveys during 1988. The purpose of these surveys was to evaluate radioactivity levels in the environment at SRS and in its immediate vicinity. Selected locations were chosen to collect soil, vegetation, and water samples, while thermoluminescent dosimeters (TLDs) were placed at additional monitoring station locations.

Tritium in the Environment

Routine and nonroutine atmospheric releases of tritium are responsible for 67% of the radiation dose to the maximum exposed individual at the plant perimeter and 76% of the dose to the population within 80 km of the plant boundary. Tritium may be present in a variety of chemical forms including oxide (HTO, T_2O), elemental (HT, T_2), or as tritium-containing organic substances. Because of its chemical similarity to a water molecule, tritium oxide is more readily assimilated into environmental media and human tissues than either the elemental or organic form. The organic forms represent less than 1% of the tritium releases from SRS.

Tritium has a physical half-life of 12 years. The low-energy beta particle emitted by tritium during decay will penetrate only 0.013 cm of human tissue. As an elemental gas, tritium is nearly biologically inert and constitutes relatively little hazard. The weak beta particle is completely attenuated by the inert external skin layer (epidermis) and only 0.004% of elemental tritium inhaled is converted to oxide and retained in the body [NCRP79].

Almost all of the oxide form (water vapor) inhaled is absorbed in the lungs and enters the body water pool, thereby exposing all body tissues. In addition, approximately one-half as much tritium oxide is absorbed through the skin as is absorbed in the lungs by inhalation [ICRP79]. The half-life for biological removal of tritium oxide from the body is approximately 10 days.

Both tritium oxide and elemental tritium are released to the atmosphere during routine operation of the tritium facilities. The reactor facilities also release tritium, but this tritium is primarily in the oxide form. Because hydrogen in tritium oxide readily exchanges with hydrogen in other materials (such as water), low-level concentrations are routinely detected in the SRS environment. The average of all atmospheric tritium released from SRS facilities in 1988 was approximately 1,240 Ci per day, representing a 21% decrease compared to 1987. Tritium oxide comprised approximately 62% of the total amount of tritium released to the atmosphere in 1988.

All of the tritium released to SRS streams is in oxide form. The average of all liquid release of tritium from SRS sources in 1988 was approximately 53 Ci per day compared to approximately 62 Ci per day in 1987. A steady decline in the amount of tritium released from plant sources is shown in Figure 9-1.

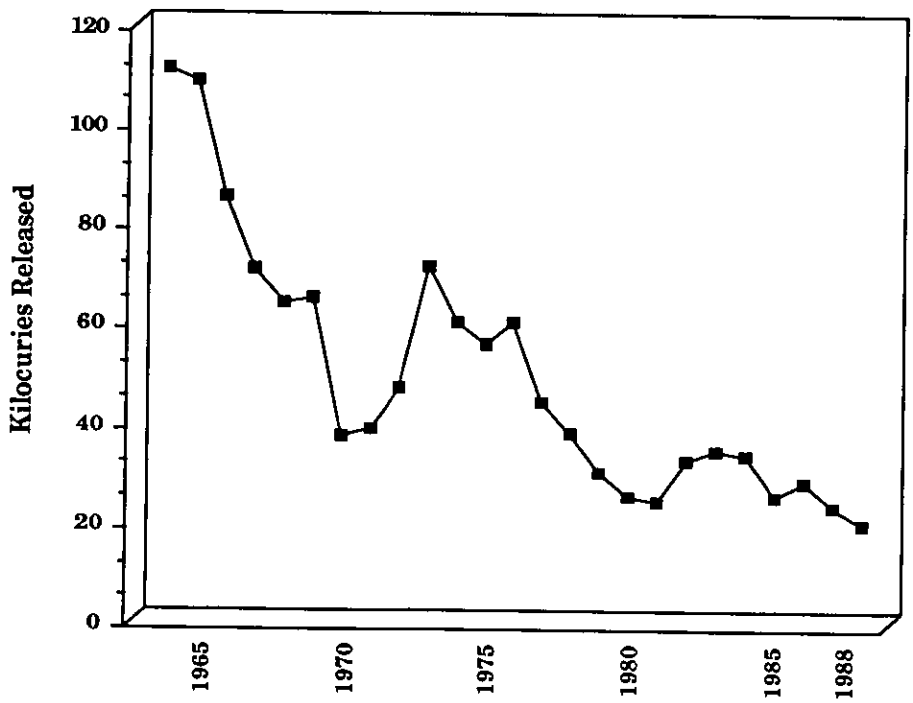


Figure 9-1. Tritium released from SRS

Special environmental surveys were conducted when eight short-term tritium releases occurred in 1988. The surveys were used to determine whether the releases carried a significant risk of detriment to the public health or to the environment.

Atmospheric Tritium Releases

Atmospheric Tritium Release on March 1, 1988. On March 1, 1988, approximately 20,000 Ci of tritium was released to the atmosphere from an H-Area tritium facility. Approximately 15% of the tritium released was in the oxide form (HTO) and 85% was elemental tritium (HT). The maximum calculated dose to an individual at the site boundary from this release was 0.04 mrem (0.0004 mSv).

The TRAC (Tracking Radioactive Atmospheric Contaminants) van, SRL's mobile laboratory, responded to the release and seven air samples were collected at locations approximately 100 miles southwest of SRS in the vicinity of McRae, GA. Additional air samples were collected along the intersection of US 221 and I-16, west of the TRAC van sampling locations. The tritium concentrations in air ranged from <3.6 to 85.7 pCi/m^3 of HT and <4.3 to 79.6 pCi/m^3 of HTO.

Additional special environmental sampling was conducted downwind from the release, along the intersection of Roads A-13 and A-13.2. Following is a summary of special sampling results:

Type of Sample	Number Collected	Tritium (pCi/mL) Maximum	Minimum
Vegetation	5	42.68 ± 1.02	17.10 ± 0.39
Standing Water	1	8.28 ± 1.46	–

Atmospheric Tritium Release on June 7, 1988. On June 7, 1988, approximately 3,650 Ci of tritium was released to the atmosphere from an H-Area tritium facility. Approximately 96% was released as elemental tritium (HT) and 4% of the tritium was released in oxide form (HTO). The maximum calculated dose to an individual at the plant boundary from this release was 0.001 mrem (0.00001 mSv).

Additional special environmental sampling was conducted downwind from the release point, along Road 8 on a seven mile stretch from Par Pond to the Darkhorse air monitoring station. Following is a summary of special sampling results:

Type of Sample	Number Collected	Tritium (pCi/mL) Maximum	Minimum
Vegetation	8	23.20 ± 1.41	6.50 ± 0.99

Atmospheric Tritium Release on October 6, 1988. On October 6, 1988 approximately 7,000 Ci of tritium was released to the atmosphere from an H-Area tritium facility. Approximately 10% of the tritium was in the oxide form (HTO) and 90% was elemental tritium (HT). The maximum dose to an individual at the site boundary from this release was 0.02 mrem (0.0002 mSv).

Additional special environmental sampling was conducted downwind from the release point, in the vicinity of C and D Areas. Following is a summary of special sampling results:

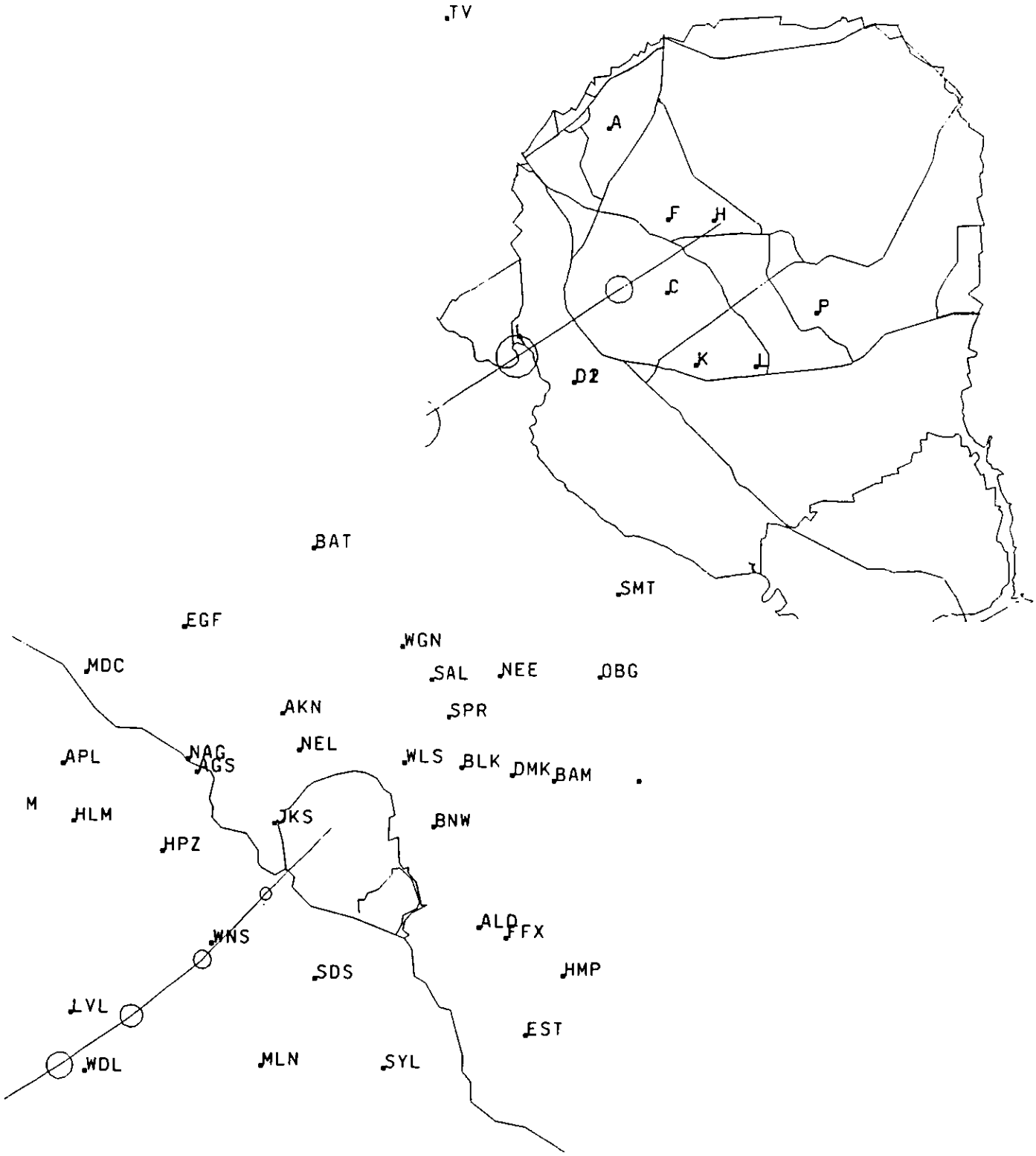
Type of Sample	Number Collected	Tritium (pCi/mL) Maximum	Minimum
Vegetation	11	67.52 ±1.26	7.26 ± 1.13
Standing Water	7	19.10 ±0.82	2.56 ± 0.59

Tritium concentrations were within routine on- and offsite sample concentrations observed in previous years.

Atmospheric Tritium Release on December 7, 1988. On December 7, 1988, 3,500 Ci of tritium was released to the atmosphere from an H-Area tritium facility. Approximately 99.5% of the 3,500 Ci was tritium oxide (HTO) and 0.5% of the release was in elemental tritium (HT) form. The maximum calculated offsite dose to an individual at the plant boundary was 0.2 mrem (0.002 mSv) (see Chapter 2).

Additional special environmental sampling was conducted downwind from the release point, along Road 8 from 4 miles southwest of the Darkhorse air monitoring station to the plant perimeter. Following is a summary of special sampling results:

Type of Sample	Number Collected	Tritium (pCi/mL) Maximum	Minimum
Vegetation	5	77.2 ± 1.7	7.2 ± 1.7
Standing Water	1	16.9 ± 2.3	–



Movement of tritium cloud as predicted by the WIND System During the October 6, 1988 tritium release

Liquid Tritium Releases

Liquid Tritium Release Between October 1 and October 14, 1988. Between October 1 and October 14, 1988, 15.3 Ci of tritium was released to Par Pond via the P-Area Process Sewer. The release estimate was based on tritium concentration analyses of continuous process sewer samples, and the reported effluent flow rate.

Liquid Tritium Release on November 17, 1988. On November 17, 1988, 111.9 Ci of tritium was released to Pen Branch Creek via the K-Area Process Sewer. The tritium release estimate was based on samples collected from a continuous Brailsford pump sampler on Pen Branch, and USGS flow rates.

Liquid Tritium Release on December 16, 1988. On December 16, 1988, approximately 0.09 Ci of tritium was released to Par Pond from the P-Area Process Ssewer. The release estimate was based on a tritium concentration analysis of a 24 hour process sewer sample, and the reported effluent flow rate.

Liquid Tritium Release on December 30, 1988. Between December 30, 1988 and January 1, 1989, approximately 70 Ci of tritium was released to Pen Branch via the K-Area Process Sewer. The tritium release was based on continuous samples collected daily from the process sewer, and the reported effluent flow rate.

Other Radionuclide Releases

F-Area Atmospheric Plutonium Release. On January 15, 1988, approximately 160 μCi of ^{238}Pu was released to the atmosphere from an F-Area laboratory facility. The release occurred during a filter change in the 772-F laboratory.

Health Protection field survey results indicated that the deposition of particulate radioactivity spanned approximately 50 meters west-southwest of the F-Area southwest fence. Results from special vegetation samples collected downwind of the release point confirmed this deposition location as within the general vicinity of the F-Area fence. Normal levels of alpha concentrations were measured from air filters collected from the plant perimter sampling stations.

F-Area Atmospheric Uranium Release. On March 15, 1988, approximately 135 μCi of uranium was released to the atmosphere from an F-Area facility. The isotopic composition of the uranium was approximately 89% ^{238}U and 8% $^{234,235}U$. The release occurred during maintenance work on a valve in an F-Area uranium reclamation facility.

No significant increase in alpha activity in ambient air downwind of the F-Area stack was detected. Vegetation samples collected downwind of the stack also indicated no increase in alpha activity from the ranges observed in previous years.

F-Area Atmospheric Plutonium Release. On March 16, 1988, approximately 32 μCi of plutonium was released from an F-Area facility. The release occurred as repair work was being performed on a vacuum system in a contaminated shielded service area.

Special air and vegetation samples collected downwind from the release point showed no increase in alpha activity from the ranges observed in previous years.

H-Area Retention Basin Liquid Discharge. On July 8, 1988, wastewater containing 27 mCi of ^{137}Cs was inadvertently released from the 281-8H Retention Basin to Four Mile Creek. Water samples were taken upstream and downstream of the retention basin release point. Samples taken downstream of the release point (Four Mile Creek 2) indicated elevated ^{137}Cs activity on July 9, 1988.

Results from stream sampling locations FM-2 and FM-6 (at Road A) are given in Table 9-1, Vol. II. According to SRL analyses, ^{137}Cs concentrations in the Savannah River remained within previously observed levels both during and after the release.

Samples of water pumped from the retention basin to the H-Area Seepage Basin subsequent to the release were analyzed for hazardous metals (barium, chromium, lead, mercury, and silver) by the Savannah River Laboratory to determine levels of these metals in the retention basin water. All analyzed metal concentrations were below RCRA limits.

F-Area Liquid Release to Four Mile Creek. On August 1, 1988, approximately 125 gallons of contaminated water was pumped to Four Mile Creek. The contamination level in the water released was approximately 20 dpm/mL of nonvolatile beta activity. Four Mile Creek stream samples taken downstream of the release revealed no elevated nonvolatile beta concentrations above 1987 ranges of 10.23 pCi/L to 80.48 pCi/L.

Liquid Release to Upper Three Runs Creek. On September 29, 1988, approximately 0.031 mCi of alpha activity was released to Upper Three Runs Creek as a result of water pumped from an evaporator apron into a storm drain. Following the reporting of slightly elevated concentrations of alpha activity in the F-Area effluent outfall to Upper Three Runs Creek, Environmental Monitoring collected special samples of stream water from three continuous samplers on Upper Three Runs Creek (U3R-2, U3R-F3, U3R-3). Alpha activity levels in these samples were within ranges seen in previous years.

F-Area Atmospheric Plutonium Release. During October 1988, approximately 83 mCi of ^{238}Pu was released to the atmosphere from the F-Area laboratory facility. Health Protection field survey detected alpha contamination within a 200 ft radius of the building's exhaust stack. Ambient air filters, routine water samples, and vegetation samples collected outside the F-Area fence were within normal activity levels.

H-Area Concentrate Transfer System (CTS) Atmospheric Release. On November 24, 1988, an estimated 10 mCi of ^{137}Cs was released from the H-Area Concentrate Transfer System (CTS) tank exhaust. A HEPA filter breakthrough during startup of an H-Area waste evaporator was the cause of the release. Ambient air samples were collected downwind from the release point (at the Burial Ground South and 400-D air monitoring stations). In addition, water samples were collected from the H-Area effluent surface water drainage location. Analyses of these samples revealed activity levels within normal ranges.

Upper Three Runs Special Survey

Description of Monitoring Program. A radiological survey of Upper Three Runs Creek was completed by Environmental Monitoring in October 1988. The purpose of the survey was to determine and document baseline data prior to the November 1988 startup of the Effluent Treatment Facility (ETF) in H Area. Creek bank and floodplain soil samples, tree (timber) samples, and vegetation samples were collected and environmental gamma radiation measurements were taken at six monitoring locations along the Upper Three Runs Creek, shown in Figure 9-1, Vol. II. The monitoring locations begin approximately three miles above the ETF effluent outfall at Road F, into Upper Three Runs Creek and extended approximately 6.5 miles downstream to within approximately 100 yards of the Savannah River. Future surveys at these locations will continue on a routine basis.

Monitoring Results. Twenty-four soil samples were collected from both the floodplain and creekbed along Upper Three Runs Creek and analyzed for gamma-emitting nuclides. The average concentration of ^{137}Cs was 1.06 pCi/g. The maximum concentration of ^{137}Cs was 8.11 pCi/g in a sample collected at the north side floodplain of Upper Three Runs above the ETF outfall. Plutonium-238 concentrations ranged from 3.60 fCi/g to 76.9 fCi/g, and ^{239}Pu concentrations ranged from 1.65 fCi/g to 233 fCi/g. Twenty-four vegetation and eight timber samples were collected at similar sampling points along the six Upper Three Runs Creek monitoring locations. Tritium, strontium, and ^{137}Cs (gamma PHA) analyses were performed on all vegetation samples, while tritium and ^{137}Cs were performed on the timber samples. Tritium concentrations in vegetation ranged from 1.32 pCi/mL to 56.32 pCi/mL, while tritium in timber ranged from 3.2 pCi/mL to 12.12 pCi/mL. Cesium-137 concentrations in vegetation ranged from 0.00 ± 0.60 pCi/g to 15.49 pCi/g, while concentrations in timber ranged from 0.00 ± 0.26 pCi/g to 0.75 pCi/g. Strontium concentrations in vegetation ranged from 0.00 ± 0.37 pCi/g to 3.69 pCi/g. Higher radioactivity concentrations in vegetation and soil samples were found at the upstream monitoring locations. Environmental gamma radiation measurements were made at each of the six transect locations. The highest exposure measurement was 0.31 mR/day made at location 5. Fish, clams, and snails were also collected from five of the six transect locations. All results from the Upper Three Runs Creek survey are provided in Tables 9-2, 9-3, 9-4, 9-5, and 9-6, Vol. II.

Savannah River Swamp Survey

Description of Monitoring Program. The Savannah River Swamp, between Steel Creek and Little Hell Landing, was contaminated with approximately 25 Ci of ^{137}Cs and less than 1 Ci of ^{60}Co in the 1960s. The contaminated swamp area extends beyond the SRS site boundary to private property known as Creek Plantation. The offsite swamp area is uninhabited and inaccessible except for possible occasional hunting or fishing.

The sources of the contamination were a result of failed fuel elements that leaked radioactivity into storage basin water used to shield and cool irradiated fuel elements. Over time, portions of the fuel storage

TLDs were placed at 10 locations for the 1988 Savannah River Swamp cursory survey

basin water containing the ^{137}Cs and ^{60}Co were discharged to Steel Creek. The radioactivity settled in the swamp during periods when Steel Creek flowed across the swamp before entering the river at Little Hell Landing. The failed fuel elements were removed from P-Area fuel storage basins in 1970.

Ten sampling trails were established in the swamp in 1974 so that specific locations could be repetitively monitored to determine the amount of radioactivity and migration of radioactivity in the Creek Plantation swamp as a result of the 1960s contamination incident. (Figure 9-2, Vol. II).

Comprehensive surveys were made annually along the trails between 1974 and 1977. These comprehensive surveys included TLD gamma radiation measurements and analysis of vegetation, soil, and fish samples. The frequency of comprehensive surveys was reduced to five-year intervals after 1977 because the surveys indicated no significant changes in radiological conditions. Interim monitoring was provided by annual TLD measurements along the 10 transects. A routine comprehensive survey was conducted in 1982. Another comprehensive survey was performed in 1985 during construction of L Lake. Cursory surveys were performed in 1986, 1987, and 1988.

The following tasks were performed during the 1988 cursory survey:

- Soil core samples were collected at selected locations along Trails 1, 5, and 10, and analyzed for gamma-emitting radionuclides, ^{90}Sr, ^{238}Pu, and ^{239}Pu.
- Vegetation samples were collected at the same locations as the soil samples, and were analyzed for gross alpha and gamma-emitting radionuclides.
- TLDs were placed 1 m above ground at routine identified locations along the 10 trails to measure environmental gamma radiation.
- Fish were collected from two of the three lakes in close proximity to the swamp trails and analyzed for ^{137}Cs. Boggy Gut Lake is normally sampled but was dry in 1988.

Monitoring Results. Soil core samples, collected at selected locations, were analyzed for gamma-emitting radionuclides, ^{90}Sr, ^{238}Pu, and ^{239}Pu. Analytical data are presented in Tables 9-7, and 9-8, Vol. II. Cesium-137 was the only gamma-emitting radionuclide detected. The concentrations of ^{137}Cs in soil were within ranges observed during the last several years and showed a maximum of 179 pCi/g. Strontium-90 concentrations in soil showed a maximum of 0.08 pCi/g and were within ranges observed in previous years. The maximum ^{238}Pu and ^{239}Pu concentrations in soil were 0.029 and 0.067 pCi/g, respectively. Concentration of radionuclides in soil vary from year to year and from sample to sample because of slight differences in sampling locations and the non-homogeneity of soil.

Vegetation samples were also collected along Trails 1, 5 and 10 and analyzed for alpha- and gamma-emitting radionuclides. Gross alpha concentrations were within the ranges observed in previous years and showed a maximum of 0.70 pCi/g. Alpha concentration results are presented in Table 9-9, Vol. II. The only gamma-emitting radionuclides detected in vegetation were ^{137}Cs and naturally occurring ^{40}K. Cesium-137 concentrations were within the ranges detected in previous surveys. The maximum ^{137}Cs and ^{40}K concentrations were 45 pCi/g and 29 pCi/g

respectively. Cesium-137 and ^{40}K sample concentration results are presented in Table 9-10, Vol. II.

Environmental gamma radiation measurements were made by placing dosimeters 1 m above the ground at previously identified locations along the trail. The dosimeters were collected for processing after an exposure period of approximately 30 days. The 1988 results ranged from 0.17 to 0.88 mR/day and were in agreement with data from previous years. TLD gamma radiation measurement results are presented in Table 9-11, Vol. II.

Fish were collected from two of the three lakes near the swamp trails. Concentrations of the four fish collected were within ranges observed during previous years and are presented in Table 9-12, Vol. II. The maximum ^{137}Cs concentration was 1.3 pCi/g in a sucker fish from Cannuck Lake. The maximum ^{137}Cs concentration in the 28 fish collected from the River-2 control location upriver of SRS was 1.2 pCi/g. Concentration results from the 28 control fish collected upriver of SRS are also presented in Table 9-12, Vol. II.

Radionuclides detected and their concentrations were consistent with results from previous Savannah River Swamp surveys. No new migration of the radionuclides analyzed was detected from the 1988 survey results.

Lower Three Runs Radiological Survey

Description of Monitoring Program. Before the construction of Par Pond, the R-Area radioactive liquid effluents were discharged directly into Lower Three Runs (L3R) Creek. Several surveys have been conducted to monitor the area for radioactivity.

During the initial L3R surveys in 1971 and late 1982, 11 stations were established in L3R Creek to collect samples for radiological analysis. Two additional stations were established in 1982 on the Savannah River below the mouth of L3R. Sample locations are shown in Figure 9-3, Vol. II. Results from the 1988 survey are compared with appropriate results obtained in 1971 and 1982.

The following tasks were performed during the 1988 Lower Three Runs Survey:

- Soil composites were collected from the L3R floodplain and analyzed for gamma-emitting radionuclides and plutonium.
- Semi-aquatic and aquatic vegetation samples from the creek and leaf stem composites from trees in the floodplain were collected and analyzed for gamma-emitting radionuclides, tritium, total strontium, gross alpha, and nonvolatile beta.
- Fish were collected from Stations 1, 5, 10, and 11 and analyzed for gamma-emitting radionuclides.
- Clams, snails, and turtles were collected at several stations and analyzed for gamma-emitting radionuclides.
- Gamma radiation was measured at 10 m intervals along both sides of the creek bank to high ground. Measurements were made about 1 in. above the surface of the ground with a portable Ludlum Gamma-Scintillometer Model-3.
- TLDs, which measured environmental gamma radiation, were positioned 1 m above ground at routine identified locations on the stream bank, in the floodplain (midway between the stream and high ground), and on high ground near the floodplain. The TLDs were exposed for approximately one month.

Monitoring Results. Measurable concentrations of ^{137}Cs were detected in sediment-soil samples from the L3R stream bed and floodplain locations. Overall, soil from the floodplain had higher concentrations of ^{137}Cs than stream bed soil. The average of the maximum concentrations of ^{137}Cs in the stream bed was 6.86 pCi/g compared to 29 pCi/g in the 1982 survey. The average of the maximum concentrations of ^{137}Cs on the floodplain was 52.7 pCi/g, compared to 28.4 pCi/g in 1982. The stream bed and floodplain sediment/soil ^{137}Cs concentration results are provided in Table 9-13, Vol. II.

Five soil composites from each of the three stations 1, 5, and 6 on the L3R floodplain were analyzed in triplicate for ^{238}Pu and ^{239}Pu. Core samples taken from the stream bed at the same locations in 1988 were also analyzed for ^{238}Pu and ^{239}Pu. The average of the mean concentrations of ^{238}Pu in the floodplain along the three stations was 0.013 pCi/g compared to 0.009 pCi/g in 1982. The average of the mean concentrations of ^{239}Pu in the floodplain was 0.027 pCi/g compared to 0.042 pCi/g in 1982. The 1988 mean ^{238}Pu concentrations in the stream bed averaged 0.0138 pCi/g and 0.0137 pCi/g of ^{238}Pu. Analyses of ^{238}Pu and ^{239}Pu in the stream bed sediment-soil were

not performed in previous surveys. The stream bed and floodplain sediment/soil ^{238}Pu and ^{239}Pu concentration results for 1982 and 1988 are shown in Table 9-14, Vol. II.

Five samples of chips from saw timber growing at each station were checked for gamma-emitting radionuclides and tritium. Cesium-137 was found in all samples analyzed, with the highest concentrations in 1988 found in tree samples from Stations 5 and 7. The maximum concentration of 42 pCi/g was detected at Station 7. The averages of the maximum ^{137}Cs concentrations at the 13 stations in the 1982 and 1988 surveys were 14.5 pCi/g and 9.01 pCi/g, respectively. Tritium concentrations in the 1988 survey were similar to concentrations observed in the 1982 survey. The average of the maximum tritium concentrations in timber in the 1988 survey was 2.69 pCi/g compared to 2.95 pCi/g in 1982. Concentrations of gamma-emitting radionuclides were at or near background levels in trees sampled at Stations 11, 12 and 13. Analysis results for ^{137}Cs and tritium concentrations in timber for 1982 and 1988 are shown in Table 9-15, Vol. II.

A comparison of leaf-stem composites in Table 9-16, Vol. II shows lower measurements of tritium in 1988 than in 1982. Total strontium was the predominant radionuclide found in the leaf-stem composites, where the maximum concentration was 285 pCi/g; no analyses of strontium in leaf-stem composites were performed in 1982.

Samples of rooted semi-aquatic and aquatic vegetation were analyzed for gamma-emitting radionuclides, gross alpha, tritium, total strontium, and nonvolatile beta. These data are reported in Table 9-17, Vol. II. The predominant nuclide found in the aquatic vegetation was ^{137}Cs with a maximum concentration of 83 pCi/g.

Gamma radiation measurements were made at all stations in 1988. The floodplain was monitored perpendicular to the east and west sides of L3R Creek with a portable gamma-scintillometer. Radiation measurements for 1982 and 1988 provided in Table 9-18, Vol. II show that overall differences in radiation levels are insignificant. The range of radiation levels varies from 5 to 70 μR/hr. The highest average radiation levels in 1988 were observed at Stations 3, 6, and 8.

The TLD readings taken on the stream bank, in the floodplain and on high ground are shown in Table 9-19, Vol. II. The average radiation dose measured at high ground sites was 77 mR/year (0.21 mR/day). The maximum measurement of 266 mR/year (0.73 mR/day), was made at Station 6 in the floodplain.

Invertebrates, such as clams and snails, are sedentary filter-feeders and concentrate radionuclides present in the water and/or planktonic matter. Clams and snails were collected at Stations 2, 5, 9 and 11 in 1988 for analysis and comparison with earlier results. Low levels of ^{137}Cs were detected in both surveys. The maximum ^{137}Cs concentration in clams was 0.63 pCi/g (wet weight). The maximum ^{137}Cs concentration in snails was 0.99 pCi/g (wet weight). Most results agree with the 1982 survey, and show lower levels of ^{137}Cs than detected in the 1971 survey. Survey results of ^{137}Cs concentrations in clams and snails are shown in Table 9-20, Vol. II.

Fish were trapped at Stations 1, 5, 10, and 11 and analyzed for gamma-emitting radionuclides. Average ^{137}Cs concentrations in the 1988 survey ranged from 1.0 pCi/g (wet weight) to 4.9 pCi/g (wet weight). Cesium-137 concentrations in 1988 were similar to the 1982 survey results and generally lower than the 1971 survey results. Cesium-137 concentrations in fish are presented in Table 9-21, Vol. II.

Two turtles were collected at Stations 5 and 10 and analyzed for radionuclides. Cesium-137 concentrations were slightly less at Station 5 in 1988 than in 1982 and slightly higher at Station 10. Analysis results of ^{137}Cs in turtles are presented in Table 9-22, Vol. II.

R-Area Comprehensive Survey

Description of Monitoring Program. The failure of an experimental fuel element in the 105-R emergency basin in November 1957 resulted in discharges of radioactivity to a series of excavated seepage basins north of R Area. It was estimated that approximately 200 Ci of strontium and 1,000 Ci of cesium were released to the basins. Since that time, the Health Protection Department has routinely monitored the area, and numerous special surveys and sampling have been conducted. In 1986 the fourth comprehensive survey of the 100-R seepage basin system since 1957, and the first comprehensive survey in 10 years, was conducted. The survey was conducted to identify any new areas of contamination, and to monitor for any outcropping of activity from the basins.

The extensive monitoring program included collection of vegetation, soil cores, stream water, and stream sediment samples. In addition, dry monitoring wells were surveyed, and groundwater samples were analyzed for radioactivity as well as various water quality parameters. Environmental radiation levels were determined from TLD readings. The sampling scheme was designed to be both comprehensive and representative of the R-Area Seepage Basin environment.

Monitoring Results. Analyses of results indicated that, at basin levels, no horizontal migration of radioactivity had occurred from the basins. Except for strontium, no significant vertical migration was detected. In addition, no outcropping of radioactivity from the basins to Mill Creek, which flows from the area to Upper Three Runs Creek, was discovered. Monitoring data for R-Area Seepage Basin and Sewer Line vegetation, and for Mill Creek sediment cores are presented in Tables 9-23 and 9-24, Vol. II.

R-Area Old and New Canal Survey

Description of Monitoring Program. Two special surveys were conducted in 1987 at the "old" and "new" R-Area canals. The results of these surveys were reported in 1988. Both sampling plans included cursory radiation readings using thyac instruments, collection of soil core samples for analysis, and TLD gamma radiation measurements. The old canal sampling scheme was patterned after a similar survey performed in 1976. The new canal survey was part of Environmental Monitoring's periodic special sampling of the R-Area canal system. It included sampling at the new R-Area effluent canal, as well as Pond A.

Monitoring Results. Other than naturally occurring ^{40}K, the only detectable gamma ions measured in old canal soil were ^{60}Co and ^{137}Cs. The maximum ^{60}Co concentration, 9.00 pCi/g, was near the lower limit of detection. The average ^{137}Cs concentration was 68.7 pCi/g, with a maximum of 400 pCi/g measured 700 m from the diversion box along the old canal.

TLDs were placed along the old canal bottom, at the north side of the canal, and 100 m north of the canal. The average reading, 0.29 mR/day, was similar to levels observed during routine R Area monitoring and observed at various onplant sites. The maximum reading, 1.34 mR/day, was measured by a TLD placed 100 m north of the canal, 900 m from the diversion box.

Cesium-137 concentrations from the new R-Area effluent canal soil ranged from the lower limit of detection to 232 pCi/g. The maximum result was detected in the canal, 1,200 m from the diversion box. The average ^{137}Cs concentration from new canal soils was 55.7 pCi/g. The maximum ^{137}Cs concentration measured at Pond A was 28.7 pCi/g, collected at the south side of the pond. Total strontium measurements in the canal ranged from 0.06 pCi/g to 0.56 pCi/g, with an average of 0.26 pCi/g. The maximum strontium concentration, 0.35 pCi/g was measured in a sample at the Pond-A inlet.

TLDs were placed on stands 1 m above ground in the new canal (which is dry), and at the edge of the canal. Measurements ranged from 0.19 mR/day to 1.23 mR/day, with an average of 0.42 mR/day. The higher exposure levels were measured in the canal; TLDs placed at the canal edge were within routine ranges seen at onplant stations. R-Area canal survey results are presented in Tables 9-25, 9-26, and 9-27, Vol II.

Low-Level Gamma Analysis of River Water

Environmental sampling and analysis of ^{137}Cs in the Savannah River continued in 1988. Cesium-137 was detected by SRL both upriver and downriver of SRS using a special low-level analysis technique, which consists of sampling large volumes of water and measuring the radioactivity in a low-background counting facility. The continuous sampler typically processes 300 to 500 L of water per week. Cesium-137 in the water is selectively concentrated on ion exchange material and counted for approximately 16 hours on an HPGe detector in a low-background counting facility. The special low-level ^{137}Cs data are presented in Table 9-28, Vol. II. A graph of all data collected since 1983 is shown in Figure 9-2 (Figure 9-4, Vol. II).

In 1988, ^{137}Cs concentrations upriver of SRS (Shell Bluff) averaged 0.004 pCi/L. The downriver (Highway 301) concentrations averaged 0.076 pCi/L. The difference between the upriver and downriver concentrations is attributed to releases from SRS operations. Annual average ^{137}Cs concentration in drinking water, collected downriver of SRS, results in a dose of less than 0.003 mrem/year, which is 0.075% of the 4 mrem/year limit from the liquid pathway (drinking water).

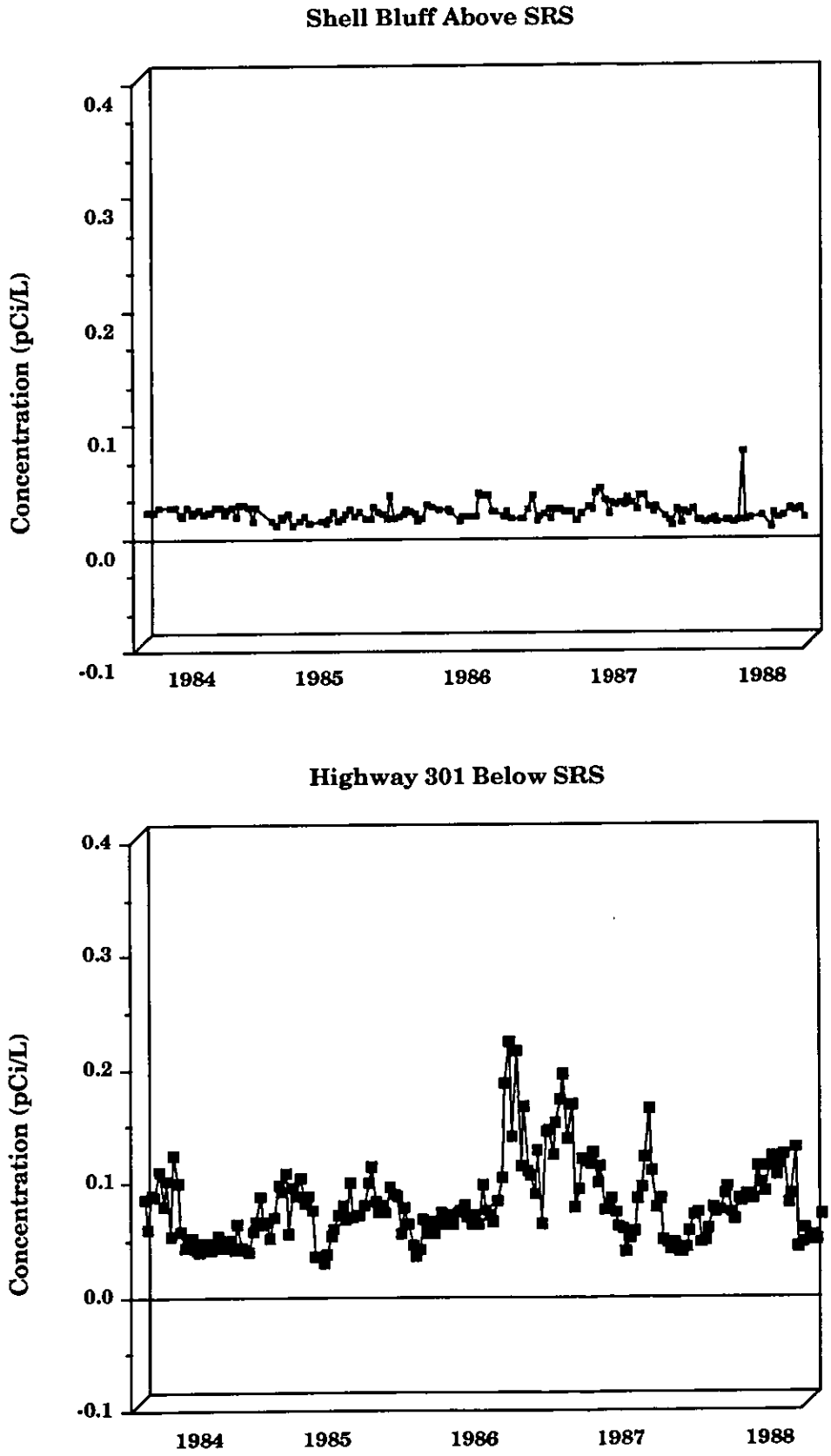


Figure 9-2. Low-level ^{137}Cs concentrations in the Savannah River

Aiken Airport Ambient Air Study

Particulate samples from very large air volumes (approx. 10,000 m^3) were collected at the Aiken Airport monitoring station every two to three days in 1988. The air samples were analyzed on high sensitivity gamma detectors in the Savannah River Laboratory Ultra-Low-Level Counting Facility. Cesium-137 fallout was the only man-made radionuclide detected at very low levels which ranged from 0.05 to 0.25 fCi/m^3. The natural radioactive background levels were over 1,000 times higher than were levels from man-made radionuclides. During the 1986 Chernobyl incident, the highest measured concentration of ^{137}Cs was 281 fCi/m^3 at the Aiken Airport monitoring station. The DOE Derived Concentration Guide (see chapter 3) is 400,000 fCi/m^3.

Measurements of ^{129}I in Groundwater and Surface Water

The Savannah River Laboratory has conducted a study at irregular intervals since 1970 to determine the ^{129}I content of groundwater and surface water at onplant and offplant locations [Ka87]. Measurements were made by neutron activation analysis. Iodine-129 was detected in groundwater near the RWBG and near the seepage basins of F- and H Areas. Iodine-129 concentrations in the groundwater can be compared to the EPA drinking water standard. At a few locations, the concentrations exceeded both the existing and pending EPA drinking water standards of 1 and 100 pCi/L, respectively. In surface water, Four Mile Creek was the only SRS stream found to transport the majority of the ^{129}I to the Savannah River. Dilution by C-Reactor discharge and the Savannah River reduced the offplant ^{129}I concentrations in river water to less than 1% of the existing EPA drinking water standard and less than 0.01% of the pending standard.

A quarterly sampling program for ^{129}I in Savannah River water upstream and downstream of SRS was reactivated in 1986 after five years of dormancy. No ^{129}I analyses results of SRS surface water or SRS groundwater were published in 1988. Analyses of the samples are planned for late 1989 with the support of an offsite laboratory.

Environmental Data Exchange

During 1988, representatives from the South Carolina Department of Health and Environmental Control (SCDHEC), Georgia Department of Natural Resources (GDNR), Georgia Power Company, Chem-Nuclear, Inc., Department of Energy (DOE), and Savannah River Site (SRS) met to discuss mechanisms for routine exchange of data from environmental radioactivity sampling. The exchange of sample results among the groups is intended to provide an additional interlaboratory quality assurance (QA) check, to increase confidence in each group's monitoring program, to enhance public confidence in monitoring around SRS, and to provide a mechanism for timely communication of technical data.

Common sampling locations and types were identified, and analytical schemes were selected. Other types of samples such as vegetation, soil, and fish were identified as possible candidates for split sampling and parallel analysis among the participants in future data exchanges.

Surveys of Dry Monitoring Wells in F- and H-Area Waste Management Facilities

Profile radiation measurements were taken in dry monitoring (DM) wells in both the F- and H-Area waste management facilities. Figures 9-5 and 9-6, Vol. II show locations of the dry monitoring wells. DM wells are 2-in.-diameter, closed-bottom steel-cased wells, that stop above the water table. Each monitoring well has gravel packing in the screen zone. Bentonite and cement grout seal the well from leakage of shallow groundwater into the well. The top of the well is either capped or sealed to prevent introducing atmospheric water into the well. The wells are located at points considered most vulnerable to leaks from piping which serves the storage tanks.

Eleven DM wells that monitor diversion box #1 in F-Area facilities were surveyed in 1988. Background radiation levels were measured in all wells.

Radiation measurements were made in 38 additional DM wells installed in a contaminated area near Tank 8 in the F-Area waste management facilities. Radiation levels measured in the Tank 8 wells define the zone of major contamination, as shown in Figure 9-7, Vol. II. This contamination is attributed to overfilling the tank in 1961. Radiation levels around Tank 8 remained high during the 1988 survey. The maximum radiation level in the wells was 83 R/hr in RP-6 well at a depth of 19 ft.

Fifteen of 16 DM wells in service in the H-Area waste management facilities were surveyed. These wells showed no significant changes in 1988 from previous years. Radiation levels for dry wells in the F- and H-Separations Area waste management facilities are represented in Figure 9-7 and 9-8, Vol. II.

NONRADIOLOGICAL SURVEYS

Spills

Description of Monitoring Program. A sitewide procedure requires prompt reporting of oil and chemical spills to a spill coordinator. The spill coordinator ensures that spills are reported to the DOE, EPA, and SCDHEC as appropriate to satisfy regulatory requirements.

A spill is defined as any unintentional discharge to the environment. Environment is broadly defined as any water, land, or ambient air. If a substance is spilled on a concrete floor inside a building, it is not reportable because it does not reach the environment. If the same spill were to go down a drain to a sewer line, it would be reportable. All chemical releases to the atmosphere (e.g., chlorine gas) are considered spills for reporting purposes.

The spill coordinator advises custodians on remedial action and helps determine whether a spill is reportable to the EPA and SCDHEC under guidelines of the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA), commonly called Superfund. A well-trained spill response team is on call to assist with confinement and cleanup of spilled material, as determined by the site spill coordinator.

Spills During 1988. In 1988, there were 155 minor spills reported to the spill coordinator. Most of these were minor spills of petroleum products. Due to their significance, fifteen spills were reported to DOE and 11 were reported to SCDHEC. There have been no Superfund-reportable spill incidents at SRS since January 1986.

Academy of Natural Sciences of Philadelphia - River Quality Surveys

Description of Monitoring Program. The Division of Environmental Research of the Academy of Natural Sciences of Philadelphia (ANSP), under contract at SRS, has carried out continuing surveys of the aquatic environment and water quality of the Savannah River upriver (Station 1) and downriver (Station 6) from SRS since 1951. Survey locations are shown in Figure 9-3 (Figure 9-9, Vol. II). These studies were expanded in 1982 to include Station 5, below Steel Creek. The purpose of these studies is to determine the effect, if any, of SRS effluent discharges on general river health. All surveys performed in previous years, which have not been reported, are covered in this section.

The ANSP has conducted several types of studies since 1951, including:

- detailed surveys (every four years): these surveys study algae and rooted aquatic plants, protozoa, macroinvertebrates, insects, fish, and water chemistry
- continuous cursory studies of aquatic life (quarterly):these studies focus on algae, insects, and fish
- continuous surveys of diatom communities (semi-monthly)

Biological Surveys (Cursory Surveys) of the Savannah River. Cursory surveys of algae, macrophyte, insect, and fish communities of the Savannah River in the vicinity of the SRS conducted during 1988 were continuations of long-term biomonitoring studies that have been conducted on the river since 1951. Since the initial series of biological surveys were conducted prior to the start of SRS operations, the Academy of Natural Sciences of Philadelphia (ANSP) has performed comprehensive surveys at regular intervals, supplemented by quarterly cursory surveys during those years when comprehensive surveys were not performed.

During 1988, surveys of algae and aquatic macrophytes were conducted March 29-31 and November 29 through December 1. Aquatic insects were collected from artificial and natural substrates on March 29-31, July 12-14, September 14-15, and November 29 through December 1. Fish communities were sampled September 15-16, 1988. A map of the survey stations along the Savannah River is provided in Figure 9-3. The three stations studied were Station 1 (a reference station located upstream of all SRS operations), Station 5 (a potential impact station located below Steel Creek within the area expected to be most affected by effluents from the plant) and Station 6 (a downstream station where additional effects and/or recovery can be monitored).

River flow, measured during the four survey periods by the U.S. Geological Survey (USGS), was relatively low in March and July (gauge heights of approximately 2.5 ft and 1.2 ft, respectively). The September survey was conducted within a few days after a high flow period (gauge height maximum approximately 6 ft) and water levels fluctuated from approximately 1.8 to 3.1 ft during the September collecting period. River levels were lower and more stable during the November and December survey, averaging approximately 1.7 ft.

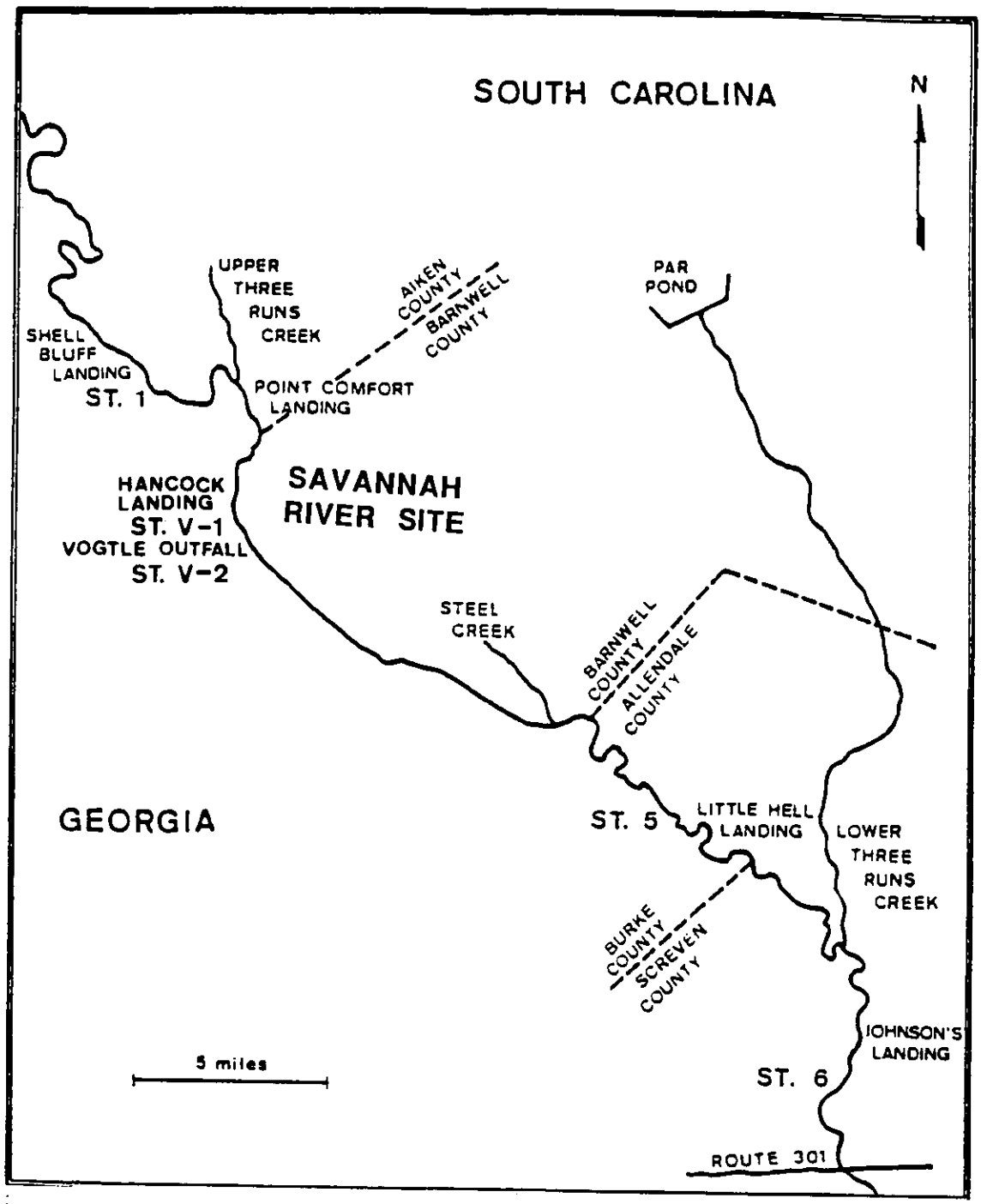


Figure 9-3. Academy of Natural Sciences (ANSP) river survey

The relatively low water levels encountered during the algal and macrophyte surveys resulted in readily accessible habitats for collection. The algal and macrophyte communities of all stations were fundamentally similar to each other, although area-wide seasonal changes were apparent. In March, Station 1 was dominated by diatoms and blue-green algae while Stations 5 and 6 were dominated by yellow-green algae. During the November and December survey, Station 1 was dominated by blue-green algae and the lower two stations by diatoms. The overall dominant diatom species in hand collections from each of the stations during both surveys was *Melosira varians*. The blue-green flora was always dominated by *Schizothrix calcicola*, *S. mexicana* and *Microcoleus vaginatus*. The dominant yellow-green flora was *Vaucheria* sp. and the most commonly occurring aquatic macrophytes were elodea (*Egeria densa*) and parrot feather (*Myriophyllum aquaticum*). *Oedogonium* sp. dominated the green algal flora, although *Spirogyra* sp. was also common in the study area in the November and December survey. The algal and aquatic macrophyte surveys of 1988 showed no detectable differences in water quality among the three stations and no evidence of a change in overall water quality from that seen in recent years. The dominant algal flora of the studied portion of the Savannah River consists of cosmopolitan forms characteristic of moderate to high nutrient levels. The common species of algae encountered during 1988 have changed little since the studies were initiated in 1951.

Results of the analysis of hand collections of insects from natural river substrates throughout the study area indicated that there were more species of mayflies than any other insect order. A variety of beetles, caddisflies, dragonflies, damselflies and true flies (Diptera) were also collected during the 1988 surveys. Overall, the estimated number of species in the 1988 hand collections is comparable to or higher than the 1986 and 1987 collections. The number of species recorded from Station 1 was lower than at Stations 5 and 6 during three of the four sampling periods. Analysis of the quantitative artificial substrate data indicates that significant differences among stations existed in taxa richness, community evenness and Shannon-Wiener diversity. Taxa richness was always lower at Station 1 than at either of the downstream stations. Average values of community evenness and Shannon-Wiener diversity also tended to be lower at Station 1 compared with Station 5 and is similar to the pattern observed in 1987. As in 1987, a smaller number of taxa were dominant at Station 1, primarily the chironomid midges. As in previous years, the average value of Hilsenhoff's biotic index was usually highest at Station 1, intermediate at Station 5, and lowest at Station 6. These changes in the biotic index indicated that the assemblage of aquatic insects becomes progressively more pollution-tolerant moving in an upstream direction within the study area, suggesting that water quality is lowest above the area of influence of SRS. The reduction in pollution tolerance in a downstream direction indicates improving conditions for the maintenance of more pollution sensitive taxa. Collectively, the results of the insect surveys indicate that water quality continues to be lower at Station 1 while improving in the vicinity and downstream of the SRS.

Rotenone collections of fish taken in September indicated the continued presence of diverse fish communities at all stations. A total of 303 fishes of 26 different species was collected. The species richness at Stations 1 and 5 was similar to that observed in previous years, while richness at Station 6 was lower, most probably due to the physical nature of the habitat from the relatively low water level at the time of sampling. Specific long-term trends in species

Diatom communities in the Savannah River attach to glass slide substrates of diatometers

occurrance and abundance were found to continue. The ironcolor shiner, taillight shiner and Eastern silvery minnow appear to have decreased in numbers since 1980, while the pirate-perch, banded pygmy sunfish, and blue-spotted sunfish appear to have increased. Several other species, including the flathead and brown bullhead, have shown between-year fluctuations in frequency which appear to be related to strong between-year differences in reproductive success. Two species, the lake chubsucker and striped mullet which have not been recorded since 1980, were collected during the 1988 sampling.

1987 Diatometer Survey of the Savannah River. A Catherwood diatometer study was conducted December 30, 1986 through December 29, 1987 to monitor water quality conditions in the vicinity of the SRS. This study represents the 34th year of ongoing diatometer studies on the Savannah River. Catherwood diatometer artificial substrates were placed in the river downstream of two tributaries (Steel Creek and Lower Three Runs Creek) which carry varying amounts of SRS wastewater, as well as in an upstream reference area. Diatom communities developing on these substrates were analyzed by quantitative methods to assess the nature and severity of any effect of the effluent upon community parameters of diversity, dominance, and species composition.

During the 1987 studies, diatom community composition was similar at the three stations in the vicinity of the SRS. Differences in community diversity (as measured by richness and evenness parameters) between the reference station (Station 1) and Station 5 were small and inconclusive. However, there was a large and consistent reduction in diversity from Station 1 to Station 6. Also, the number of species (from detailed readings) found at Station 6 was among the lowest for the period of monitoring (1954 through 1987). These reductions, though not representing a fundamental change in diatom communities above and below the SRS, are indicative of deteriorating conditions at Station 6. As in previous studies, the species observed throughout the study area (heavily dominated by *Gomphonema parvulum*) are characteristic of alkaline and eutrophic waters.

1988 Diatometer Survey of the Savannah River. Catherwood diatometers were deployed at three stations on the Savannah River for 26 consecutive two-week exposure periods from December 29, 1987 through December 27, 1988. Diatom communities attaching to the glass slide substrates of the diatometers were analyzed for species richness, dominance and relative abundance of species. Additional diatometers were deployed for a single exposure period, ending November 1, 1988 to supply statistical information on within-station variation. Preliminary results of analyses completed through the exposure period ending October 11, 1988 indicate that species richness was lower and percent dominance was higher at downstream Station 6 than at the upper two stations. This trend, also identified in 1987, was especially apparent from mid-June through October.

1989 Studies. To enhance the 1989 environmental studies, the ANSP has instituted a more rigorous protocol involving linkage of diatometer data with the cursory insect data. These comparisons will enable the ANSP's scientists to make direct correlations between diatom and insect data.

Steel Creek Survey. The first comprehensive environmental survey following the startup of L Reactor in late-December 1984 was conducted in 1986 by the Academy of Natural Sciences of Philadelphia (ANSP). The survey concentrated on the area of the Savannah River near the mouth of Steel Creek. The purpose of this study was to assess the possible effect of L Reactor operation on the water quality of the Savannah River. The 1982 and 1983 surveys conducted prior to operation of L Reactor provided baseline data on preoperational conditions in that area of the river. In addition to analysis of water chemistry, the survey also included the study of algae, aquatic macrophytes, protozoa, non-insect macroinvertebrates and aquatic insects.

The goals of the Steel Creek survey included:

- operational characterization of the biological and chemical nature of the right and left banks of the Savannah River near the mouth of Steel Creek
- comparison of biological and chemical data from both banks of the Savannah River near the mouth of Steel Creek to determine the possible effect of Steel Creek discharge on the Savannah River
- comparison of the 1986 data with data from previous, preoperational studies to determine Steel Creek discharge characteristics and the possible effects of L-Reactor operations on the Savannah River water quality

The survey was conducted September 16-22, 1986, except for the primary productivity studies which were conducted September 30, 1986. Results of the study indicated that slight differences in many of the characteristics investigated between banks existed at the time of the 1986 survey, although the water chemistry data were similar for both banks. The insect collections, in particular, suggested important ecological differences between the two banks.

In general, the 1986 survey indicated that discharge from Steel Creek had no deleterious effect on the biota of the Savannah River at their confluence, and in fact, may have improved water quality slightly at the left bank. The species richness for algae and insects, and the water chemistry data were similar to the 1982 and 1983 preoperational studies. For the other biological components studied, species richness was greater during the 1986 operational study than in the preoperational studies.

Just upriver from the SRS, the Plant Vogtle towers are a prominent sight along the Savannah River

1987 Plant Vogtle Comprehensive Survey. In September and October 1987, the third in a series of comprehensive surveys was conducted by the Academy of Natural Sciences (ANSP) in the vicinity of the Georgia Power Company Vogtle Nuclear Power Plant site on the Savannah River. The 1987 survey elements were identical to the 1986 ANSP survey and included chemical analyses of river water and fish tissue and community analyses of algae, macrophytes, protozoa, macroinvertebrates, and fish. The 1985 and 1986 surveys were conducted prior to plant startup to provide baseline data on river conditions in the area of the river to be affected by the plant's cooling water discharge. Commercial operation of Plant Vogtle began in early summer of 1987, approximately three months before the river survey. The goals of the study were to characterize and compare the biological and chemical conditions of stations above and below the Plant Vogtle cooling water discharge after startup, and to relate these findings to data derived from similar surveys of other Savannah River stations studied in the ANSP's long-term monitoring program.

All elements of the 1987 survey were conducted during September 21-24 at Stations V-l (above the Vogtle discharge) and V-2 (below the discharge) with the exception of the insect collections, which were conducted during October 21-22 at the same stations. River discharge immediately prior to and during the September portions of the work was greater and more variable than during the previous two surveys. This higher and more variable river stage proved to be an important factor in the 1987 findings. Discharge at the time of the October insect collections was similar to that of the previous Plant Vogtle surveys.

In general, the survey results indicate that Stations V-l and V-2 were fundamentally similar with regard to water chemistry and the community structure of the biological groups investigated during 1987. However, most of the communities studied during the September portion of the survey were found to be less diverse with fewer numbers of individuals than was the case in previous surveys at the same sites. These differences between years are believed to be related to the higher river levels during collection periods and not as a consequence of Plant Vogtle operations.

Station comparisons showed no appreciable differences between Stations V- 1 and V-2 for any water

chemistry parameter studied during the 1987 survey. Comparison with the 1985 and 1986 studies showed little differences among years. Chlorides, conductivity, ammonia, and nitrate were slightly lower in 1987 than in previous years, while manganese and pH were slightly higher than in previous years. Fecal coliform counts declined from levels seen in 1986 but were slightly higher than observed in 1985. Trace metal analyses in tissues of five species of fish showed no significant differences in metal concentrations either between stations or with similar data obtained in the 1986 survey.

Results of the algae and macrophyte portions of the survey were similar to the findings of the baseline surveys. The most noticeable difference in the 1987 data was a decrease in the diversity and quantity of aquatic macrophytes at both the upstream and downstream stations, due to the higher river flow. The algae and macrophyte communities at the two stations continue to closely resemble those found routinely at the other Savannah River stations surveyed by the ANSP. Likewise, protozoan communities collected in 1987 were fundamentally similar between stations and to those communities found in the two previous surveys, although the number of species collected was less than in previous years due to the high flow conditions. An apparent downward trend in the number of protozoan species found over the past three years at both stations indicated a possible change for that region of the river. However this is not attributable to Plant Vogtle.

The number of non-insect macroinvertebrates collected from the two stations in September was only slightly more than half the number collected during either of the two previous years. The abnormally high river stage and varying water levels affected the microinvertebrates habitat and their collection efficiency. No significant differences were apparent between the upstream and downstream stations. In contrast to collecting conditions at the time of the non-insect macroinvertebrate survey, qualitative and quantitative collections of aquatic insects were facilitated by lower water levels which prevailed in mid-October. The number of individual insects taken in qualitative collections at the upstream station was slightly less than at the same station in 1986, while the number of taxa collected at the downstream station was greater than in 1986. In the quantitative trap collections, the average number of taxa collected at the downstream station was significantly greater than at the upstream station, although the reverse was true for Shannon-Weiner diversity, community evenness and the value of Hilsenhoff' s biotic index. The proportional abundances of different functional feeding groups was similar at both stations. Comparison of 1987 data with the previous insect surveys is hindered by a rather high degree of community variation between the baseline years (1985 and 1986). Overall, these comparisons provide little evidence to suggest that aquatic insect communities at the downstream station have been adversely affected by Plant Vogtle operations.

Fish collection efforts were complicated by the prevailing water levels during the September survey. Levels of effort utilizing various techniques had to be adjusted from previous years at selected sampling points within the stations. Nonetheless, collections from the three surveys indicate the presence of similar communities at the two stations over the three-year period. In 1987, 35 species were collected compared with 47 in 1986 and 40 in 1985. The lower total species taken in 1987 can be accounted for by the lack of rotenone sampling at the upstream station. The total species count for all methods at the upstream station during 1987 was 18 compared with 30 at the downstream station. Again, the lower total number of species taken upstream can be explained by the inability to use rotenone at Station V-1 due to the higher river stage.

In summary, chemical and biological surveys conducted during 1987 did not indicate differences between the upstream and downstream stations in the vicinity of Plant Vogtle and possibly related to Plant Vogtle operations. Lower diversity was seen in the macrophyte, protozoa, non-insect macroinvertebrate, and fish communities at both stations when compared with the baseline surveys. However, these differences are related to the river stage and flow variation existing prior to and during the September survey elements. Water chemistry parameters were well within ranges seen in previous years at the Plant Vogtle study site and levels of metals in fish tissue were comparable to those found during the 1986 survey. Biological and chemical conditions at the Plant Vogtle sites remained similar to those of the other Savannah River stations surveyed by the ANSP in previous years.

1988 Plant Vogtle Comprehensive Survey. Comprehensive biological and chemical surveys of Savannah River sites both above and below the Georgia Power Vogtle Nuclear Power Plant were conducted September 13-16, 1988. Unlike river conditions in 1987 when flow was relatively high, river

gae, aquatic macrophytes, protozoan insects and other macroinvertebrates, and fish were taken. Three days of chemical and physical measurements were used to provide additional information to aid in the interpretation of biological findings.

Preliminary findings indicated that the flora and fauna at the two collecting sites were generally more diverse than in 1987 due to improved collecting conditions in 1988 and improved water quality. Among the primary producers, the diversity was notably apparent in the aquatic macrophytes which showed increased growth and diversity compared with 1987. The protozoan communities were similar in species richness and community structure to those observed in three previous surveys at the Plant Vogtle site. As expected, the more extensive weed beds provided habitat for larger populations of a broad diversity of macroinvertebrates at sites above and below Plant Vogtle. Fish samples at both stations contained larger numbers of fish than in the previous year resulting in part from the higher efficiency of sampling gear related to the lower river stage.

1988 HIGHLIGHTS

- The average atmospheric tritium release from all SRS facilities in 1988 was approximately 1,238 Ci per day which represented a 21% decrease compared to 1987. Tritium oxide comprised approximately 62% of this total amount.
- The average liquid release of tritium from all plant sources in 1988 was approximately 53 Ci per day compared to approximately 62 Ci per day in 1987.
- The maximum calculated dose to an individual at the site boundary from the largest nonroutine release of atmospheric tritium was 0.2 mrem (0.002 mSv).
- Analytical results of vegetation and water samples collected after all three plutonium accidental atmospheric releases were within ranges for alpha activity from previous years.
- In the Academy of Natural Sciences of Philadelphia survey, a total of 303 fishes of 26 different species was collected. The ironcolor shiner, taillight shiner, and Eastern silvery minnow appear to have decreased in numbers from 1980 to 1988, while the pirate-perch, banded pygmy sunfish, and blue-spotted sunfish appear to have increased.
- In 1988, ^{137}Cs concentrations upriver of SRS (Shell Bluff) averaged 0.004 pCi/L while those downriver (Highway 301) averaged 0.076 pCi/L. The difference between the upriver and downriver concentrations is attributed to releases from SRS operations.

10
Quality Assurance of Environmental Monitoring Programs

SUMMARY—This chapter focuses on the goals and objectives of the Environmental Monitoring Quality Assurance/Quality Control (QA/QC) program at the Savannah River Site. Routine QA/QC measures, carried out for both radiological and nonradiological laboratory data and field measurements, include the use of laboratory blanks, field blanks, reference standards, spiked environmental samples, blind samples, duplicate analyses, performance evaluation samples received from an external source, calibration verification standards, and calibration verification blanks.

A quality control collection team was formed in 1988 to routinely monitor collection sites and to document quality control corrections, and a "chain-of-custody" procedure was established to document official custody of environmental samples from collection to data storage. Extensive interlaboratory comparisons were undertaken to test the accuracy of SRS and subcontractor analyses with each other and other nationwide laboratories.

Quality control for the radiological monitoring programs involves the calibration of counting instruments, source and background counts for all counting systems, yield determinations of radiochemical procedures, and replicate analyses to check precision.

The quality control program for nonradiological monitoring of surface water, air, liquid effluents, and groundwater are presented, and performance audits and program results are described.

QUALITY ASSURANCE/QUALITY CONTROL PROGRAM GOALS AND PROCEDURES

QA/QC Program Goals, Objectives, and Policies

The goal of the Environmental Monitoring quality assurance/quality control (QA/QC) program is to continually monitor the scientific reliability, accuracy (degree of agreement between a measured or computed value and the true value), and precision (degree of agreement within a set of measurements taken under equivalent conditions) of reported laboratory data generated by the Savannah River Site's radiological and nonradiological monitoring programs.

The QA/QC program is designed to detect problems that may introduce unreliability into the sample collection, sample preparation, or the analytical procedures.

Following is a list of objectives established in 1988 for the Environmental Monitoring QA/QC program:

- to routinely assess all standard operating procedures for adequacy regarding accuracy, precision, sensitivity, and specificity
- to use system checks to monitor the performance of the routine laboratory operations and to ensure that all aspects of the QA program are operative
- to perform internal blind sample audits of analyses for frequent assessments of routine analyses
- to perform corrective action when necessary
- to meet or exceed laboratory certification standards established by the U. S. Environmental Protection Agency (EPA) and the State of South Carolina

- to conduct the Environmental Monitoring QA program in accordance with the SRS Site Quality Assurance Program

The policies of the Environmental Monitoring QA/QC program are listed below:

- A minimum of 10% of all samples will be used as QA/QC control samples.
- QC samples, such as reagent blanks or samples that represent an appropriate blank, direct spikes, and indirect spikes, will be analyzed with each batch of routine samples.
- Control charts will be used in all radiological and nonradiological laboratories.
- Periodic calibrations will be performed on all field and laboratory instruments using specific National Institute of Standards and Technology (NIST) traceable sources or other standards recognized by DOE.
- Fresh reagents and chemicals will be used, as appropriate, in all laboratories.
- Environmental Monitoring will routinely participate in interlaboratory quality evaluation programs.

QA/QC Plan for Environmental Sampling

A quality control team was formed in 1988 to routinely monitor sample collection sites and to identify, correct, and document problems.

The sample collection QC team identified many quality improvements in the environmental sample collection area. Preventive maintenance activities were initiated to assure effectiveness of sampling equipment; this program improved the efficiency of the paddlewheel samplers and Brailsford pumps.

Housekeeping of all sampling areas was performed regularly.

Strategic sampling points were evaluated and necessary improvements were implemented in 1988. Backup paddlewheel samplers were installed at these stream locations: Upper Three Runs-4, Four Mile-6, Pen Branch-3, Four Mile-3A, Four Mile-2, and P-019. The backup sampler at each location will serve as an alternate means to collect environmental samples in the event of a primary sampler failure.

Because EPA regulations require that official custody of environmental samples be documented from sample collection and analysis to data storage, a chain-of-custody procedure for quality control was created and now provides instructions on the chain-of-custody requirements for environmental sampling.

Interlaboratory Comparisons

The absolute test of an analytical procedure is to measure the correct concentration of constituents present in standard or reference samples. SRS Environmental Monitoring laboratories and commercial laboratory subcontractors routinely participate in interlaboratory comparisons. These comparisons not only test the laboratory accuracy of SRS and subcontractor analyses and procedures, but compare SRS and subcontractor laboratories with other nationwide laboratories. Below are descriptions of interlaboratory comparisons conducted in 1988:

- The principle external quality assurance program is the U. S. Department of Energy (DOE) Quality Assessment Program (QAP) which is designed to test the quality of environmental data reported to DOE by its contractors. Reference samples for this program are prepared by DOE Environmental Measurements Laboratory (EML) and includes sample matrices of soil, water, vegetation, animal tissues, and air filters. Analysis results are reported to EML within 90 days and compared with the test results of other participating laboratories. A comprehensive evaluation report is generated by EML and distributed to test participants. This program is one of the most essential elements of the SRS Environmental Monitoring QA program.
- The Quality Assurance Division (QAD) of the EPA Environmental Monitoring System Laboratory/Las Vegas (EMSL-LV) is responsible for quality control of environmental radiological measurements. The EPA provides milk, water, air, and food samples which contain a variety of radionuclides with activity concentrations near environmental levels. This program enables the SRS Environmental Monitoring laboratories to document the precision and accuracy of radiological analysis data, to identify instrument and procedural problems, and to compare analysis performance with participating laboratories.

- All SRS Environmental Monitoring subcontracted laboratories that perform NPDES analyses participate in the EPA nonradioactive Discharge Monitoring Report Quality Assurance (DMR QA) assessment program. In this program, participating laboratories receive performance samples containing constituents normally found in industrial and municipal waste waters. These water samples contain known concentrations of constituents such as total suspended solids (TSS), chemical oxygen demand (COD), oil and grease, and certain trace metals. The EPA provides a comprehensive data evaluation report to the program participants. The report is based on statistical analysis of reported data from all laboratories participating in the study and contains documentation of the "true" sample value with stated "acceptance limits" and "warning limits."

- The SRS ambient air monitoring program, subcontracted under Zedek Corporation, participates in the EPA ambient air audit program. The program consists of an audit of the sulfur dioxide (SO_2) monitors with a range of SO_2 concentrations. A report is provided by an EPA contractor which lists the "indicated" results reported by SRS, as well as the EPA "actual" values. The two values are compared and the differences and percent differences are reported.

QA/QC Monthly Report

A report of QA/QC data from all areas of the Environmental Monitoring program is provided monthly. All QA/QC information, including data evaluations of inter- and intralaboratory comparisons, control charts, training, and new programs, are included in each report.

QUALITY CONTROL OF RADIOLOGICAL MONITORING PROGRAMS

Quality control of the SRS radiological monitoring programs are maintained through routine internal checks and through participation in interlaboratory quality assurance programs.

Internal QC Program

An internal quality control (QC) program for SRS radiological monitoring programs is maintained by the following routine checks:

- calibration of counting instruments
- source and background counts for all counting systems
- yield determinations of radiochemical procedures
- precision checks using replicate analyses

The accuracy of radioactivity measurements is established by use of standards traceable to NIST. Performance histories of the counting instruments are maintained in logbooks and computer files.

Blind Sample Program. A major objective of the QA/QC program is to establish and monitor the routine operational performance of Environmental Monitoring laboratories through internal audits using blind standard samples. The blind samples consist of water or air filters prepared with known radioactivity levels for each nuclide that correspond to typical values found in routinely analyzed samples.

Whenever possible, blind samples are prepared from NIST-traceable material or standardized against NIST material. A blind sample program for ^{134}Cs, ^{106}Ru, ^{65}Zn, and ^{60}Co analyses on HPGe (High Purity Germanium) detectors was completed in 1988. After completing a study of the accuracy and precision of gamma spectroscopy analyses, the effectiveness of data retrieval was improved through a system that labels blind samples with "QC Blind." When samples labeled "QC Blind" enter the counting room, the analyst informs the QA compartment coordinator of the blind sample results. The compiled data are used to verify that procedural controls have been maintained by the laboratory.

A blind sample program for tritium analyses in water was initiated during 1988. Samples containing concentration levels from less than the LLD (0.38 pCi/mL) to approximately four times the LLD were submitted for evaluation. Also in 1988, blind samples for ^{90}Sr and ^{35}S were submitted for evaluation following the improvement of the nuclide analyses.

Blind Sample Program Results. The accuracy of the blind sample analyses on SRS Environmental Monitoring's HPGe Detectors 2, 3, and 4, was as follows:

- Accuracy - Average percent error between 3.7% and 6.6%.

- Precision - Relative standard deviation range of 1.6% and 7.1%.

Results of the blind sample program for gamma spectrometry are shown in Tables 10-1 and 10-2, Vol. II. Tritium blind sample results are shown in Table 10-3, Vol. II, and ^{90}Sr and ^{35}S blind sample results are shown in Table 10-4, Vol. II.

SRS Control Chart Program. Control charts are graphical representations which provide a probabilistic approach of identifying problems with analytical processes through the use of control limits. By plotting the variation in computed statistics of the process, control charts enable integration of changes. When analytical results follow a normal distribution, 95% of the results should lie within two standard deviations on either side of the historical mean, and 99.9% of the results should lie within three standard deviations on either side of the historical mean. Three standard deviation limits are most often used for control limits; two standard deviation limits are used for warning limits.

The use of control charts does not ensure quality. Quality improves only when control chart results are used to identify and correct underlying factors adversely affecting analytical results.

Under the QA/QC program, control charts will be required and implemented for all counting room instruments. Although the statistical nature of radioactive decay will cause uncertainties in the determination of source-check and background count rates, the instrument operator can detect deviations (instrument malfunctions) from the "true" value by recording routine source-check and background determinations on control charts.

When an instrument's calibration is considered out of statistical control, the control chart will reflect one of the following conditions:

- any one point is outside of control limits
- any three consecutive points are outside of warning limits

"Precision" control charts are prepared with percent recovery data from analyses of EPA standard reference materials. Figure 10-1 is an example of QAD sample analyses of tritium in water.

"Accuracy" control charts are developed by compiling percent recoveries of spiked samples. The charts reflect any noticeable trends in data analysis or differences in analyst technique. Short-count tritium-spiked sample recoveries are shown in Figure 10-2.

Computerization of control charts for liquid scintillation counter instruments began in 1988. An example of a control chart plot, shown in Figure 10-3, indicates the tritium standard check is within control limits.

When an instrument is found to be out of control limits, laboratory personnel and managers are notified of apparent problems. The instrument is inspected and necessary adjustments are made to correct the problem.

Interlaboratory Programs

In addition to the internal quality control program, SRS annually participates in two interlaboratory quality assurance programs. One program is conducted by the Quality Assurance Division (QAD) of the Environmental Protection Agency. The second is the Quality Assessment Program (QAP) conducted by the DOE Environmental Measurements Laboratory (EML). Under both programs, a variety of samples are sent to participating laboratories at intervals throughout the year. Sample results and the performance rating for SRS in the QAD and QAP programs are presented in Tables 10-5 and 10-6, Vol. II.

The ±20% indicator shown in the tables is a convenient measure of overall relative performance, but it cannot be used solely to determine accuracy and/or precision. SRS's participation in the interlaboratory comparison programs is based on the assumption that the QAD and QAP samples are similar in activity level to routinely analyzed samples, and that the samples are analyzed for radionuclides included in the routine program. When the true value of the comparison sample approaches the MDC (minimum detectable concentration) for the analysis, the associated statistical uncertainty of the measurement at the 95% confidence level will most likely exceed the ±20% range. In such cases, the routine analytical process is not designed to quantify the presence of those particular radionuclides at the specified activity levels. A more precise determination of laboratory performance is adherence to established analysis control limits.

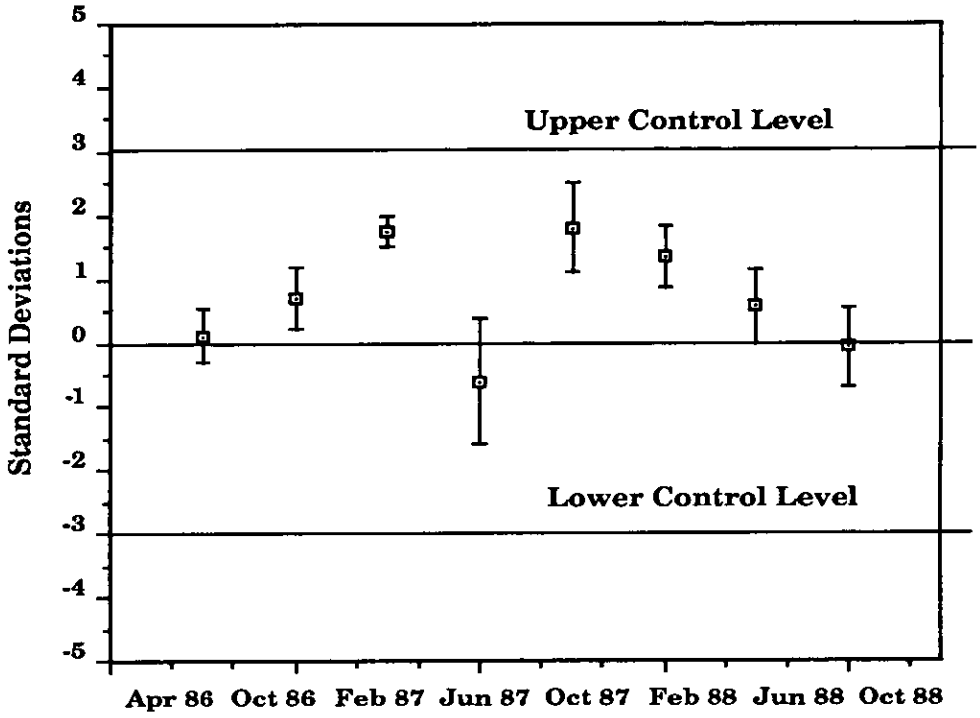


Figure 10-1. QAD sample analyses of tritium in water control chart

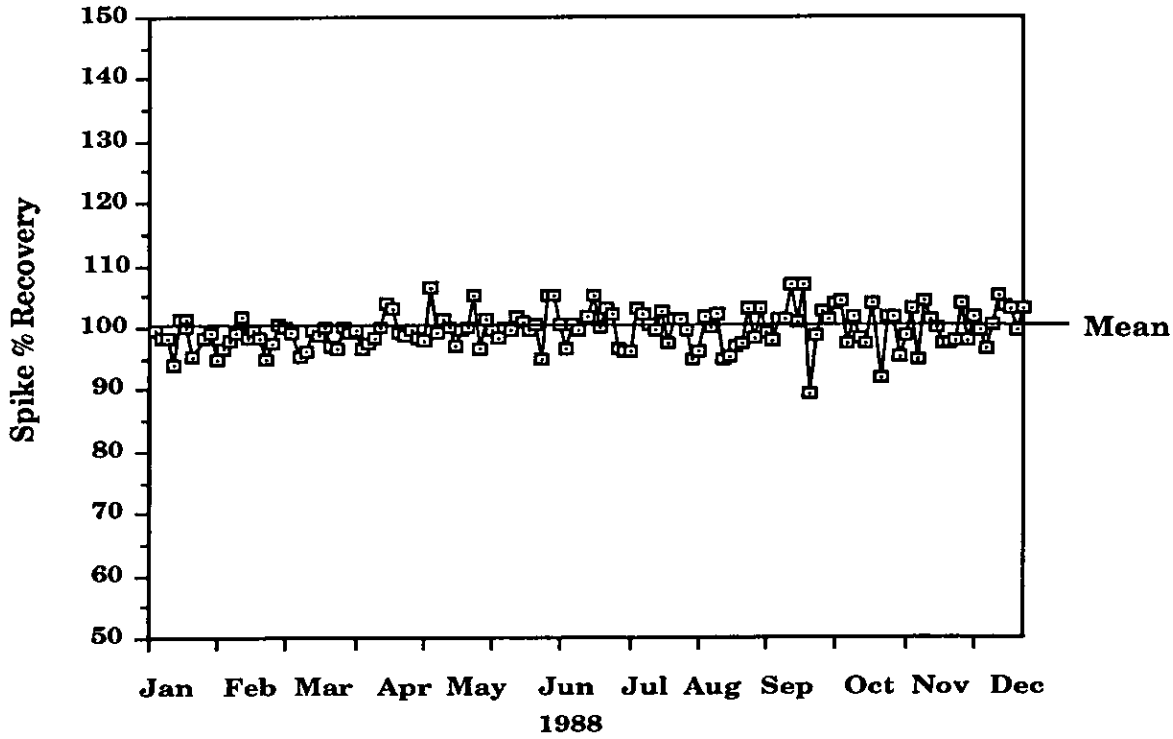


Figure 10-2. Tritium short-count control chart

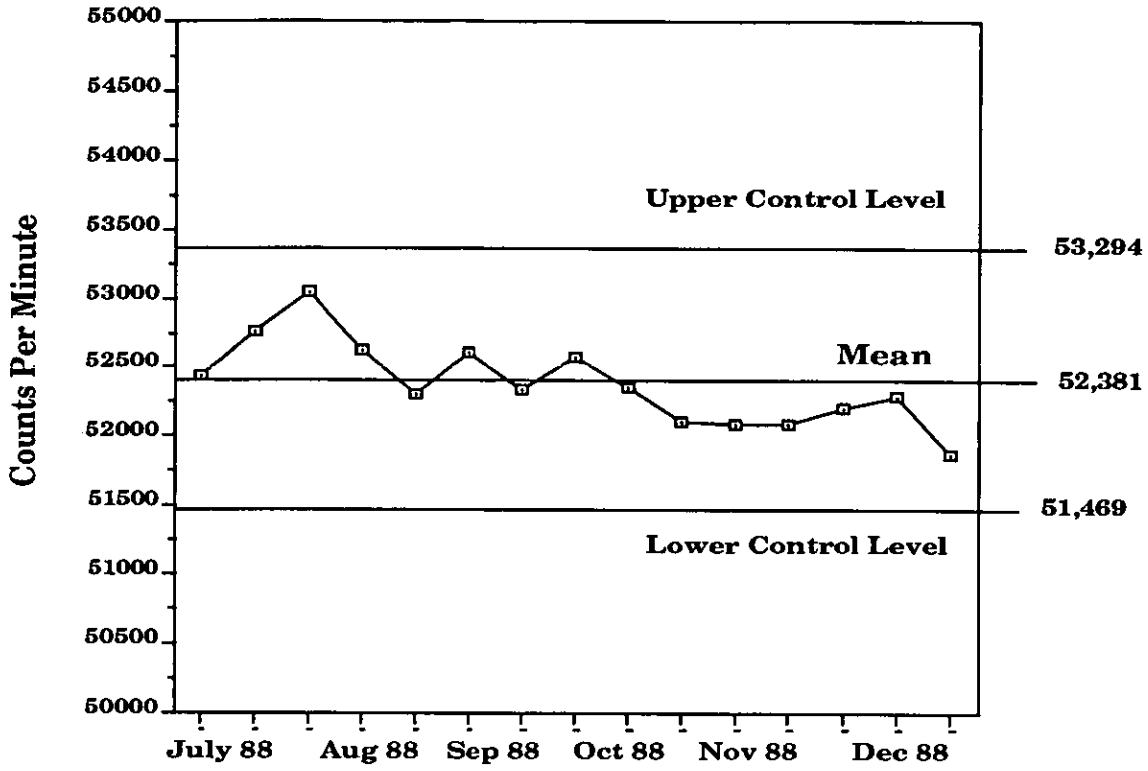


Figure 10-3. Liquid scintillation counter control chart for tritium standard check

The SRS results in the QAD and QAP programs were generally within ±20% of the EPA or DOE values. Results which fell outside of the ±20% range were investigated, and corrective action was taken when deemed necessary.

QUALITY CONTROL OF NONRADIOLOGICAL MONITORING PROGRAMS

The purpose of the quality control program for nonradiological monitoring is to continuously monitor the precision and accuracy of the analytical laboratory measurements established for air, and for surface water, groundwater, and drinking water. Standard laboratory operating procedures ensure precision and accuracy for the data generated. The data are then compared to acceptance criteria established for specific analytes. Corrective action is taken when the measured precision or accuracy is outside the acceptance criteria.

Quality control measures applicable to environmental analyses include the use of laboratory blanks, field blanks, reference standards, spiked environmental samples, blind samples, duplicate analyses, performance evaluation samples received from an external source, calibration verification standards, and calibration verification blanks.

A large portion of the nonradiological monitoring analyses are performed by independent subcontracted laboratories. The quality of the analytical data provided by the subcontracted laboratories is checked by laboratory evaluation processes established for subcontractors. The major methods involved in these processes are as follows:

- evaluation of laboratory performance by using EPA Performance Evaluation (PE) samples and EMSL-LV inorganic data audits as a part of the EPA Water Pollution Study (WP020)
- periodic testing of the precision and accuracy of commonly analyzed inorganic and organic parameters using Environmental Resource Associates (ERA) quality control samples
- using onsite laboratory evaluations to ensure that technical competence is maintained and that required quality control programs are being applied by the subcontractor

The procedure, which outlines and defines the water quality laboratory QA/QC plan, was completed in 1988. The procedure consists of the following sections:

- introduction
- organization
- document control
- training
- sampling
- human factors
- chain of custody
- instrument calibrations
- internal quality checks
- performance audits
- quality correction
- quality assurance reports

Ambient Air Quality Program

The ambient air quality monitoring program is conducted by Zedek Corporation, under contract to SRS. Quarterly QA audits are performed by an independent subcontractor, Environmental Testing, Inc. (ETI), to verify instrument calibration, accuracy, and performance of SRS's five ambient air quality monitoring stations. The stations are equipped with gaseous analyzers which monitor for sulfur dioxide, oxides of nitrogen, and ozone, as well as samplers which monitor for ambient air particulate matter. In addition to the quarterly audits, daily zero and span checks are performed on each analyzer.

Results of the quarterly audits are evaluated by two methods: (1) by a comparison of audit values and instrument measurements at each audit point; and (2) by linear regression. The linear regression analysis uses paired points (audit concentration and analyzer response) to generate the best straight line that represents the sets of paired points. The difference determined by the slope of the linear regression line and the bias determined by the intercept of the line are used to determine the status of data quality and analyzer calibration.

Ambient Air Quality Program Results. The following difference criteria are used for data evaluation and corrective action for the gaseous analyzers:

Slope:	satisfactory	($\leq \pm 15\%$)
Intercept:	satisfactory	($\leq \pm 15\%$)
Correlation Coefficient:	satisfactory (0.9950 to 1.0000)	

Calibration of each analyzer is checked quarterly using the appropriate calibration gas. According to the audit results, all of the gas analyzers in the air quality stations produced satisfactory data throughout the year. Thirty-three calibration tests were conducted in 1988; all showed a less than 15% difference. The tests revealed that all gaseous analyzers produced satisfactory data throughout the year.

The audit criterion for satisfactory calibration of the total suspended particulate samplers is a difference of ±7%. All of the samplers, including one control sampler placed adjacent to a primary sampler, are audited on a quarterly basis. Of the 16 tests conducted in 1988, 14 showed a difference of less than 7%. The two samplers with a difference greater than 7% were adjusted and recalibrated.

Individual results of the Zedek Corporation and ETI quarterly audits are presented in Table 10-7, Vol. II. Zedek results of an EPA interlaboratory audit are given in Table 10-8, Vol. II.

Liquid Effluents Program

SRS liquid effluent samples are collected at the outfalls according to the National Pollutant Discharge Elimination System (NPDES) sampling schedule approved by the South Carolina Department of Health and Environmental Control (SCDHEC). The effluent samples are collected by SRS personnel for onsite analyses for fecal coliform and biochemical oxygen demand and for offsite analyses by an independent subcontract laboratory for other constituents.

In 1988 the primary subcontractor for this program was Environmental & Chemical Sciences/Normandeau Associates, Inc., (ECS/Normandeau), formerly Environmental & Chemical Sciences (ECS), New Ellenton, SC. Under the SRS Environmental Monitoring QA/QC program, all NPDES analyses performed by ECS/Normandeau are subjected to a comprehensive quality control effort using the following methods:

- SRS intralaboratory checks
  - 10-15% duplicate samples
  - blind samples analyzed twice a year
  - periodic blanks

- SRS interlaboratory comparisons
  - quadruple samples twice a year
  - two sets of duplicate samples analyzed by two laboratories twice a year
  - duplicate spikes analyzed by two laboratories twice a year
  - EPA QC samples once a year

ECS/Normandeau Programs. ECS/Normandeau maintains analytical quality assurance programs to ensure the reliability of its analytical data. The established programs, based on the ECS/Normandeau QA manual, address the following topics:

- laboratory administrative control
- personnel qualifications
- personnel training
- procedural compliance
- sample acquisition and custody documentation
- laboratory specifications
- instrument specifications, calibrations, and maintenance
- analytical quality assurance

ECS/Normandeau uses its QA manual in conjunction with *Methods for the Chemical Analysis of Water and Wastes,* EPA-600/4-79-020, and *Standard Methods for the Examination of Water and Wastewater,* 15th edition, American Public Health Association (APHA), 1980, to assure the quality of the analytical data.

ECS/Normandeau's quality assurance program includes the following specific items:

- standard curves prepared and verified daily
- precision of each analysis determined daily using quality control charts
- precision data reviewed and approved by the laboratory director
- precision data outside of control limits reviewed and signed by QA coordinator
- bias determined for at least 10% of the samples analyzed and plotted on control charts
- bias data reviewed by the laboratory director
- bias data outside of control limits reviewed and signed by QA coordinator

ECS/Normandeau's quality assurance and quality control procedures, described in their QA manual, include regularly scheduled performance checks and calibrations to ensure the reliability of measurements as well as the following instrumentation checks:

- balances – daily performance check using known weights
- pH meters – daily intercalibrations by obtaining a second reading on pH 7 buffer after adjusting the slope with a different buffer
- UV/visible spectrophotometers – daily preprogrammed performance checks; tolerance for all wavelength checks is ±1.0 nm
- conductivity meters – monthly standard check; measured conductivity of the standards should be within ±5%
- dissolved oxygen meters - monthly performance check
- temperature measuring devices - quarterly check against NIST traceable thermometers
- Technicon Auto Analyzer - calibration curve based on secondary standards
- gas chromatograph/mass spectrometer - daily performance check
- in addition to the instrumentation QA, ECS/Normandeau's program includes procedures for glassware, sample management, data management, corrective action, and audits

In addition to instrument tests, analytical performance checks are made in which 10% of all samples in a batch are replicated and precision of the analysis is determined. Spikes (samples to which known concentrations of the standard solution are added) represent another 10% of each batch of samples. The accuracy of the analysis is determined from the spike

results. Laboratory blanks (deionized water) are analyzed with each batch of samples.

Known standards from the EPA or another reliable source are analyzed quarterly for each routine parameter. Data verification procedures require that 20% of all calculated analytical values must be recalculated by another analyst or supervisor. If any calculations are in error, the entire set of sample analyses for that time period must then be recalculated.

Performance Audits and Results of ECS/Normandeau Programs. During 1988, 68 blanks and 288 duplicate and quadruple samples were analyzed for various parameters. ECS/Normandeau analyses results reported to SRS Environmental Monitoring indicated less than 5% difference between each duplicate set. A total of 23 SRS-submitted blind samples were analyzed for various parameters. ECS/Normandeau reported results were in general agreement with SRS-submitted blind samples. Results of duplicate and blind sample analyses completed during 1988 are presented in Table 10-9 and Table 10-10, Vol. II.

SRS Environmental Monitoring laboratories conducted two interlaboratory comparisons between ECS/Normandeau and James H. Carr & Associates. In May 1988 and September 1988, split samples of identical chemical composition were sent to both laboratories for analyses.

In the first comparison in May, ECS/Normandeau was requested to analyze 33 parameters and Carr was requested to analyze 26 parameters. The analysis results in the first comparison revealed that ECS/Normandeau and Carr performed within acceptable levels of proficiency (81%-100%). ECS/Normandeau was rated with a 97% proficiency and Carr was rated with 88% proficiency. The correlation of the analytical results between the two subcontract laboratories was good, which verified the solutions used in the test were valid. The results of this interlaboratory comparison are presented in Table 10-11, Vol. II.

The second comparison in September 1988 was a comprehensive interlaboratory test. Each laboratory was requested to perform analyses of 62 specific parameters. The analysis results in the second comparison revealed that ECS/Normandeau and Carr performed within acceptable levels of proficiency (81%-100%). ECS/Normandeau was rated with a 92% proficiency and Carr was rated with a 90% proficiency. Three parameters were omitted from the comparison because there was no agreement between the SRS "true" value, the ECS/Normandeau result, or the Carr result. The results of the interlaboratory comparison are shown in Table 10-12, Vol II.

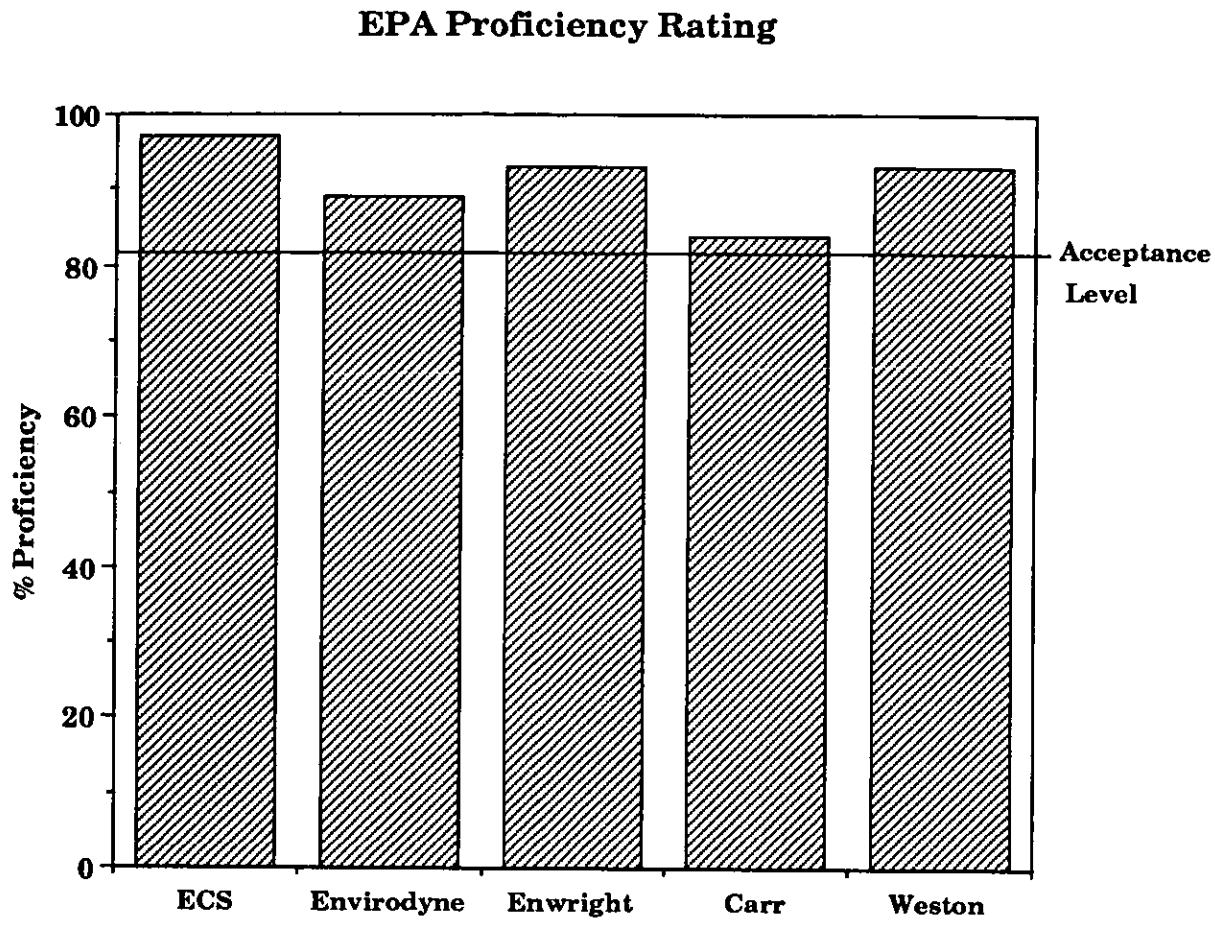
In 1988, ECS/Normandeau participated in an EPA-sponsored performance evaluation program in which EPA provided samples spiked with known concentrations of the constituents of interest to SRS. The evaluation was required by the SRS NPDES quality assurance program. The samples were forwarded to ECS/Normandeau for analysis of trace metals (aluminum, cadmium, chromium, copper, iron, lead, manganese, nickel, and zinc), nutrients (nitrate-nitrogen and total phosphorus), biochemical oxygen demand, and miscellaneous constituents such as pH, oil and grease, and total suspended solids. A summary of the EPA performance evaluation of the study Discharge Monitoring Report (DMR) QA is presented in Table 10-13, Vol. II. Results of EPA Performance Evaluation (PE) sample audits under the EPA Water Pollution Study (WPO20) are presented in Table 10-14, Vol. II. Figure 10-4 shows the SRS subcontractor's overall proficiency of nonradiological analyses.

Compliance Audits and Sampling. In 1988, SCDHEC performed eight NPDES compliance audits at SRS during seven monthly visits and one comprehensive annual survey conducted in September. SCDHEC collected two series of samples from the 71 active NPDES sampling stations and SRS collected duplicate samples from each series for comparison.

In addition to collecting samples for the NPDES-permit constituents, SCDHEC also collected samples at each location for dissolved oxygen and chlorine analyses during the annual audit. Of the over 900 parameters monitored, SRS received a satisfactory rating on all but one sample parameter.

Stream and River Water Quality

Most stream and river water quality analyses are performed by the SRS Environmental Monitoring laboratory. The analytical procedures are based on guidelines detailed in EPA's *Methods for the Chemical Analysis of Water and Wastes* (EPA-600-4-79-020) and *Handbook for Analytical Quality Control in Water and Wastewater Laboratories* (EPA-600-4-79-019), and in the APHA's *Standard Methods for the Examination of Water and Wastewater 15th edition.* Measures taken as part of the quality control program are as follows:



Subcontracted Laboratory	No. of Analyses	Acceptable	Not Acceptable	% Proficiency
ECS/Normandeau[a]	122	118	4	97
Envirodyne[b]	138	123	15	89
Enwright[c]	144	134	10	93
Carr[c]	85	71	14	84
Weston[c]	144	134	10	93

Each laboratory is certified by its respective state. To maintain certification, each laboratory must pass an annual review of all certified analyses.

In general, a proficiency of 81% is considered the minimum acceptable score according to EPA guidelines of the Contract Laboratory Program (CLP).

[a] Environmental & Chemical Sciences/Normandeau Associates, Inc., a major subcontractor for the NPDES program.
[b] Envirodyne Engineers Inc. (EEI) is a major subcontractor for the groundwater monitoring program.
[c] Subcontractors primarily used for the quality assurance sample analysis programs.

Figure 10-4. Subcontractor performance in nonradiological analyses

- EPA-analytical methods are used
- "spiked" samples with known analyte concentrations are analyzed with every run to determine accuracy
- 10% replicate analyses are performed to determine precision
- titrating solutions are routinely standardized
- sample chain-of-custodies are maintained
- data are verified before an analytical report is issued

The quality control measures vary depending on the type of analysis. Specific QC procedures to ensure accurate results have been established for each analysis.

The use of control charts, similar to those described for the radiological QA/QC program, are being implemented in all water quality analysis instrumentation in the nonradiological laboratories.

As part of the quality assurance program, an annual review verifying conformance of EPA-approved laboratory operating procedures is performed and formally documented. NIST traceable standard reference solutions are used to verify the accuracy of calibrated yield determinations. The percent of spike recovery is calculated from the true values of the NIST standards and documented on control charts. Control chart acceptance limits are well defined to provide an immediate evaluation of the accuracy and precision of each analytical method.

Operating procedures define the frequency of replicates and spikes and of standard reagent determinations. The procedures also provide instruction for using work sheets for method calibration and instrument settings documentation.

The chain-of-custody form lists the methods of sample collection and transport, preservatives to be used, the identification of the person collecting the sample, the identification of the person receiving the sample, the time and date of collection, and which analyses are required. When samples are transferred to another person, verification signatures are required by the persons relinquishing and receiving the sample. When a sample has been analyzed, it is discarded and its last custodian verifies on the form that the sample was discarded.

Data verification is documented by authorized signatures on the operational work sheets. All calibration information is verified, and control charts are reviewed to determine that the methods are within control limits. Each sample concentration calculation is checked and approved. Data transfer to the final report is verified by signature approval.

The metals analyses for water quality samples were performed by Environmental and Chemical Sciences (ECS/Normandeau) in 1988. Interlaboratory comparisons on these sample types were also performed. Split samples were sent to ECS/Normandeau and James H. Carr Associates, Inc. (Carr) as a quality assurance check of the primary contractor. Metals analyses from the interlaboratory comparisons are given in Table 10-15, Vol. II.

Field measurements are measurements most susceptible to variation from a QA/QC standpoint. A new blind sample program for field measurements has been developed and implemented for the sample collections subgroup of Environmental Monitoring. Blind sample results for pH and conductivity field measurements are given in Table 10-16, Vol. II.

Groundwater Program

Sampling and nonradiological analyses of groundwater are performed by subcontractors. Sampling procedures, the addition of preservatives, and chain-of-custody procedures are consistent with EPA-recommended procedures. Samples are analyzed within recommended holding time intervals.

During 1988, five quality control practices enhanced the quality of groundwater analyses. The following items are the quality control practices performed:

- Duplicates representing 5% of the samples were submitted to the primary laboratory, Envirodyne Engineers Inc. (EEI).
- Replicates of 5% of the samples were submitted to two additional laboratories, Roy F. Weston, Inc. Weston Analytical Laboratory, Lionville, PA and Enwright Laboratories, Greenville, SC, for comparative analyses in 1988. Duplicate and replicate analysis data are shown in Table 10-17, Vol. II.
- A new QA/QC bar chart for the groundwater program has been developed. These charts are routinely generated for all analytes of the ground-

water analyses. They reflect the precision between the laboratories QA performance results for each parameter. Figure 10-5 shows fourth quarter results of nitrate, sulfate, and zinc analyses for the QA/QC groundwater program for selected wells.

- Field blanks representing 2% of the total number of samples were sent to the two laboratories for comparative analyses.
- In the fourth quarter 1988, an SRS QA program for SRS groundwater subcontractors was initiated. Quality control samples of known concentrations were sent to each of the three laboratories. Each lab received one set of samples prepared and preserved, while EEI was sent an additional batch of unprepared samples for comparative purposes. Selected results of the ERA Quality Control samples are presented in Table 10-18, Vol. II.

EEI Program. To ensure the reliability of its analytical data, EEI has established a QA/QC program specifically for SRS samples [ENV]. This established program is based on EEI's *Manual for Analytical Assurance / Quality Control*, which covers the topics listed below:

- approach to analytical quality control in the EEI laboratory
- data handling and reporting
- experimental design for preliminary estimate of precision and bias
- calibration and quality control procedures for the following instruments: atomic absorption spectrophotometers, UV/visible spectrophotometers, Technicon auto-analyzers, gas chromatographs, and gas chromatograph/mass spectrometers
- preparation of reference standard solutions for gas chromatography
- chain-of-custody procedures
- approved EPA test procedures

The standard QA/QC program consists of the following established methods:

- applying recommended preservation techniques and holding times
- analyzing samples within the prescribed daily calibration of instrumentation and adhering to scheduled maintenance procedures for instruments and equipment
- training personnel in use of equipment and methods
- data validation

With each lot of samples, analysis of a blank, a duplicate, and a spiked method blank or check standard (an aliquot of deionized water fortified with known concentrations of the material of interest) are performed.

Typically, a lot consists of 10 or fewer samples. The results of the spiked method blank are recorded on a quality control chart and compared by EEI. Blanks and duplicates are also recorded for each lot. If the results of any one of these analyses are considered to be out of control limits, the cause of the problem is investigated, corrected, and the entire sample lot is reanalyzed.

In addition to daily quality control, EEI periodically participates in interlaboratory programs sponsored by the EPA. These involve analyzing unknown performance evaluation samples, known EPA performance standards, and laboratory check standards.

A summary of the quality control procedure used for each measurement is given in Table 10-1.

PROGRAM CHANGES FOLLOWING INTERNAL REVIEW OF SRS QA/QC PROGRAMS

During 1987 both the radiological and the nonradiological programs of the SRS Environmental Monitoring quality assurance/quality control program were internally evaluated. As a part of a continuing effort to enhance the SRS Environmental Monitoring QA/QC program, the following program areas were reviewed:

- sampling techniques
- instrument calibration
- radioanalytical procedures
- counting methods
- error limits

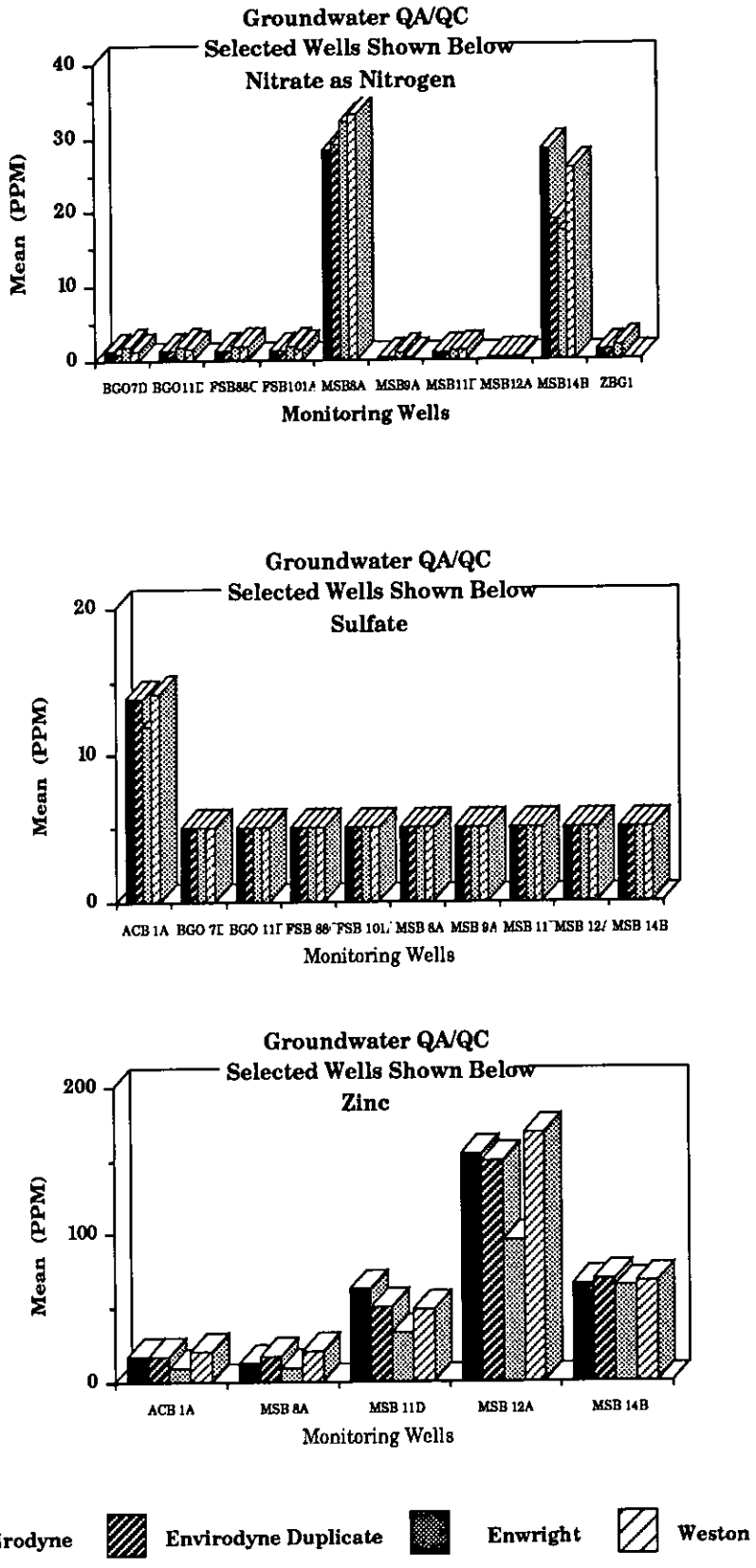


Figure10-5. Precision bar charts for performance of groundwater analyses

Table 10-1. Quality Control Procedures for EEI Measurements

Measurement	Typical Procedure
Cyanide	Blank, check standard to verify previously established calibration curve, duplicate sample.
Sulfate	Seven-point calibration curve, blanks between samples, check standard every 10 samples, one duplicate/10 samples.
Total Organic Carbon	Four-point calibration curve, blank, duplicate, check standard.
Fluoride	Blank, check standard to verify previously established curve, duplicate sample.
Phenol	Five-point calibration curve, blanks between samples, check standard and one duplicate per 10 samples.
Surfactants	Six-point calibration curve, one blank,one duplicate/10 samples.
Sulfide	Standardize titrant, blank.
Metals	Five-point calibration curve, two check standards, two blanks, one duplicate/10 samples.
Pesticides	Blank, calibration standard to verify curve, duplicate, check standard
Herbicides	Blank, calibration standard to verify curve, duplicate, check standard.
GC scan	Blank, calibration standard to verify curve, duplicate, check standard.

- data reporting
- documentation of QA/QC activities

Improvements to the program in 1988 following the 1987 review includes the following:

- employment of a full-time QA/QC coordinator
- continued development of a comprehensive quality assurance manual
- establishment of a complete calibration plan for all equipment and standards
- chain-of-custody for all samples.

TECHNICAL CONSULTANT REVIEW AND IMPLEMENTATION

As an additional response to the internal review in 1987, SRS Environmental Monitoring hired a technical consultant in 1988 to review the radiological and nonradiological environmental monitoring programs and to make needed technical changes. Improvements to the Environmental Monitoring program methodologies included the following:

- An internal standard is now used to calibrate liquid scintillation counters for quench correction for ^{3}H, ^{32}P, ^{35}S, ^{91}Y, and ^{147}Pm analyses. The proper counting efficiency is now determined for each sample, regardless of the sample's color or characteristic.
- Efficiency calibration curves were established for the gas-flow proportional counter for gross alpha and beta analyses. The weight of the solid on the sample planchet is now included in calibration curve determinations. Errors associated with absorption of alpha and beta activity by solids in the samples are alleviated through use of the calibration curves.
- Improved chemical preparation and separation procedures for ^{3}H, $^{89,90}Sr$, ^{91}Y, ^{147}Pm, and ^{137}Cs have resulted in better chemical recoveries, shorter analysis times, and more precise anlytical quantification.

1988 HIGHLIGHTS

- An extensive blind sample program for tritium analyses in water was initiated in 1988, and blind samples of ^{90}Sr and ^{35}S were evaluated following the upgrade of the nuclides' analyses.
- The computerization of control charts for liquid scintillation counter instrumentation began in 1988. Control charts provide a probabilistic approach to identify problem areas in an analytical process.
- According to audit results, all of the gas analyzers in the air quality stations produced satisfactory results in 1988.
- Fourteen of 16 total suspended particulate samplers were satisfactorily calibrated. The two samplers that were not were adjusted and recalibrated.
- During 1988, 68 blanks and 288 duplicate and quadruple samples were analyzed for various parameters. Less than 5% difference was reported between the duplicates.
- In 1988, SCDHEC performed eight NPDES compliance audits at SRS during seven monthly visits and one comprehensive annual survey. Of over 900 parameters monitored, SRS received a satisfactory rating on all but one sample parameter.
- An internal standard is now used to calibrate liquid scintillation counters for quench correction for ^{3}H, ^{32}P, ^{35}S, ^{91}Y, and ^{147}Pm analyses.

Part III

Environmental Management and Research Programs

11
Savannah River Site Environmental Management Programs

SUMMARY—This chapter reviews the extensive SRS environmental management programs at the Savannah River Site (SRS) during 1988.

The Savannah River Site (SRS) has developed a comprehensive Environmental Implementation Plan (EIP) that sets specific site environmental policies, objectives, and implementation strategies for the next five years. To provide guidance to SRS operations, the Environmental Protection Section (EPS) drafted a NESHAP Radionuclide Compliance Manual during 1988. In November 1988, the South Carolina Department of Health and Environmental Control (SCDHEC) regulations required that all personnel involved in asbestos projects be licensed.

Working groups were developed to provide a coordinated approach for the preparation of an Environmental Impact Statement (EIS) for a new production reactor proposed by the DOE to Congress in August 1988.

Special environmental programs were initiated in 1988. The SRS Environmental Awareness Program was conducted in April 1988. This program is designed to inform site employees of environmental programs at SRS. The objectives of the sitewide program include publicizing environmental goals, providing information on environmental protection activities, and coordinating sitewide environmental awareness activities. In addition, a new program designed to inform the public of environmental activities and research at SRS was initiated in 1988. "Environmental Outreach" focuses on the impact of SRS operations on the environment, highlighting environmental protection performance and waste management practices.

The Needs Assessment Plan (some components originating from the Glenn Plan) was submitted to DOE/HQ in December 1988. The document contains detailed information on the environmental, safety, health, and waste management needs for SRS from 1989 to 1995, and estimates for needs beyond 1995.

Environmental oversight by DOE Savannah River Site Environmental Division (DOE/SR-ED) of SRS facilities expanded considerably compared to 1987. WSRC also developed a sitewide coordinated internal environmental appraisal system focusing on management, facility, and program appraisals.

ENVIRONMENTAL PROTECTION PROGRAMS

Environmental Implementation Plan

The Savannah River Site (SRS) has developed a comprehensive Environmental Implementation Plan (EIP) that sets specific site environmental policies, objectives, and implementation strategies for the next five years. The EIP provides an integrated approach to SRS environmental programs. The plan outlines specific programs to maintain air quality, prevent surface water and groundwater contamination, manage waste handling, treatment, storage and disposal, and protect wildlife. The site's environmental program manpower and budget requirements are also established by the EIP.

AIR QUALITY PROGRAMS

NESHAP Issues

SRS reviewed and submitted comments to the Environmental Protection Agency (EPA) on their proposed rule-making for benzene under Section 112 of the Clean Air Act. Benzene was the first chemical proposed for National Emissions Standards for Hazardous Pollutants (NESHAP) regulation in which EPA must weigh health effects above cost in setting air standards. The rule was expected to have major implications for subsequent NESHAPs, most notably for radionuclides.

The Environmental Protection Section (EPS) drafted a NESHAP Radionuclide Compliance Manual during 1988. The purpose of this manual is to provide guidance to SRS operations on regulation requirements, administrative procedures that will enhance regulatory compliance, and technical guidance in preparing applications for EPA approval. The manual is scheduled to be issued in 1989.

Because of NESHAP regulation requirements for new facilities that have radioactive emissions, several new facilities at SRS were required to have a permit for construction and operation. SRS applied to EPA for approval to construct and operate these new facilities. SRS received the construction and operation NESHAP approval for the F- and H-Area Effluent Treatment Facility (ETF) in March 1988. EPA issued the construction and operation NESHAP approvals for the Defense Waste Processing Facility (DWPF) and Replacement Tritium Facility (RTF) in April and May 1988, respectively. Conditional approval was received from EPA in September 1988 for the construction and operation permit for the Uranium Solidification Facility (USF). A NESHAP application was prepared and given to DOE for the proposed Consolidated Incineration Facility. DOE submitted the reviewed application to EPA in September 1988.

Asbestos Abatement License

The South Carolina Department of Health and Environmental Control (SCDHEC) regulations require that all personnel involved in asbestos projects be licensed. The application package for this license was submitted to SCDHEC in November 1988. SCDHEC is scheduled to issue a sitewide license for SRS operations and construction personnel who were properly trained in asbestos work by the end 1988. A total of 416 asbestos projects were performed during 1988 with 307,000 square ft and 37,500 linear ft of asbestos containing material removed and disposed.

SURFACE WATER PROGRAMS

Thermal Mitigation

A recirculating cooling system was selected by DOE as the preferred alternative for thermal mitigation of K-Reactor cooling water discharges to Indian Grave Branch in the Record of Decision (ROD) for the Final Alternative Cooling Water Systems Environmental Impact Statement issued in February 1988. Draft schedules for funding and construction of the system were provided to DOE. Negotiations with SCDHEC concerning the alternative system, consent order, and permit application requirements were conducted throughout the year.

NPDES Compliance

Monitoring of physical, chemical, and biological characteristics of SRS effluents is required by SCDHEC under the National Pollutant Discharge Elimination System (NPDES). Seventy-one active outfalls were monitored by the NPDES permit program in 1988. This program included monitoring of the F- and H- Area ETF and the TNX Effluent Treatment Plant (ETP), both of which became operational in late 1988. SRS had a 99.8% compliance rate in 1988 which met the site goal. This is a continued improvement over the 1987 compliance rate of 99.7% and the 1986 compliance rate of 99.4%. Only 14 of the 6,250 NPDES analyses performed exceeded permit limits. This represents a reduction from the number recorded during 1987 (20). The SRS application to renew the NPDES permit was submitted to SCDHEC in June 1988.

NATIONAL ENVIRONMENTAL POLICY ACT (NEPA) ACTIVITIES

Preparation of NEPA Documentation for SRS/SRL Activities

The National Environmental Policy Act (NEPA) of 1969, the Council on Environmental Quality implementing regulations (40 CFR 1500-1508), and DOE guidelines (52 FR 47662) require the early consideration of environmental factors during the planning and assessment process for all proposed federal actions. The NEPA Group of EPS is responsible for preparation and coordination of NEPA documenta-

tion for SRS/SRL activities under oversight from DOE-Savannah River (DOE-SR). The NEPA group manages the transmittal of NEPA document recommendations and information to the DOE-SR, with approval of the SRS/SRL management required for all formal transmissions. DOE is then responsible for determining the appropriate level of documentation.

In 1988, the NEPA Group reviewed 317 SRS/SRL proposed activities for potential environmental effects. The NEPA and Permits groups of EPS reviewed the SRS/SRL NEPA, safety analysis, and permits checklists for these activities to determine a recommended level of NEPA documentation for DOE-SR and for permitting requirements. DOE-SR issued 9 Memoranda-to-File (MTF) for projects based on draft MTFs prepared by SRS personnel. The final Environmental Assessment (EA), Management Activities for Retrieved and Newly Generated Transuranic Waste—SRS (DOE/EA-0315), was issued in August 1988. The NEPA Group is preparing a draft EA for the Consolidated Incineration Facility. Following completion of the EA, a determination will be made whether to issue a Finding Of No Significant Impact (FONSI) or to begin preparation of an Environmental Impact Statement (EIS).

NEPA Review for New Production Reactor Capacity

Working groups were developed to provide a coordinated approach for the preparation of an EIS for a new production reactor proposed by the DOE to Congress in August 1988. Public meetings on the scope of the EIS were held by DOE-SR during December in Aiken and Columbia, SC, and in Augusta and Savannah, GA. Public concerns included the need for tritium, alternate sources of tritium, waste management issues, reactor safety, emergency response, and potential long term effects on local residents.

GROUNDWATER PROTECTION

Water Resources Management

Management of the underground water resources at SRS is a very important part of the groundwater protection program. A Water Resources Management Plan is being developed to provide specific direction on ways to manage the quantity (and quality) of groundwater supplies. A planning guide (Hubbard et al., 1988) on water resources management was issued in October 1988 as the basis for the subsequent proposed plan. Issues such as hydrogeologic regime, impact consumption goals, hydraulic relationships among aquifer systems, geographic location of pumping centers, and predictive groundwater plan modeling will be addressed in the final plan. [Hu88]

Groundwater Monitoring

Several important groundwater monitoring issues were addressed during 1988. Piezometer installation specifications and the procedure for a work clearance permit, both to be incorporated into the hydrogeologic data collection procedures (DPSOP 254), were issued. In May, a plan was issued describing the function and organization of the Groundwater Monitoring Program. In October, the results of an investigation into possible causes of elevated pH in monitoring wells were issued in a report entitled "Review of Monitoring Wells Exhibiting Elevated pH in F- and H Areas". The issue of purged water from monitoring wells at SRS was addressed in November 1988 in a draft plan transmitted to DOE.

Water Quality and Consumption Reporting

As required by environmental regulations, reports on groundwater quality were prepared and submitted during 1988. Three quarterly reports and an annual report were prepared to satisfy the assessment reporting requirements for the F- and H-Area Hazardous Waste Management Facilities (HWMF). The same sets of reports (quarterly and annual schedule) were prepared to comply with corrective action reporting requirements for the M-Area HWMF. Two groundwater quality reports on the Sanitary Landfill were prepared and submitted on a semi-annual basis.

The Water Resources Commission of South Carolina requires that quarterly reporting of pumpage be made on any well which produces more than 100,000 gal/day. During 1988, four quarterly reports were compiled on water usage from nearly 50 production wells.

Underground Storage Tanks

The DOE/SCDHEC Memorandum of Agreement (April 1985) was amended in May 1988 granting SCDHEC regulatory control of underground storage tanks containing petroleum products. The SCDHEC regulations require that inventory records be kept for all tanks. The first permit package prepared under the new underground storage tank regula-

tions was submitted to SCDHEC in March 1988. The permit package covered the replacement of the Central Services Works Engineering (CSWE) underground fuel storage tanks at all plant service stations. The permit was received in May 1988.

Numerous underground storage tanks were tested throughout the site during 1988. Leaking tanks were either removed or abandoned-in-place. Contaminated soils were removed for proper disposal. Groundwater monitoring programs were implemented in certain instances with the concurrence of DOE and SCDHEC. EPA promulgated final underground storage tank regulations in September 1988 which require a phased-in upgrading of existing tank systems over a ten year period.

RCRA/CERCLA PROGRAMS AND WASTE SITES

Waste Site Closure

Fourteen nonhazardous waste management units were closed prior to 1989 as required by SCDHEC. During 1988, seven nonhazardous waste sites were closed and plans for closing 12 nonhazardous sites were approved.

Completion of the M-Area Settling Basin and Lost Lake closure is scheduled for 1989. Closure plans for the F- and H-Area Hazardous Waste Management Facilities were submitted to SCDHEC and are awaiting approval.

The Post-closure Care Permit Application for the F- and H-Area Hazardous Waste Management Facilities is being developed. Closure plans are being written for the Metallurgical Laboratory Basin, the F-, H-, K-, and P-Area Acid/Caustic Basins, the new TNX Seepage Basin, and four Savannah River Laboratory Seepage Basins.

An MTF for the Mixed Waste Management Facility Closure was issued on November 1988. The MTF satisfies the NEPA documentation requirements by including closure details in addition to those covered in the EIS, "Waste Management Activities for Groundwater Protection at SRS."

Waste Site Activities

Since August 1987, 46 new waste sites have been identified. Over 85% of the sites are "housekeeping sites" composed of inert rubble, while seven sites were identified as candidates for the RCRA Facility Investigation (RFI) Program.

Comprehensive Environmental Response Compensation and Liability Act (CERCLA) preliminary assessments for 66 SRS potential CERCLA sites were submitted to EPA Region IV. Site inspections were not required. DOE-SR, EPA Region IV, and SCDHEC are currently negotiating an interagency agreement under CERCLA Section 120, which will outline procedures for cleanup actions at the site.

RFI Program

The RCRA Part B Permit issued in 1987 required SRS to conduct RCRA Facility Investigations (RFI) at 65 waste sites to determine if environmental impacts have occurred that require remediation. An RFI plan was prepared and submitted to EPA and SCDHEC. The plan was revised and resubmitted in November 1988 and the EPA described the plan as an "excellent framework for investigation." Approval of the plan is pending. An additional 10 sites are proposed for addition to the RFI list, bringing the total to 75 sites.

Preliminary evaluations under the RFI have been completed for 65% of the sites. Site screening plans were developed for 31 sites. The background soil study was completed by SRL and is in draft form. Soil cores taken at the waste sites will be compared to background soil values to determine the next step in the site-specific investigations. The RFI program schedule requires all 75 sites have a site-specific work plan for investigation within 24 months of program approval.

CERCLA 'Superfund' Reportable Spills

In 1988, as in 1987, the site had no Superfund reportable spills of hazardous substances. The last Superfund reportable spill at SRS occurred in January 1986. This makes almost three years without a Superfund reportable release of hazardous substances to the environment.

Waste Minimization Program

In 1988, SRS initiated a program to consolidate Waste Minimization (WMin) activities and develop a centralized WMin program for the site. The program goal is to minimize the amount of solid waste generated by SRS operations.

The site strategy includes the implementation of departmental and facility-specific WMin programs to: 1) identify and characterize SRS solid wastes; 2) prioritize all waste streams for minimization projects; and 3) evaluate and implement methods to reduce or eliminate waste generation. Source reduction and recycling will be emphasized as top priorities for reducing waste generation.

A draft Site Waste Minimization Plan has been completed and a Site Waste Minimization Guidance Manual is currently under development. SRS is also developing training, awareness, and resource materials to support WMin activities. The WMin program is a proactive approach to the increasing national and community emphasis on waste minimization.

Environmental Awareness/Training Program

The SRS Environmental Awareness Program was initiated in April 1988. The objectives of the sitewide program include publicizing environmental goals, providing information on environmental protection activities, and coordinating sitewide environmental awareness activities. In August, the first onsite Environmental Awareness Day for employees was held. The day's theme was "Savannah River Plant: Protecting the Future." Several thousand SRS employees attended the Environmental Awareness Program which featured speakers, poster displays, videotape presentations, and opportunities for a first-hand view of environmental surveillance equipment (TRAC mobile laboratory, spill response equipment, and environmental monitoring equipment). Similar activities were held on the same day in other areas on a smaller scale.

Families of SRS employees were also involved in environmental awareness during 1988. More than 200 children of employees took part in a logo coloring activity with each child receiving a certificate, ribbon, and letter encouraging them to protect their future by protecting the environment.

A new program designed to inform the public of environmental activities and research at SRS was initiated in 1988. "Environmental Outreach" focuses on the impact of SRS operations on the environment, highlighting environmental protection performance and waste management practices. The program includes talks by representatives from DOE, SRS, SRL, Savannah River Ecology Laboratory (SREL), and the Savannah River Forest Station (SRFS), and a tour of the site. Local and state public officials and members from a local chapter of the Sierra Club were the first two groups to attend the day-long program. Future visits by national and local media, civic organizations, and other environmental groups are planned in 1989.

State and local public officials from Georgia and South Carolina attended the first "Environmental Outreach" held at SRS

In December 1988, the SRS Fire Division hazardous materials (HAZMAT) Response Team and CSWE "Spill Busters" HAZMAT Response Team promoted environmental awareness by displaying new environmental protection equipment during an open house.

EPS continued to assist line management by providing and developing the following environmental training enhancements to meet regulatory requirements:

- Environmental protection orientation was provided to more than 2,100 persons through the upgraded First Line Supervisor Training Program, the New Exempt

Employee Orientation Seminar, the Contract Administration Workshop, and the Subcontractor Orientations Program. About 75% of these participants were new to the site. Feedback from the presentations affirmed improved employee awareness of potential environmental impacts.

- Three specialized courses "Fundamentals of RCRA," "OSHA 1910.120 Overview," and "Regulatory Training for Management of Hazardous Waste," were offered to over 50 environmental professionals onsite.

- RCRA training coordinators were provided a site-specific videotape (Hazardous Waste Training) and background materials for initial training and annual retraining of personnel handling hazardous waste and mixed waste at SRS staging areas.

- A pilot project was initiated to evaluate the use of computer-assisted instruction (CAI) technology as a means to provide effective environmental training sitewide. "Spill Response Training" was chosen as the initial subject area since a previous assessment indicated that appropriate, applicable training materials were not commercially available.

OTHER ENVIRONMENTAL ACTIVITIES

Glenn Report and Needs Assessment Plan

The Needs Assessment Plan (some components of which originated from the Glenn Plan) was submitted to DOE/HQ in December 1988. The document contains detailed information on the environmental, safety, health, and waste management needs for SRS from 1989 to 1995 as well as estimates for needs beyond 1995. The SRS long-range plan was combined with plans from other DOE sites in a report for U. S. Senator John Glenn.

External and Internal Oversight of Environmental Programs/Facilities

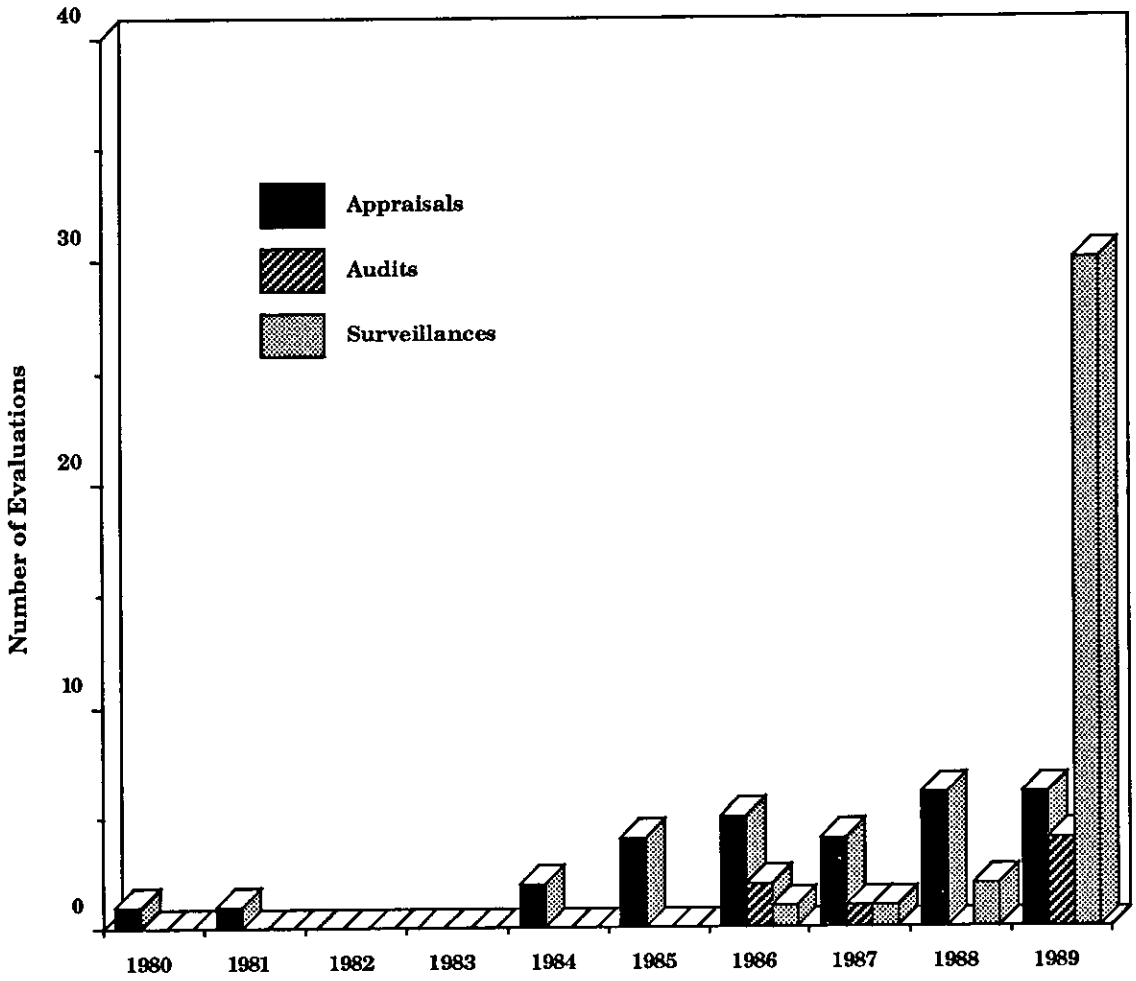
Environmental oversight by DOE Savannah River Site Environmental Division (DOE/SR-ED) of SRS facilities expanded considerably compared to 1987. As in recent years, these oversight evaluations were conducted under DOE/SR-ED's Comprehensive Environmental Protection Appraisal Plan (CEPAP). Ten major CEPAP evaluations were conducted in 1988, covering such areas as solid/hazardous waste, water supply, air/water pollution, groundwater wells, and radiological sampling. These evaluations consisted of a site-wide inspection of SRS hazardous waste satellite accumulation and staging areas, and environmental functional appraisals of the following topics: nonhazardous solid waste management; water supply treatment operator certification; nonradiological air pollution control-emission sources; Savannah River Ecology Laboratory (SREL) radiological and hazardous waste management; water pollution control-discharge of dredged or fill material; water pollution control-NPDES; hazardous waste management-sources and waste streams; environmental radiological programs-environmental sampling; and groundwater facilities and services.

DOE/SR-ED also continued to conduct short term, narrowly focused evaluations in 1988. Efforts were initiated to document these evaluations using formal surveillance procedures adopted from Quality & Materials Assurance Division (QMA) for use in CEPAP. Surveillances initiated by DOE/SR-ED in 1988 included the following: surveillance of the P-Reactor tritium release of October 14, 1988, surveillance of the K-Reactor tritium release of November 17, 1988, P-Reactor tritium release of December 16, 1988, K-Reactor restart database safety objectives, environmental surveillance conducted at the D-Area Oil Staging Area, surveillance of the DWPF well pump replacement, and M-Area Settling Basin force main in the treatment system.

The following functional final appraisal reports by DOE/SR-ED were issued in 1988: the 1987 NEPA appraisal, hazardous materials transportation appraisal, environmental radiological programs: atmospheric releases effluent monitoring appraisal, and the wastewater treatment operator certification appraisal. The majority of findings from these appraisals dealt with administrative procedures. None of the findings represented an imminent threat to human health or the environment. Corrective actions in relation to the findings are currently being implemented and verified.

In related matters, DOE-HQ conducted a follow-up visit to verify the status of the findings from the 1987 HQ Environmental Survey. Many of the findings were informally closed, with DOE-HQ formal closure procedures pending.

External surveillance by EPA and SCDHEC continued in 1988. EPA conducted Compliance Evaluation



The number of appraisals, audits, and surveillances of SRS programs and facilities increased in 1988, particularly in the area of external surveillance by state and federal agencies

Inspections from April through May and responses to four findings were provided. The SRS 1988 performance in the annual EPA inspections was better than in 1987. In addition to numerous routine evaluations, SCDHEC conducted three major inspections in 1988. Two of the inspections were sanitary surveys, conducted in the D-Area Surface Water Treatment Plant and on the drinking water systems (wells). SCDHEC also conducted an annual NPDES compliance inspection, siting only one non-compliance.

Du Pont Petrochemicals Department conducted an independent multimedia program review of environmental programs. Most of the findings were administrative issues sited under the RCRA program.

WSRC also developed a sitewide coordinated internal environmental appraisal system focusing on management, facility, and program appraisals. The first annual management environmental appraisal was conducted on 14 site organizations by the EPS from May through August 1988. Results of the appraisal were provided to DOE/SR in November 1988. Facility appraisals, although not new to many site organizations, were scheduled for the first quarter 1989 by environmental coordinators within each site organization. Routine program appraisals will comprise detailed field compliance appraisals by EPS program specialists over a three-year cycle, or when necessary. The new program provides enhanced documentation and comprehensive coverage of SRS programs. Implementation is scheduled for 1989.

1988 HIGHLIGHTS

- SRS reviewed and submitted comments to the Environmental Protection Agency (EPA) on their proposed rule-making for benzene under Section 112 of the Clean Air Act. Benzene was the first chemical proposed for NESHAP regulation in which EPA must weigh health effects above cost in setting air standards.
- A Water Resources Management Plan is being developed to provide specific direction on ways to manage the quantity and quality of groundwater supplies.
- Fourteen nonhazardous waste management units were closed prior to 1989 as required by SCDHEC. During 1988, seven nonhazardous waste sites were closed and plans for closing 12 sites were approved.
- The RCRA Part B Permit issued in 1987 required SRS to conduct RCRA Facility Investigations (RFI) at 65 waste sites to determine if environmental impacts have occurred that require remediation. The approval of a plan issued by SRS is pending and an additional 10 sites are proposed for addition to the RFI list.
- SRS initiated a program to consolidate Waste Minimization (WMin) activities and develop a centralized WMin program for the site. The program goal is to minimize the amount of solid waste generated by SRS operations.
- DOE-HQ conducted a follow-up SRS visit to verify the status of the findings from the 1987 HQ Environmental Survey. Many of the findings were informally closed, pending formal closure procedures.
- DOE/SR-ED performed 10 major CEPAP evaluations and issued four evaluation reports.

12
Savannah River Laboratory Environmental Management and Research Programs

SUMMARY—This chapter reviews program results from the Savannah River Environmental Technology Division and the Savannah River Environmental Sciences Division. (1) The Environmental Technology Division developed an EPA approved stack sampling and analysis protocol for the H- and F-Areas' Effluent Treatment Facility (ETF) and the Defense Waste Processing Facility (DWPF) to demonstrate compliance with the NESHAP radionuclide emission standards promulgated in 40 CFR 61.

The division's emergency response planning included the linking of the Remote Environmental Monitoring System (REMS) with the WIND system so that radioactivity release information can be received from all major SRS facilities. Programs continued in radiometrics detector development, radionuclide effluent studies, and atmospheric research, which was centered on the STABLE (Stable Atmospheric Boundary Layer Experiment) program to understand the dispersion of contaminants.

(2) The Savannah River Environmental Sciences Division undertook research activities at L Lake to meet Environmental Impact Statement requirements, and an extensive waste management and groundwater protection program which included preparation of the Part B Permit Application and Closure Plan for the Metallurgical Laboratory Basin.

The groundwater protection program encompassed the SRS Aquifer Characterization study, a continuation of the SRS Baseline Hydrogeologic Investigation completed in 1987, and the modeling of groundwater flow at SRS. Special studies of the fate and effect of pollutants from SRS focused on remote sensing surveys and development as a means of environmental monitoring of large areas, the transport and cycling of tritium in the environment since tritium releases account for about 85% of the offsite radiation dose to man from SRS activities, and the Microbiology of the Deep Subsurface Program to demonstrate the presence and diversity of microorganisms associated with the sediments of the terrestrial deep subsurface.

SAVANNAH RIVER ENVIRONMENTAL TECHNOLOGY

Radionuclide Effluent Studies

Long-Lived Airborne Radioisotopes. Carbon-14 sampling equipment was installed at the H-Area separations facility. Similar sampling equipment has been in operation in the F-Area separations facility for the past several years. In cooperation with the Reactor Technology Department, a new ^{14}C sampling system was designed and will be installed in all three functional reactors (P, K, L) by the end of the first quarter of 1989.

Iodine-129 monitoring for EPA compliance continued at both separations areas and was initiated in the three reactor areas. Existing Environmental and Health Protection (EHP) sampling equipment was utilized for this purpose.

Uranium Analysis by Laser Fluorescence. A large number of samples analyzed for uranium content by the Environmental Technology Division

(ETD) do not require the reporting of isotopic distribution or, in some cases, activity of the sample. In order to relieve a portion of the workload currently held by the mass spectrometry facility and the alpha-counting equipment a Chemcheck KPA-10 uranium fluorescence analysis system was installed. Though able to analyze for only gross chemical uranium, sample preparation time is generally on the order of a few minutes for most samples and sensitivity is close to that of the semiconductor alpha-counting system.

ETF/DWPF Stack Monitoring. The EPA requires the F- and H-Areas Effluent Treatment Facility (ETF) and the Defense Waste Processing Facilities (DWPF) to conduct a series of stack tests within 90 days of facility startup to verify compliance with the National Emission Standard for Hazardous Air Pollutants (NESHAP) radionuclide emission standards promulgated in 40 CFR 61. The ETD developed an EPA-approved sampling and analysis protocol to demonstrate compliance with the standard. Unique sample collection systems and analysis techniques were developed to collect and analyze filterable particulate radionuclides, radioactive iodine, and tritium. The sampling and analysis protocol was defended through (DOE) review and was approved by EPA. ETD began limited operations October 14, 1988. Sample collections in two ETF stacks and radiometric analyses to verify compliance with requirements in the NESHAP licensing agreement began on December 14, 1988. During spring, 1989, compliance tests will be conducted in the Z-Area Saltstone facilities Tank 50, Low Point Drain Tank, Saltstone Process stack, and the Saltstone Operations Building stack.

1988 Radiometric Analyses of SRS and Plant Vogtle Effluents in Savannah River. Trace radionuclide concentrations in the Savannah River are continually studied to distinguish between the effluent contaminants from SRS and the Georgia Power Company Plant Vogtle nuclear reactor. During 1988, radionuclide concentrations of these effluents were well below DOE guide values. The largest gamma component in the Vogtle effluent was ^{58}Co and its maximum concentration was 15.5 pCi/L, far below the DOE guide of 40,000 pCi/L. The maximum radionuclide concentrations in the SRS effluents were 3,000 pCi/L tritium and 0.4 pCi/L ^{137}Cs, also well below the DOE guide levels of 2,000,000 pCi/L tritium and 3,000 pCi/L ^{137}Cs. These low-level radiometric studies continue to provide early detection to avoid potential hazards.

The radionuclide concentrations in the river are appraised using several methods. Previously the most sensitive method was to collect samples on resins for about two weeks and then count them overnight on high purity germanium (HPGe) and sodium iodide (NaI(Tl)) detectors in the ETD Underground Counting Facility (UCF). Periodic sediment samples were also counted in this fashion. A more real time sampling mode has involved consecutive one-day counts with an underwater NaI(Tl) detector located on the ETD monitoring platform at Highway 301 bridge; the activities measured by this underwater detector are in good agreement with those from the resin samples. Tritium concentrations were measured with a low-level liquid scintillation counter.

The results indicate that Plant Vogtle effluents primarily contain only neutron activation products (^{51}Cr, ^{54}Mn, ^{57}Co, ^{58}Co, ^{59}Fe, ^{60}Co, ^{95}Zr, and ^{95}Nb). The SRS effluents primarily contain a small amount of tritium and a single fission product (^{137}Cs).

Radiometrics Detector Development

91% Efficient HPGe Detector. An ultra-low-level HPGe gamma detector with 91% efficiency relative to a 3 in × 3 in NaI(Tl) detector has been specially developed for use in the Underground Counting Facility (UCF). The detector is more than three times as efficient as current UCF detectors, and further background reduction is planned using an active/passive low-level gamma ray shield. This shield is designed to have an outer plastic scintillator to actively cancel cosmic background events, while an inner shield of low-level lead will ensure that radiations from the sample do not cause unwanted cancellation signals. This detector system should improve the lower-level detection limit by at least a factor of five and thus enhance the analyses of environmental samples.

Underwater Sodium Iodide [NaI(Tl)] Detector. This detector system collects one gamma spectrum/day for two to three weeks in an unattended mode and stores the spectrum on a disk using an automatic sequencing program of an on-location personal computer. The disk with the spectral files is then returned to the lab for analysis, while a new disk collects the next series of gamma spectra. Remote data monitoring via satellite communication to a laboratory terminal is being explored as a means for improving the overall operation.

Underwater sodium iodide [(NaTl)] detector

Underwater HPGe Detector. An underwater HPGe detector with 30% efficiency, 2.5 keV resolution, and peak/compton of 45/1 is scheduled for field service in 1989. This detector will operate on board a new pontoon boat platform for river and lake monitoring. The boat is being outfitted with a special trap door for lowering the detector into the water. The system will be useful for tracking effluents in near-real-time incidents and for mapping locations for long-term aqueous samplers.

Real-time Aqueous Tritium Monitor. A tritium detection system is being developed to monitor nonroutine continuous aqueous effluent low-level tritium releases that would provide adequate time to mitigate the potential problem. The goals of this project are to develop a liquid tritium monitor capable of detecting a concentration of 2,000 pCi/cc within two minutes, detecting changes at the 2 pCi/cc level in a 24-hour period, and measuring concentrations within 10% at the 7 pCi/cc level in a 24-hour period. A system has been developed that is capable of detecting an upset at 2,000 pCi/cc concentrations. However, the system can not reliably quantify the release until the 7,000 pCi/cc level is reached. Current research to overcome this lack of sensitivity involves the development of ultra-thin plastic fiber scintillators and pulse shaping techniques. Completion of the system field test is scheduled for 1989.

Particulate Effluent Studies

Stack Effluent Measurements at F Area. Measurements of activity and particle size relationships were made on effluents from the 772-F Area stack. Total activity versus particle size was determined by using a cascade impactor and analyzing the stages of the impactor with alpha and gamma spectrometry. Normal effluent from the stack passes through HEPA filters and the primary activity detected in the effluent was from submicrometer sized particles. Material collected in the local stack environment which had associated trace alpha activity, was examined by optical microscopy and electron microprobe. The material contained some iron particles associated with zinc which indicated galvanized material such as commonly used in air ducts. Although most of the ducting in the facility is fabricated from stainless steel, some air ducts were found to be fabricated from galvanized sheet metal. Many stainless steel particles were also present in the environmental samples examined by electron microprobe. Plans are in effect to replace these ducts containing galvanized steel.

Mass Spectrometry Environmental Research

Ultra-low-level Tritium and Helium Analyses. A previously developed high sensitivity $^3He/^4He$ mass spectrometer is used as an indirect detector in a scheme to confirm very low concentrations of environmental tritium. Water samples are collected directly or by removing moisture from air with absorbents. Trapped background helium is removed from the sample by vacuum degassing, and the sample is then sealed to allow ^3He to accumulate from tritium decay. After a suitable delay (30 to 120 days), the helium is extracted for measurement in the mass spectrometer. The $^3He/^4He$ mass spectrometer is also used to measure the variation of the atmospheric helium isotope ratio in a variety of small air samples. Studies are in progress on hourly, daily, and weekly time scale variations at one site, as well as geographic variations from many sites. The resulting data sets will be useful in studying very low concentrations of atmospheric tritium and understanding deviations in future measurements.

Plutonium Bioassay. High sensitivity isotope dilution mass spectrometric (IDMS) methods were developed to measure plutonium in body fluids. IDMS

bioassay methods are more than 1,000 times more sensitive than ultra-low-level counting techniques.

Long-Lived Isotope Mass Spectrometry. An expansion of the ultra-low level mass spectrometer laboratory facilities is in progress. The laboratory will provide space for four additional mass spectrometers when completed in 1989. The first facility will hold an existing single stage thermal ionization mass spectrometer (TIMS) that is being upgraded for ultra-low-level isotopic analyses.

Noble Gas Mass Spectrometry. The design and construction of a mass spectrometer to measure the nonradioactive fission-product isotopes of krypton and xenon at ultra-low -levels in the environment is currently in progress. Direct measurement of these isotopes will permit an accurate assessment of environmental releases of the short-lived radioactive xenon and krypton isotopes.

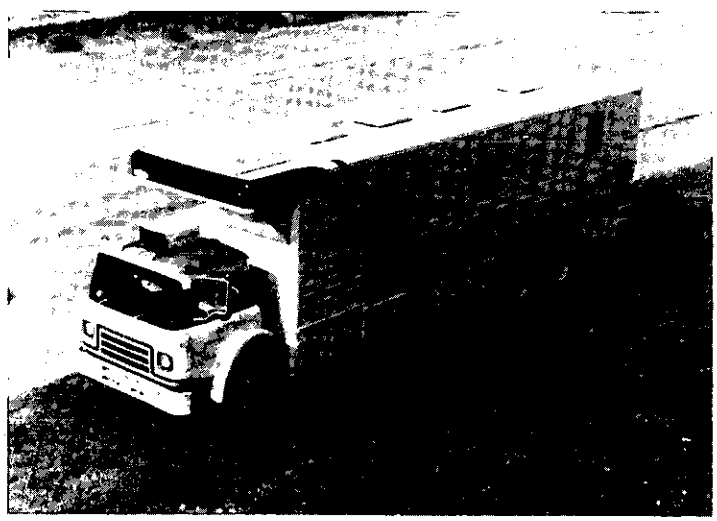
Long-Lived Iodine-129 Measurement. A laser technique is being investigated for use with low-level ^{129}I detection. The method avoids the use of an operating nuclear reactor necessary for the usual environmental level neutron activation detection technique.

Emergency Response Systems

Remote Environmental Monitoring System (REMS). Several advances were made to the Remote Environmental Monitoring System (REMS). Radiation monitors installed in the stacks of the reactor and separations areas were linked to the Weather INformation and Display (WIND) system computer. With the inclusion of these signals, the WIND system can now receive radioactivity release information from all major SRS facilities (tritium facilities, separation areas, and reactor areas). In addition to these signals, the WIND system computer is also linked in real time to river and stream monitoring data, L-Lake thermal monitoring data, meteorological data, and SRS perimeter radiation monitors. When fully implemented, this system will provide automatic monitoring of abnormal stack releases from all process facilities, and automatic inclusion of these source terms in the emergency response codes.

WIND System. The SRL computer programs used for emergency response in the event of a reactor incident have been extensively revised. The revisions provide upgraded and improved SRL emergency response capabilities by establishing standalone modularized programs that facilitate maintenance and modifications. The revisions also provide an improved user interface by eliminating all nonessential user interactions and retaining all essential options. The new user interface utilizes the VAX Forms Management System which facilitates rapid and error-free data entry. Documentation of the program is integrated into the source program such that the intent of each program module is clear, making essential documentation permanently available. Additional features of the program include the automatic archiving of all I/O data, laser-printed hard copy of text and graphics and concurrent color displays for rapid visual assessments. Additional software also provides enhanced color graphic displays of dose distributions, including spatially distributed doses from gamma shine. These programs are now being evaluated for quality assurance before being placed into service.

This year preparations were made to move the WIND system computer to a new computer room in 1989. The new computer room is controlled for humidity and temperature to assure more reliable operation of the computers. Two new VAX 8550 computers were purchased to replace the VAX 11/780 and 11/750. These new computers were needed to assure continued reliable operation and to accommodate the improvements that are being made in the software and the increased sensors that are being linked to the system.



TRAC mobile laboratory

Geographical Information System. United States Geological Survey (USGS) map data bases are being installed for use with the new Geographic Information System (GIS). The GIS will link these map data with output from the emergency response codes. Coupling of the data will provide and display information on population distribution and dose, road networks, routing and location of emergency response vehicles, land use, topography, and maps of the impact regions.

TRAC Mobile Lab. The Tracking Atmospheric Contaminants (TRAC) mobile laboratory underwent various equipment upgrades during 1988. The upgrades included the installation, calibration, and operation of the terrestrial monitors, the replacement of all hard-wired multichannel analyzers with computer-based data acquisition and analysis systems, and the development of a back-up method for collecting and analyzing tritium oxide (HTO). Many refinements to the data acquisition modes for the terrestrial and plume monitor detector arrays were accomplished using multichannel scaling (MCS) techniques. These enhancements alert the TRAC personnel to changes in general area radiation dose rates in real-time. Off-line data analysis of these MCS spectra combines the LORAN navigation coordinates with the wheel counter data to normalize the TRAC movements out of the time spectra and results in scans of observed count-rate versus distance from known landmarks. These data were used to construct detailed background dose rate maps along the major roadways on site.

Atmospheric Research: STABLE (Stable Atmospheric Boundary Layer Experiment)

Atmospheric research during 1988 was centered around the STABLE program. The STABLE (Stable Atmospheric Boundary Layer Experiment) is an effort to understand how turbulence and diffusion in the stable boundary layer (SBL) affect dispersion of contaminants. The stable planetary boundary layer is the warm layer in the night air. Lying just above the ground, it is cooled by contact with the cold ground. DOE-affiliated laboratories (SRL, the Atmospheric Turbulence and Diffusion Laboratory, Lawrence Livermore National Laboratory, and North Carolina State University) are participating in the research.

The first field program under project STABLE was completed April 18, 1988. The goal of this field program was to investigate the structure of the nocturnal planetary boundary layer, to measure dispersion, and to find cases of turbulent episodes which influence vertical transport. Measurements of turbulence were made every five seconds with cup anemometers and bivanes on the 300 m WJBF television tower and the SRS area towers. Sonars were also operating at two locations. Horizontal dispersion was determined by real time monitoring of an atmospheric passive tracer gas, sulfur hexafluoride (SF-6), released through a 61 m stack and measured by continuous analyzers aboard the TRAC van and another instrumented van. Heat flux was measured with a sonic anemometer and momentum flux with a three-component propeller anemometer. Dispersion model evaluation was done by Lawrence Livermore National Laboratory (LLNL). LLNL transmitted Atmospheric Release Advisory Capability (ARAC) model results back to SRL via computer link. Preliminary analysis of data collected during the experiment emphasized the complex nature of dispersion in the nocturnal stable boundary layer.

Aqueous Research

Stream Studies. A program was started in 1988 to measure the travel times, velocities, and dispersion coefficients for each of the major SRS streams. These coefficients are used in the aquatic emergency model to predict downstream and river concentrations for unplanned releases from SRS. The siting of new outfalls and changes in SRS water release operations require that these coefficients be measured every few years.

These coefficients are measured in the stream by using environmentally suitable dye tracers (Rhodamine WT). The dye is released upstream of the SRS facilities and dye/time concentration curves are measured at several downstream locations. The travel times, velocities, and dispersion coefficients are calculated using stream and river computer models.

Computer Display of L-Lake Temperature Distributions. A computer program has been developed to calculate and display L-Lake temperature distributions within the mid-lake monitoring field obtained from temperature data transmitted to the SRL Weather Center. This is a continuous high resolution color display that provides a rapid visual assessment of conditions pertinent to regulatory compliance, and is dynamically updated as new data are obtained at hourly intervals. The display is generated by the application of a bivariate interpolation

algorithm over a two-dimensional grid. Each node on the grid corresponds directly to a pixel (unit display area) of the display surface. The display provides information pertaining to temperature distributions, spatially averaged wind speed and direction, percent of the lake surface area less than 90° F, operative temperature sensors, and the date and time.

SAVANNAH RIVER ENVIRONMENTAL SCIENCES

Activities to Meet Permit or Environmental Impact Statement Requirements

L-Reactor Environmental Commitments. Completed in November 1985, L Lake is relatively new when compared to the successional histories of many other regional impoundments. Succession is defined as the structural and functional changes that occur within the lake's communities and the ecosystem as a whole. These internal restructurings respond to several external physical, chemical, and biological forces which include the water quality of the Savannah River input, thermal loads from L Reactor, the depth of withdrawal at the lake's outlet dam, weather conditions including rainfall, cloud cover, and temperature, and the nature of the drainage basin itself. This successional process, occurring in all lakes and often termed "reservoir aging" for impoundments, is best discussed at the community level following the classic divisions of lake communities.

The pelagic region of L Lake contains most of the lake's biomass and is responsible for most of the lake's energy flux. In L Lake, temperatures have ranged between 12°C and 34°C from 1986 through 1988. When the lake was thermally stratified, epilimnetic temperatures were in the range from 14°C to 34°C. Hypolimnetic temperatures were in the 12°C to 28°C range. Temperatures during the fall and early winter of 1988 were obviously lower due to the L-Reactor shutdown. Dissolved oxygen (DO) has ranged from 1 ppm to 6 ppm, similar to other southeastern reservoirs. Correspondingly, pH varied from 6.5 to 10.0 during these periods, which is also comparable to other basins in this region of the United States.

Phytoplankton and zooplankton populations in L Lake reflect regional conditions. During the isothermal winter months diatoms and green algae dominate algal populations, while during thermally stratified periods blue-green species have dominated L Lake. Eutrophic conditions appear to have stabilized in the community with the dominance of the blue-green Microcystis lessening during the summer of 1988. Zooplankton assemblages have remained stable in the lake. Probably due to intense planktivorous fish predation, only smaller species of protozoa and rotifers dominate the lake. Characteristic of many southeastern reservoirs, the genus Daphnia is virtually absent or occurs in very low amounts.

The littoral community, known for its high rates of macrophyte productivity, is an important nursery for juvenile fish and smaller adult species and plays a significant role in physically stabilizing the lake's shoreline. From January through August 1987, five vegetative types of macrophytes were planted in L Lake by Savannah River Ecology Laboratory (SREL) personnel. In October 1987, monitoring efforts with plot counts and remote sensing techniques indicated that the plantings were successful. During 1988, macrophyte coverage of shallow waters continued to increase, providing important habitats for juvenile sunfish and the re-emerging brook silverside.

For the past three years midges (Chironomidae) have dominated the benthic and littoral invertebrate communities. Midges are an important food resource for the redbreast sunfish and bluegill. In addition to the midges, the amphipod Hyalella asteca, common throughout North America, has been another summertime dominant in L Lake. Total macroinvertebrate densities have been comparable to other southeastern reservoirs, including Par Pond.

Successional changes have been apparent in the fish community from the time of L Lake's inception. The present populations are considered healthy and the observed succession in L Lake has been typical of other reservoirs. In the spring of 1988, redsore disease was observed in L Lake and in other regional fish populations. Initially, stream, swamp, and pond species were successful in L Lake. These species included golden shiners, several species of minnows, brook silversides, and mosquitofish. By late 1987, these species decreased and the threadfin shad, a common pelagic species in southeastern U.S. reservoirs, made a significant increase. During 1988 threadfin shad populations continued to increase. Also noted was the return of brook silverside probably due to the increase macrophyte coverage in littoral areas which provide habitat and shelter from predators. Largemouth bass and adult bluegills continue to play an important role as the top key-

stone predators in the lake. During 1988 bluegills and redbreast sunfish shifted in their age distribution with adults being more abundant than during 1987. During the past two years, L-Reactor restarts have caused fish kills in the outfall canal and the upper fourth of the lake. During the 1987 restart, an estimated 27,000 fish were killed during restart. There was no restart fish kill this year because of the L-Reactor shutdown during 1988.

Waste Management and Groundwater Protection

Horizontal Wells for In-Situ Remediation of Groundwater and Soils. A new combination technology using vacuum extraction and air injection will be tested for in-situ remediation of soils and groundwater. Horizontal wells will be utilized to maximize the efficiency of the process. A patent on the new technology was recently granted.

The combination technology consists of an injection well below the water table and a vacuum extraction well in the vadose zone. A vacuum will first be drawn on the shallow well to remove volatile organic contaminants from the soil above the water table. This technology has been previously tested at SRS using vertical wells, and it removed approximately 1,500 lb of solvents over a period of three weeks. After a steady-state concentration is obtained on the vadose-zone well, air will be injected into the deeper well to strip the volatiles into the gaseous phase. The vadose- zone well will continue to operate to collect and extract the organics stripped during air injection.

In 1988 two horizontal wells were installed along an old process sewer line that is known to have leaked volatile organics. The air-injection well was installed below the major portion of the volatile organic plume at a depth of approximately 175 ft. The second well, used for vacuum extraction, was installed in the vadose zone at a depth of approximately 75 ft. The two wells were screened along the entire horizontal lengths of each well. The air-injection well has a horizontal length of approximately 300 ft; the vadose-zone well has a horizontal length of approximately 200 ft.

The drilling of the horizontal wells in unconsolidated materials at very shallow depth for environmental applications is a prototype and required a tremendous effort from a number of different technologies. The two wells were drilled using a rotary mud system with a curved drill guide and flexible drill pipe. The geologic materials that were drilled consist of unconsolidated sands and clayey sands with calculated permeabilities up to 0.09 cm/sec in the cleanest zones. The combination test is expected to begin in the spring or summer of 1989.

Waste Site Closure Support. Technical Data Summaries for the SRL Seepage Basin and the New TNX Seepage Basin were transmitted to DOE for submittal to SCDHEC under the requirements of the Natural Resources Defense Counsel (NRDC) Lawsuit Consent Decree. Site Assessment Reports for the Old and New TNX Seepage Basins were completed in draft form and are currently under review. Preparation of the Part B Permit Application and Closure Plan for the Metallurgical Laboratory Basin is underway; draft copies are scheduled for completion.

Metlab Basin Well Abandonments and Installations: Three existing wells were replaced by four new wells in response to the NRDC Lawsuit Consent Agreement. The existing wells were abandoned and the new wells were installed.

TNX Burying Ground Characterization: The soil boring portion (45 borings) of the characterization plan was completed. Approximately 130 samples were collected and then shipped for analysis. Exploratory trenching was completed at one location and is currently underway at the second of three areas to be trenched. Material discovered at the first trenching area was excavated and hauled off for proper onsite disposal. The installation of seven monitoring wells around the area containing six burial sites was completed in 1988.

Old TNX Seepage Basin Monitoring Well Abandonment Installations and Hydrogeologic Definition: Three geologic cores to the Ellenton Formation were collected and one well was abandoned. Three additional monitoring wells are scheduled for abandonment and three new replacement monitoring wells will be installed.

F/H Effluent Treatment Facility (ETF) Filter Fouling Program. Test runs of the new ETF process resulted in rapid and unexpected fouling of the Norton microfilters. These 0.2 mm pore size filters are designed to remove suspended solids from the wastewater prior to several subsequent treatment steps. Samples of the mock feed water and permeate (filtrate) were examined by a variety of microbiological techniques. Microscopical analyses revealed

massive amounts of flocculent metallic particulates that appeared to be ferric hydroxide. Biological material in the samples was sparse. Only a few bacteria, less than are typically found in drinking water, were detected. It was evident from these results that the fouling was not caused by biological material in the feed water. However, on the basis of these samples, biofouling was not completely ruled out because of the possibility that significant quantities of microorganisms (live and/or dead) could be attached to the filter surfaces, thus influencing fouling.

Additional feed-water samples, electron micrographs showing ceramic filter material after use, and an intact filter unit recently taken out of service were provided to the SRL Environmental Sciences Division (ESD). The feed-water samples were found to be essentially sterile. Few bacteria were observed in the electron micrographs. The filter unit was disassembled to expose the bundle of ceramic tubes that comprises each Norton filter unit. The inner diameter of virtually every tube was coated with an adherent red-brown gelatinous material that appeared to be ferric hydroxide. A few of the tubes were completely clogged with the material. Pieces of the fouled tubing were stained with Acridine Orange and examined by epifluorescence microscopy. Few or no bacteria were observed. Samples of the red-brown material scraped off the tubing were examined microscopically using an inverted microscope. Only particles believed to be ferric hydroxide were observed.

After conducting these examinations, it was concluded by ESD that the fouling of the Norton filters was primarily, if not exclusively, a non-biological phenomenon. This was in sharp contrast to a conclusion by the filter vendor, who also analyzed fouling material and concluded the fouling material was biological. Personnel from SRL Interim Waste Technology (IWT) and SRS Waste Management Technology (WMT) are now developing additional pretreatment steps such as flocculation prior to ultrafiltration to solve the problem.

Aquifer Characterization Study. The SRS Aquifer Characterization Study is the continuation of the SRS Baseline Hydrogeologic Investigation which was completed in 1987. The SRS baseline investigation included the installation of 129 observation wells, detailed lithologic description of the sediments cored during well installation, and the collection of water-level data. Expanding on the data collected as part of this baseline program, the Aquifer Characterization program will delineate the hydrogeologic system underlying the site in terms of water quality, hydraulic characteristics, flow patterns, contaminant transport potential, and recharge/discharge patterns. This program is part of an ongoing investigation to better understand the geologic, stratigraphic, and hydrogeologic framework of the site and the immediate region surrounding the site.

The objective of the Aquifer Characterization Study is to obtain chemical and physical data on the water-bearing units as an aid to the following characterization of the aquifer systems:

- establish the nature and distribution of chemical species in groundwaters
- establish the relationships between groundwater chemistry and sediment chemistry (i.e. water-rock interactions)
- model groundwater chemistry using existing computer codes
- determine flow paths, flow rates, and residence time of aquifer waters
- map zones of different transmissivity across the site and within aquifer units

Dedicated submersible pumps were installed in the baseline wells for groundwater sampling and conducting limited pumping tests. The collection of groundwater samples began in November 1988 and should be completed in 1989. The groundwater samples are analyzed initially for major cations and anions, trace metals, ^{18}O, deuterium, ^{13}C, ^{14}C, and tritium plus the stable isotopes of oxygen, hydrogen, and carbon. The stable isotopes are commonly used in the interpretation of groundwater flow paths, whereas the radioactive isotopes are useful in determining the flow rates of aquifer systems.

Groundwater Flow Modeling Program. In 1988, ESD conducted groundwater modeling which included the following steps:

- development of a water resource management plan for SRS
- characterization of groundwater flow and transport in the general separations area to study the

effects of various closure options on solute transport

- evaluation of the effects of pumpage of production wells in F and H Areas

ESD also provided technical support to groundwater regulatory issues at seepage basins and the Mixed Waste Management Facilities. A program for modeling the A- and M- Area groundwater remediation program, which provides technical support for placement of recovery wells, was also initiated.

Bioremediation of Oil-Contaminated Soils. Du Pont Biosystems personnel assisted ESD staff with bioremediation demonstrations of oil-contaminated soils. All contaminated soils, designated for disposal and placed at the landfill, have been sampled. Treatment, if required, will be determined after the results are received.

Use of Herbicide-Impregnated Polymer Matrix to Exclude Plant Roots from Buried Waste. Radionuclides and some toxic wastes can move from burial in the ground to the surface through uptake by plant roots. Roots have the potential to not only remove waste but to penetrate physical barriers and disrupt the waste containment systems. Under extremely favorable conditions living roots were found at more than 100 ft below the surface. For this reason, there has been a great deal of interest in systems to limit root growth. The herbicide trifluralin (Treflan) is a root retardant. If trifluralin is introduced into a layer in the ground, roots will not penetrate the layer. However, trifluralin is biodegradable, a good characteristic for a herbicide, but undesirable for the long term exclusion of roots. Research scientists at Batelle Northwest Laboratories have overcome this problem by incorporating trifluralin in a slow release matrix. They have bonded this matrix to the geofabric material, Typar (R) for ease of handling.

This system is very promising because of the following characteristics. The trifluralin is released at such a rate that it should be active for as long as 100 years. Because trifluralin is biodegradable and adheres strongly to soil, the zone of action is about 4 in. below the retardant layer and trifluralin is not transported to the groundwater. Trifluralin retards root growth, but is not a systemic herbicide and will not kill plants growing above the retardant layer. This last characteristic is important since vegetation is often used to stabilize the overburden of waste sites.

The root retardant system is manufactured by Reemay, Inc. of Old Hickory, TN. Because of its potential as a root barrier to root penetration into radioactive and hazardous waste, SRL, in cooperation with SREL and LLNL, has begun a series of tests to evaluate the potential of the root biobarrier. Three species of plants, soybean, bermuda grass, and bamboo have been grown above biobarrier in the SREL rhizotron. Observations of root growth near clear glass walls indicate that the roots of these three species will not penetrate the barrier and will still grow in the soil above the barrier. Potted plant experiments with bahia grass, grown over simulated waste isolation caps also indicate that this grass will grow over the barrier while its roots will not penetrate the biobarrier. Root observation trenches with biobarrier were established at Bikini Atoll in the Marshall Islands to demonstrate the potential for excluding the roots of garden plants grown in clean soil adjacent to the areas contaminated by weapons fallout. This will test the effectiveness of root biobarrier for the exclusion of tropical plants such as banana, bread fruit and screw pine.

Justification for Open Burning of Vegetation within the M-Area Seepage Basin/Lost Lake Area. The closure plan for the M-Area Settling Basin and vicinity was approved by SCDHEC in March 1987 with the condition that SRS use a burn box system with air emissions control devices to dispose of the vegetation within the overflow ditch, seepage area, and Lost Lake. Since that time, SRS has actively pursued cost effective techniques for complying with this condition. One alternative examined by SRS was open burning of the vegetation.

Calculations of the concentration of airborne metals from the open burning were made by ESD. The calculations were made on the basis of the U.S. Forest Service Smoke Management Guide and a Gaussian plume model. Initial estimates of metal concentrations in the vegetation were based on measured soil concentrations and uptake factors from literature and past SRS work. Later vegetation samples collected by SRS, with the help of SREL, indicated the vegetation uptake factors had provided conservative estimates of vegetation concentration. Air concentrations calculated under either the initial estimates or the measured vegetation concentrations were well below the occupational concentration guides for all metals of concern.

On the basis of these calculations, SCDHEC has given preliminary approval for open burning. The

cost savings, compared to the burn box alternative, is estimated to be $1.2 million.

F- and H-Area Seepage Basin Closure—ACL Technical Support. The seepage basins in the separations areas have been in operation since the mid-1950s for the handling of wastewater containing low levels of radioactivity and various nonradioactive chemical constituents. The basins are currently operating under RCRA interim status and a Part B application has been filed with SCDHEC. One element of RCRA that is critically important to SRS is the provision that allows technical development of groundwater concentration limits based on protection of human health and the environment. These Alternative Concentration Limits (ACLs) then define whether "corrective action" (groundwater treatment) is required in the vicinity of a waste site. In the absence of ACLs, the chemical concentrations in groundwater must be maintained at background or below drinking water standards even if there is no potential drinking water use. There is significant variability in ACL guidance from SCDHEC and EPA, and few ACLs have been granted. However, SRS is in a unique position to develop strong ACL proposals because of the site ecology and geohydrology programs, and because of the high level of institutional control.

ESD staff have completed a program to support the ACL Demonstration for the F- and H-Area seepage basins. Since there is no potential human drinking water exposure, the objective of the ACL Demonstration is to determine whether EPA specified hazardous constituents in a facility's waste have caused, or are likely to cause, environmental damage. Regulatory agency approval of the ACL Demonstration would alleviate the need for any remedial action beyond closure of the waste facility itself.

Outcropping of groundwater contaminated by F- and H-Area seepage basin constituents was detected in wetlands adjacent to Four Mile Creek in the mid-1960s. Remote sensing studies by ESD in 1985 detected stress in vegetation of bottomland areas suspected of being influenced by seepage basin water outcropping. Sampling revealed that water from all of the outcropping areas originated from the basins.

The documentation of environmental damage beyond the immediate vicinity of the seepage basins required that efforts be focused on determining the causes of the damage. Under a strict interpretation of the EPA guidelines, only environmental damage resulting from hazardous constituents would necessitate remediation of areas beyond the facility boundary. Candidate environmental stressors included: increased flooding from hydraulic loading into the basins, 'salinity' stress from generally high water conductivity levels, chemical stress from one or more of the non-hazardous constituents of the seepage basin groundwater plume (e.g. nitrate, pH), and chemical stress from one or more hazardous constituents of the groundwater plume (e.g. cadmium, copper).

The short time available for the ACL document preparation precluded extensive field studies to provide data for the initial evaluation. ESD efforts included reviewing literature and historical data that determined which of the possible stressors, singly or in concert, likely caused the environmental damage. Additional water samples were collected for detailed analyses of hazardous and non-hazardous constituents in water of the outcrop zones and in Four Mile Creek adjacent to the outcrops. Comparisons of these concentrations with literature values for hazardous constituent toxicity on trees suggested strongly that these constituents were not likely to have caused the observed damage. Similarly, site evaluations by plant ecologists and evaluations of relevant literature strongly suggested that the tree species present in the outcrop areas should not be killed by moderate increases in water table elevations that could result from basin operations.

The work to date supports the absence of adverse environmental effects as a result of hazardous constituent movement from the seepage basins. The absence of adverse effects attributable to hazardous constituents will form the justification for the application for an ACL.

Biological Monitoring Program for Beaver Dam Creek

As required by Consent Order 84-4-W, a biological monitoring program was initiated in Beaver Dam Creek in October 1988. Under the Consent Order, D Area was required to begin thermal mitigation on an "as-needed basis" during the summer of 1988. When water temperatures at the D-001 outfall exceed the specified limit of 32.2°C, additional water is pumped from the Savannah River and discharged into Beaver Dam Creek via the D-Area Receiving Basin, such that stream temperatures are maintained below 32.2°C at all times. A 316 (a)

demonstration is required because water temperatures in Beaver Dam Creek still exceed the maximum allowable ΔT (temperature change) of 2.8°C.

The monitoring program consists of an 18-month study at six sampling stations. The study is designed to assess the impacts of thermal discharges and increased flow from D Area on the vegetation, zooplankton, fish, and macroinvertebrate communities of the stream, as well as to assess the impacts of increased discharge and water levels on the foraging activities of the endangered American Wood Stork. Data from this study will be compared to data from other SRS streams that were collected as part of the Comprehensive Cooling Water Study as well as data from other southeastern streams reported in the open literature.

NEPA Documentation

The National Environmental Policy Act (NEPA) of 1969, Council on Environmental Quality implementing regulations (40 CFR 1500-1508) and DOE guidelines (45 FR 20965) require the early consideration of environmental factors during the planning and assessment process for all proposed federal actions. The NEPA group of the SRS Environmental Protection Section (EPS) is charged with the responsibility to prepare and manage all appropriate NEPA documentation. SRL reviews a number of these NEPA documents prepared for DOE to assure the technical accuracy of the documentation and approves all formal transmission of NEPA documentation to DOE-SR.

Special Studies of the Fate and Effect of Pollutants from SRS

Remote Sensing Surveys and Development. Remote sensing technique development continued in 1988 as a cost effective means of environmental monitoring of large areas, such as L Lake, Par Pond, the Savannah River Swamp, and the F- and H-Area Seepage Basin outcrops along Four Mile Creek. Remote sensing methods currently used include airborne multispectral scanner (MSS) surveys, airborne (helicopter) gamma radiation surveys, vertical and oblique aerial photography, and oblique video surveys. In addition, multispectral and panachromatic Satellite Pour l'Observation (SPOT) satellite data were acquired from SRS and various lakes of South Carolina. Historical vertical aerial photography of the SRS were obtained primarily for the 1970s and 1980s for the evaluation of historical trends on the SRS, especially for waste site location and aquatic vegetational development around the Par Pond system.

Data analysis yielded information on environmental impact to wetlands, potential habitats for endangered species, thermal patterns and dye studies of L Lake, and distribution of radionuclides on the site. Techniques to evaluate the water quality and algal distributions in Par Pond and L Lake were researched. The photographic and MSS data were valuable in mapping outcrop zones in the upper Four Mile Creek watershed downslope from the F- and H-Area seepage basins. Remote sensing data from this portion of the SRS were incorporated along with soils and topographic data for a demonstration of Geographic Information System (GIS) technology for display and evaluation of environmental data. Information gathered by the remote sensing supported the L Lake/Steel Creek 316 (a) Demonstration, and various other NEPA activities and site projects.

Lower cost MSS systems are being evaluated in the newly developed SRL remote sensing analysis laboratory. SPOT satellite data were collected nearly concurrently with the airborne MSS data and are being evaluated to determine to what extent these data can provide a low cost supplement for landcover characterization for environmental, wetlands, and habitat assessment for project support and regulatory documentation. The relatively high resolution of the SPOT satellite sensor system can provide detailed seasonal and regional coverage not previously available in a format readily usable for application at SRS. For example, SPOT satellite data were used to map the aquatic vegetation coverage in seven lakes within South Carolina for comparison with aquatic vegetation development around cooling reservoirs on SRS.

Transport/Cycling of Tritium in the Environment. Tritium releases account for about 85% of the offsite radiation dose to man from the operations of SRS. Because of the great importance of tritium in the calculation of offsite doses, the transport of tritium in the environment and its implications to health protection are important to SRS operations. The following items concerning tritium transport received special emphasis:

- determining the rate of tritiated hydrogen (HT) uptake in vegetation and soils and the effect of any environmental factors controlling uptake

- determining the partitioning of tritium, absorbed from atmospheric HT, into plant organic material

- using the knowledge of tritium uptake and partitioning to make estimates of the transport of organically bound tritium by food chains and other mechanisms and to use this information to determine the effect of organically bound tritium on the dose to man from atmospheric releases of HT

- determining the relationship between the tritiated water and organically bound tritium in aquatic organisms, particularly under conditions of changing water tritium concentrations

The program objectives are researched through field and laboratory experiments, and in many cases in cooperation with other groups interested in environmental tritium. Assessment of the transport of tritium to vegetation and soils following inadvertent releases of tritium to the atmospheric or aquatic environment were continued with the cooperation of the meteorology and environmental measurements groups of ETD. Through cooperation with the fusion research community in collection of samples and analysis of data from the Chalk River, Canadian and French tritium release experiments allowed an intensive evaluation of the transport of tritium following the controlled release of tritium gas under field conditions. The results of controlled environment exposures of vegetation to tritium gas were reported as part of a cooperation program with the Japanese tritium research program on tritium radioecology and health physics. The analysis of tritium concentration in fish collected in Par Pond and Upper Three Runs Creek have allowed determination of organic tritium concentration for field exposed aquatic organisms. Continued analysis of the fish from Upper Three Runs creek will provide information on the dynamics of tritium incorporation into organic forms under a sudden increase in tritium exposure.

Microbial Life in the Deep Terrestrial Subsurface of Southeastern Coastal Plain Sediments. The distribution and function of microorganisms are vital issues in microbial ecology. A DOE program, "Microbiology of the Deep Subsurface," concentrates on establishing fundamental scientific information about organisms at depth. This investigation was initiated at the SRS with the drilling of three microbiological boreholes in 1986. A fourth borehole was drilled in cooperation with the SCWRC south of the site in 1988. This boring extended the depth of investigation to greater than 1,700 ft. The findings of this program have direct implications for a variety of subsurface activities including bioremediation.

Approximately 2,000 new and different species (principally bacteria) have been isolated as deep as 800 ft beneath the soil's surface. SRS plans to make these organisms available to U.S. industry for possible new product development under technology transfer.

The diversity of the microbiological communities in deep terrestrial sediments is one of the most striking discoveries of this study. A wide and diverse variety of metabolically active microorganisms capable of transforming a spectrum of organic and inorganic compounds were present. These sediments contained many types of aerobic chemoheterotrophic bacteria, as well as a wide assemblage of other forms.

The diversity of platable forms decreased sharply with depth in shallow aquifers, but that was not the case in the deeper sediments studied at SRS. Such differences are surprising for a presumably nutrient-limited environment and are contrary to the traditional thinking in soil microbiology. In this study, the diversity was not limited by depth; however, such limitation was observed where the concentration of clays was greater than 20%. Such zones may not be drastically different but because they contain fewer microorganisms than the more transmissive sand zones, they were not readily evaluated for diversity.

Additionally, this investigation has isolated an extensive number of bacteria which may be new to the scientific community and may provide investigators with a new source of genetic material from organisms adapted to living and metabolizing hundreds of meters below the earth's surface.

The "Microbiology of the Deep Subsurface" program is an initiative that has demonstrated the presence of numerous, active and diverse microorganisms associated with the sediments of the terrestrial deep subsurface. The understanding of the microbiology of the deep terrestrial environment is not only an important advance for the sciences of microbial ecology, geomicrobiology, and geology, but has great applicability to a variety of industrial and governmental concerns, (e.g., fossil fuel recovery and storage, deep waste repositories, groundwater storage and retrieval, biologically produced products and transformations, as well as transport and fate of

groundwater contaminants). This investigation opens new avenues for research and fundamental investigations into the interaction between the biosphere and the geosphere.

Sitewide Seismic Survey. All data acquisition using the Conoco seismic crew is complete with data processing and analysis complete. The faults previously identified on only one seismic line were also located on the recent data, so their locations have been defined. Three exploratory borings, along with a complete suite of electric logs, were completed into the basement rock. The cores from these borings were geologically logged in detail. These are the first borings cored into bedrock at SRS since the early 1960s. In-situ stress measurements were made in two of the three new borings and in DRB 8, one of the deep borings from the 1960s. Results indicate horizontal stresses are higher than vertical stresses. The estimated magnitude and direction of stress appears consistent with other measurements made in the state.

The Seismic Advisory Committee was finalized and the committee met once in the fall of 1988. The Committee was established to provide additional independent overview and guidance to management on seismic issues relevant to SRS and its operations. On August 5, 1988, a small earthquake (local magnitude 2.0) occurred south and east of the location of the 1985 earthquake. Earthquakes of this magnitude and intensity are usually not felt and are detected only by instruments. Within the Southeastern U.S., approximately 40 earthquakes per year of this magnitude are recorded by seismographic networks. About 10 events of this size are recorded in South Carolina each year. This event was not felt on site and the seismic alarms in site facilities were not triggered.

Pen Branch Fault. A previously unknown fault, named the Pen Branch Fault, has been documented at the SRS. The fault crosses the SRS near R Reactor, K Reactor and one of the proposed sites for the New Production Reactor.

Data used to document the existence of the fault were obtained from cores and geophysical data from wells drilled on the site during the past 30 years from a seismic reflection survey completed in mid-1988.

Geologists consider the fault very ancient and possibly related to a 200 million-year-old fault previously recognized. Studies of the land surface, including soil mapping and examination of aerial photographs, give no indication the fault has been active. Examination of the geology indicates that most recent movement on the fault was over 30 million years ago. The presence of the fault was detected in sediments that were deposited under the ocean millions of years ago.

No evidence has been found to suggest that the fault is capable as defined in 10 CFR-100-Appendix A. The term "capable fault" has come into use in regulatory literature to indicate a fault associated with seismicity or with the potential for seismicity.

SRL's continuing geologic research program will be expanded to evaluate the Pen Branch Fault including its dimensions, regional geologic relationships, and its magnitude and time of movement. The additional work is expected to take two to three years and will consist of drilling wells and excavating trenches. Data collected from the drilling and trenching activities will be interpreted, integrated, and presented in the scientific literature. The results will be examined for safety concerns by the SRS Seismic Review Committee which includes specialists from the U.S. Geological Survey, the University of South Carolina, Virginia Polytechnic Institute and State University, and Stanford University.

Development of Statistical Methods for Environmental Impact Assessment. Standard statistical tests for biological impact assessment assume that before-after or control-treatment pairs are identical except for the human perturbations being studied. If the systems studied are undergoing natural successional change, however, then this assumption is invalid. A new statistical framework was developed in three papers for monitoring and assessment in a successional context. It was shown that successional processes can be characterized by a nominal path that is perturbed stochastically. This provides a null model against which a treatment may be tested for impact. Specific statistical procedures were developed and tested against several datasets. Monitoring study designs were also evaluated in this context.

1988 HIGHLIGHTS:

Savannah River Site Environmental Technology

- Carbon-14 sampling equipment, similar to that in operation in the F-Area separations facility, was installed at the H-Area separations facility.
- During 1988, radionuclide concentrations of effluents from SRS and Plant Vogtle were well below DOE guide values with ^{58}Co being the largest gamma component in the Vogtle effluent, 15.5 pCi/L as compared with the DOE guide of 40,000 pCi/L.
- The maximum SRS effluent radionuclide concentrations were 3,000 pCi/L tritium and 0.4 pCi/L ^{137}Cs as opposed to respective DOE guide levels of 2,000,000 pCi/L tritium and 3,000 pCi/L ^{137}Cs.
- The USGS map data bases were installed for use with the new Geographic Information System (GIS),and the Tracking Atmospheric Contaminants (TRAC) Mobile Laboratory underwent equipment upgrade which included the development of a back-up method for collecting and analyzing tritium oxide.

Savannah River Site Environmental Sciences

- In 1988 two horizontal wells were installed along an old process sewer line that is known to have leaked volatile organic chemicals. The wells are based on a new combination technology of vacuum extraction and air injection. A patent on the new technology was recently granted.
- To comply with Consent Order 84-4-W, a biological monitoring program was initiated in Beaver Dam Creek in October 1988 to begin thermal mitigation as needed.
- A fourth borehole was drilled in cooperation with the SCWRC south of the site in 1988 for the Microbiology of the Deep Subsurface Program. About 2,000 new species (principally bacteria) have been isolated from as deep as 800 ft beneath the soil's surface in this program.
- The Seismic Advisory Committee, established to provide independent overview and guidance to management on seismic issues relevant to SRS, met in the fall of 1988 after its membership was finalized. A previously unknown fault, named the Pen Branch Fault, has been documented at the SRS.

13
National Environmental Research Park Program

SUMMARY—The National Environmental Research Park program was established to use the SRS as an outdoor laboratory for studies of the environmental impact of human activities.

During 1988, approximately 10 National Environmental Research Park program research projects were conducted, with baseline studies providing information on wetland bacteria of Okefenokee Swamp, the feeding behavior of wading birds, and the cesium-binding capacity of the Savannah River Site (SRS) soils.

In 1972 the Savannah River Site (SRS) was designated as the nation's first National Environmental Research Park (NERP) program, and since then scientists from universities and other organizations have been encouraged to use the site as an outdoor laboratory, focusing on the impact of man's activities on the environment. Visiting scientists have worked in cooperation with the Savannah River Laboratory (SRL), the Savannah River Ecology Laboratory (SREL), and the Savannah River Forest Station (SRFS).

As described in the publication *South Carolina Wildlife,* the nature of the Savannah River Site is "Rippling blackwater streams, grass-bordered freshwater wetlands speckled with coots and wood ducks, inky cypress-tupelo swamps livened by bird song, and acre upon acre of loblolly and longleaf pine, oak, ash, maple, and gum forests - its enormity is impressive: 300 square miles shielded for more than 35 years from the everyday environmental impacts endured by most of the nation. Covering parts of Aiken, Barnwell, and Allendale counties, the site forms the largest protected area of restricted access land in the entire eastern United States. Since 1952 it has served as a preserve for most of the native plant and animal species of the South Carolina Coastal Plain and as an outdoor laboratory for hundreds of environmental scientists and students."[Gi89]

During 1988, approximately 10 National Environmental Research Park program research projects were conducted to provide baseline information on the variability of plant and animal communities. One new study that began in 1988 was a survey of the variation of microscopic animals in shallow ponds, called Carolina Bays, that are scattered across the SRS. Another new study compares the natural variability of four species of aquatic plants transplanted from a variety of habitats. These plants, rooted near the shores of ponds and streams, are being planted in new lakes to provide shelter and support for small fish and other organisms.

Two baseline studies were published in 1988. One study details the seasonal changes in small, bottom-dwelling animals in Pond B. The other study, conducted by a Swedish biologist, describes new species of Pauropoda (minute, delicate, slowly evolving soil arthropods that crawl through the pores in forest soils).

Many of the research programs conducted at the SRS are comparative studies. Several studies ongoing at the site are described below:

- Comparison of wetland bacteria of the Okefenokee Swamp in Georgia with bacteria of thermally impacted swamps at SRS.
- Comparison of the feeding behavior of wading birds' at SRS with their foraging at the Okefenokee and the Belle Baruch Long Term Ecological Research Site at North Inlet in South Carolina.
- Participation in a regional study of forested wetlands of the Gulf and Atlantic coastal plains by examining community structure, factors controlling productivity, and stress responses.
- Comparison of the cesium-binding capacity of soils at SRS, Los Alamos, New Mexico, and Bikini Atoll.

Following are highlights and major events of the 1988 National Environmental Research program:

- Old-field ecologists from across the country met at SRS to share the results of their long-term observations and to develop a plan for future comparative studies. In 1951 SREL began measuring the changing patterns of weeds and trees as they invaded the abandoned agricultural fields on SRS. Their studies revitalized old-field ecology.
- Scientists visited the SRS National Environmental Research Park to learn about study opportunities of microbes found 800 ft below the land's surface.
- After a careful study, several areas around SRS were identified as being potentially valuable for research. These areas will be incorporated into the existing reserved habitats previously set aside for long-term research.
- Plans for future cooperative studies among the National Environmental Research Parks at DOE sites in Idaho, Washington, New Mexico, Tennessee, and South Carolina were established. SREL initiated the first step of the program by compiling a list of general environmental information available at each site.

1988 HIGHLIGHTS

- The site was surveyed for variation in the microscopic animals found in the shallow ponds called Carolina Bays.
- Two baseline studies, published in 1988, dealt with the seasonal changes in small, bottom dwelling animals in Pond B, and the other describes new species of soil arthropods called Paurapoda.
- Old-field ecologists, meeting at SRS during 1988, shared long-term observations and developed a plan for future comparative studies of abandoned fields.

14
Savannah River Ecology Laboratory Programs

SUMMARY—The Savannah River Ecology Laboratory Programs encompass a variety of studies from the biogeochemistry and wildlife ecology of the Savannah River wetlands environment to the impact assessment of the Defense Waste Processing Facility construction activities on stream water quality.

Three radionuclide transfer models, the NRC, the FOOD, and the AGNS models, developed to predict the interception and retention of airborne particles by agricultural crops, were tested using plutonium-bearing aerosols released to the atmosphere from F Area and H Area at SRS.

Research has also focused on the chemical speciation and transport of heavy metals and radionuclides in aquatic and terrestrial systems, the effects of flooding patterns on growth rates of native trees; and the genetics and population dynamics of wood ducks, Eastern mosquitofish, slider turtles, salamanders, and the red-cockaded woodpeckers after environmental stress.

INTRODUCTION

The Savannah River Ecology Laboratory (SREL), which is operated by the University of Georgia, is under contract with DOE. Since 1954, SREL has conducted independent environmental studies of the Savannah River Site (SRS), its streams, ponds, and the Savannah River.

ENVIRONMENTAL STUDIES OF SRS SURFACE WATERS

Biogeochemical Cycling in L Lake

During the past year L-Lake research has focused on (1) determining the operationally-defined bioavailable (labile) fraction of the total iron and manganese present in six different L-Lake basin soil types by performing a five-step chemical extraction procedure, and (2) determining the mobilization potential and dissolution kinetics of these two metals from several of the soils exposed to controlled oxidation-reduction conditions typical of those present in the hypolimnion of L Lake during extended periods of anoxia. Labile iron and manganese concentrations, expressed as a percentage of total iron and manganese in the soils, ranged from 17 to 43% and 29 to 82%, respectively. Concentrations of iron and manganese released in the controlled redox microcosms were more related to the relative amount of these metals associated with the labile components, than to the total iron and manganese concentrations in the sediments. Iron and manganese dissolution increased with decreasing redox potential, and generally were best described by first order dissolution kinetics. Controlled redox studies are continuing on these L-Lake soils. A better concentration in the soil and the dissolution kinetics of these metals as a function of redox status could enhance the capability to predict metal mobilization during reducing conditions in stratified lakes or reservoirs.

Microbial Processes in L Lake

Other L-Lake research has focused on the bacterial processes involved in dissimilation of the particulate and dissolved organic matter of the blue-green algae blooms so conspicuous in the open water regions of L Lake and the vascular plant-derived lignocellulosic detritus, which is expected to increase in ecological importance as wetlands are established around the shorelines. One of the approaches to studying the fate of organic matter has involved following the rates of degradation of radiolabeled material. Experiments have shown that selection for thermophilic decomposers occurred rapidly in this system in both aerobic and anaerobic communities, and did not require prolonged exposure to elevated temperatures. Although reactor operation may increase rates of primary production, there does not appear to be a

consequent accumulation of organic matter, due to the adaptability of the degradative microbial community in L Lake to the higher concentrations.

Biogeochemical Cycling in Pond B

To understand the long-term fate and effects of radionuclides in an aquatic ecosystem, SREL has been studying the aquatic chemistry, aquatic macrophytes, benthic invertebrates, waterfowl, and other vertebrate wildlife of the Pond B reservoir. Recent research has focused on studies of the rates and patterns by which radiocesium occurring in natural food webs of the reservoir is taken up and concentrated by free-living turtles and newly- arrived migratory waterfowl. The uptake of this contaminant has now been shown, for both groups of animals, to be best described by an S-shaped sigmoidal curve that has a significant early time lag in accumulation as compared to the commonly assumed exponential model. This time lag in initial radiocesium uptake under field conditions has important implications for predicting the impact of this contaminant on the food chain of man from the consumption of fish and wild game.

Low-Level Mercury Determinations of Upper Three Runs Creek Water

Analyses of low-level concentrations of mercury (detection limit: 1-2 ng/L or parts per trillion) in Upper Three Runs Creek water prior to its discharge to this creek from the F/H Areas effluent treatment facility were completed for five locations in April, June, and August 1988. The mean concentration of total mercury was approximately 5 ng/L. Concentrations ranged from less than 1 to 15 ng/L with no obvious trend within the watershed. This is slightly lower than the average concentration in U.S. freshwaters of 30 ng/L. Replicate samples taken at five sites during three dates provide a benchmark for comparison to similar analyses after the discharge from the F/H Areas Effluent Treatment Facility commences.

Ecological Genetics of Aquatic Bacteria

Genetic diversity in natural populations of aquatic bacteria was investigated. Those populations of bacteria examined had very high genetic diversity, and isolates collected from particular sites along the stream had unique combinations of genes as shown in Figure 14-1, Vol. II. In other words, natural selection has favored certain combinations of genes at specific sites even within the same species of bacteria. This research demonstrates that management of floodplain forests can have a direct impact on the microbiota within a stream that may in turn affect higher trophic levels. Habitat variability is essential in maintaining diverse populations of bacteria. Since coastal plain streams are among the most diverse ecosystems studied, it is important to maintain that diversity even at the lowest trophic levels.

Impact of Microbial Activities and Hydrodynamic Forces on Energy Flow in Coastal Plain Streams

Low light conditions and a scarcity of stable substrate account for the low primary production in most coastal plain streams. Therefore, the energy base upon which most secondary production depends (e.g. annual fish production) consists primarily of material produced on the floodplain, such as leaf litter. Current research is designed to determine the factors which influence the leaf decomposition process. Four factors are under investigation:

- species-specific leaf characteristics
- microbial respiration
- aquatic insect shredding activities
- flow-related abrasion

Field experiments indicate that decomposition of floodplain leaf material, which enhances diminishing food levels when it is washed into streams during high flow conditions, is depressed by naturally occurring chemical compounds. Leachates from a few slow-decomposing leaf species inhibit microbial activities and slow decomposition of all leaf materials accumulating on the floodplain. Preliminary results from on-going research indicate that microbial conditioning combined with hydrodynamic forces account for the majority of the leaf decomposition process after leaves have entered the stream. Therefore, variation in energy flow (leaf decomposition and fragmentation) in coastal plain streams appears to depend upon the spatial and temporal variation in flow conditions and microbial activities.

Effect of Low Water on Seedling Dynamics in the Savannah River Swamp

The population dynamics of the bald cypress (*Taxodium distichum*) and water tupelo (*Nyssa aq-*

uatica) and the potential regeneration of these wetland forests on the SRS are influenced by changes in the hydrologic regime. The natural flooding regime along the Savannah River and its tributaries has been altered by impoundments upstream in a series of dams and by irregular discharges from SRS operations into creeks flowing into the floodplain swamp.

Several cypress-tupelo communities on the SRS lack seedlings and saplings. In the Savannah River Swamp, seedling densities at the old-growth Georgia Power site in 1988 were one-half those in 1986 as shown in Table 14-1, Vol. II. However, densities at Stave Swamp were over 20 times those in either 1985 or 1986. Localized site conditions may account for the difference between these two sites. Survivorship each year has been extremely low (<1%), but isolated pockets of seedlings that germinated in 1985 and 1986 have survived. Along Upper Three Runs Creek, seedling densities are lower than in the Savannah River Swamp, but multiyear data are not yet available for comparison.

Since 1986, drought conditions in this region have resulted in low water levels in the Savannah River and periods of low discharge from SRS reactors, possibly enhancing the production and survival of seedlings. Measurement of seedling production, survivorship, and growth over several years will be necessary to determine whether low water conditions have a long-term effect on regeneration in the cypress-tupelo wetland forest.

Effects of Flooding on Growth Rates of Bald Cypress

Many man-related activities influence the timing and extent of flood events in streams and rivers. On the SRS, cooling water discharges into tributary streams plus upriver reservoirs have altered the hydrology of the Savannah River floodplain. Much of the cypress-tupelo swamp forest is now exposed to near-continuous inundation.

The effects of continuous flooding (CF) versus periodic flooding (PF) on growth of cypress saplings was investigated using the rhizotron facility at SREL. Cypress saplings were harvested and roots were excavated at the end of three consecutive growing seasons to determine if the flooding treatments influenced growth rates as shown in Table 14-2, Vol. II. The PF saplings were three times the size of the CF saplings (aboveground and belowground) after one growing season. After the second year, they were 1.5 times the size of the CF plants. Finally, by the end of the third year, the CF plants were nearly equal in size (aboveground) to the PF plants. Root biomass estimates for the third year are not yet available.

The data show that the CF plants were able to compensate for an initial handicap in growth rates. Two possible explanations for this result are 1) continuously flooded plants were able to acclimate to the flooded conditions by producing specialized roots or root cells and, 2) continuously flooded plants invested far more energy in aboveground growth than in root growth.

Effects of Flooding on Growth of Chinese Tallow Tree Seedlings

Flood tolerance of the exotic weed Chinese tallow tree *(Sapium sebiferum)* was compared to that of water tupelo (*Nyssa aquatica*), a native tree known to tolerate excessive flooding. Potted seedlings of the two species were grown in two light regimes (20% and 100% of full sunlight) with the seedlings divided into a flooded group and a well-drained group within each light regime. Flooded tallow tree seedlings exhibited lower mortality than did flooded tupelo (0 versus 7.5%). In both species, flooding resulted in smaller total mass, leaf area, and ratio of root to shoot mass as shown in Figure 14-2, Vol II. In 20% light, the two species were equally affected by flooding. However, in 100% light, flooding had a greater negative impact on the tallow tree than on water tupelo. Morphological adaptations to flooding in the tallow tree included hypertrophied lenticels and development of adventitious roots. High tolerance of flooding may partly explain why the Chinese tallow tree is especially successful at invading low wet areas of floodplain forests.

Zooplankton Community Development at L Lake

The zooplankton community at L Lake has changed substantially over the three years that the reservoir has existed. Changes in trophic interactions in the system are occurring against a backdrop of major adjustments in the reactor operation schedule. During much of 1988, the community was dominated by rotifers, including *Keratella, Polyarthra, Synchaeta,* and *Conochilus*. A new calanoid copepod, Eurytemora affinis, appeared in late winter but the summer dominants of previous years, *Diaptomus dorsalis* and *D. pallidus*, were absent. The most important cladoceran of previous summers, *Diaphanosoma bra-*

chyurum, was also rare. These changes were probably partly caused by the phytoplankton, which was not so heavily dominated by blue-green algae in 1988 as in previous years; they probably were also strongly influenced by increases in the populations of gizzard shad and other planktivorous fish.

Establishment of Wetland Vegetation at L Lake

Wetland vegetation was established in the southern one-third of L Lake during the period January-August, 1987. The vegetation was sampled in 1987 and 1988 to provide baseline data on plant succession and to evaluate planting success.

Three zones of vegetation have become established in areas of the lake where transplanting occurred. The shrub zone is dominated by willow (*Salix nigra*); ten-inch willow branches planted in 1987 are now small trees. Important and successful species planted in the emergent zone include cattail (*Typha latifolia*), grasses, sedges, rushes, pickerelweed (*Pontederia cordata*) and arrowhead. Cattail and spike rushes (*Eleocharis spp.*) quickly colonized areas in which they were planted. Seedlings of pickerelweed were observed during 1988. Significant changes in vegetation occurred in the submersed/floating-leaved zone between 1987 and 1988. Wild celery (*Vallisneria americana*), an important food for waterfowl, is now present in many areas of L Lake and is colonizing new ones. White water lily (*Nymphaea odorata*) was the most common floating-leaved species present during 1987. During 1988 it was replaced by American lotus (*Nelumbo lutea*). Vegetation in unplanted areas of L Lake includes willow in the shrub zone, cattail and alligator-weed (*Alternanthera philoxeroides*) in the emergent zone. No vegetation occurs in the submersed/floating-leaved zone. A quantitative summary of the data from the 1987 and 1988 samples is being developed .

DWPF Peripheral Stream Water Quality Studies

The SREL monitoring program is designed to assess the potential impact of the Defense Waste Processing Facility (DWPF) construction activities on peripheral stream water quality. Streams involved in the program include McQueen Branch and Crouch Branch, which are two streams directly impacted by the plant construction; Upper Three Runs Creek, which receives the confluence of McQueen Branch and Crouch Branch; and Tinker Creek, which is monitored as a control.

Mean total suspended solid (TSS) levels in McQueen Branch following rain events were higher during FY-1988 than during FY-1987; however, the differences were not statistically significant as shown in Figure 14-3, Vol. II. For samples taken during periods of no rainfall, TSS levels in McQueen Branch were significantly lower in FY-1988 than in FY-1987 as shown in Figure 14-4, Vol. II. Trends similar to TSS were recorded for turbidity in McQueen Branch for FY-1988. Other streams in the DWPF watershed showed a mixture of non-significant increases and decreases in TSS and turbidity concentrations from FY-1987 to FY-1988 with or without a previous rainfall event. Rainfall one day prior to sampling was two times greater in FY-1988 than in FY-1987, which may account for some of the increases in TSS, while a decrease in new construction disturbances may have facilitated the decrease in TSS during dry periods.

TSS loadings for McQueen Branch were higher after rainfall events than TSS loading in Tinker Creek in FY-1987 and FY-1988. For FY-1988 (as in past years) there were indications that during periods of rainfall inputs from McQueen Branch and Tinker Creek were sufficient to increase the TSS levels in Upper Three Runs Creek below its confluence with McQueen Branch. One increase in TSS observed in Upper Three Runs in FY-1988 was associated with McQueen Branch input alone, and was supported by similar increases in turbidity levels, specific conductance, and percent ash weight data. The combined TSS loadings from Tinker Creek and McQueen Branch appear to account for five additional times during FY-1988 when increases in TSS were observed in Upper Three Runs Creek.

Crouch Branch is a second creek draining the DWPF site. Mean TSS concentrations observed in Crouch Branch were higher than those in all other streams for all twelve months of FY-1988. Crouch Branch appears to have increased (in some cases slightly) the TSS load in Upper Three Runs Creek for three of the months in FY-1988. Data for turbidity, specific conductance, and percent ash weight are all consistent with those observed TSS concentration increases.

ENVIRONMENTAL STUDIES OF AQUATIC AND RELATED WILDLIFE

Fish Genotype and Relationship to Mercury Exposure

Populations can adapt to polluted environments by developing increased tolerance. During genetic ad-

aptation, pollutants can select for resistant allozyme genotypes. Differential survival of mosquitofish, a common and widespread fish on the Savannah River Site, was modeled during exposure to mercury, and genetically-mediated differences in tolerance were identified and quantified. When supplemented with further studies, these data will allow SREL to assess the manner by which species acquire tolerance to pollutants, as well as the potential value of gene shifts for monitoring population response to contaminants in aquatic environments.

Preliminary Results on Comparison of Whole Body Lipid Content of Dusky Shiners in Upper Three Runs Creek

Increased levels of nitrates, mercury, and tritium were scheduled to begin flowing into Upper Three Runs Creek from the new Effluent Treatment Facility on the SRS in late 1988. For one year prior to the increased pollutant discharge and through at least the first year of discharge, an examination is being made of the impact of the pollution on the health and robustness of the dusky shiner, one of the most common fish in the creek. The amount of stored fat in the dusky shiner is used as an indicator of its condition; low fat levels may indicate either low availability of food or other stressful conditions. The question being asked is whether the increased rate of discharge from the Effluent Treatment Facility causes a reduced fat level in the dusky shiner.

The dusky shiners had the same average body length, about 36 mm, and same amount of fat, 13.5% of dry weight, at all sites examined in March 1988. This fat level indicates a healthy population just after the stress of winter. Because the fish appeared healthy prior to the increased rate of discharge both above and below the planned discharge location, a good basis for comparison with the fat levels of dusky shiners after the onset of discharges into Upper Three Runs Creek has been established.

Genetic Damage in a Population of Slider Turtles *(Trachemys Scripta)*

Turtles inhabiting a contaminated reservoir (Pond B) were found to have changed DNA content from environmental exposure to low concentrations of long-lived radionuclides. Total body burdens for the 50 reservoir turtles examined in the survey ranged from 0.0045 μCi (164.7 Bq) to 0.126 μCi (4,679.3 Bq) for ^{137}Cs and from 0.125 μCi (462.6 Bq) to 0.138 μCi (5098.3 B)q for ^{90}Sr. Flow cytometric (FCM) assays of red blood cell nuclei demonstrated significantly greater variation in DNA content of the reservoir turtles than of turtles from a nearby, uncontaminated site. Furthermore, two of the reservoir turtles possessed FCM profiles that are indicative of aneuploid mosaicism. These data provide an indication of sensitive genetic response to low-level radiation in a natural population.

Wood stork foraging at Kathwood artifical foraging pond

Management of Kathwood Artificial Foraging Ponds For Wood Storks

The United States population of wood storks *(Mycteria americana)* has decreased during the last 50 years, from 20,000 breeding pairs to 5,000 pairs in 1980. Since 1980, the population has remained stable at between 4,000 and 5,000 breeding pairs. In 1984, the U.S. Fish and Wildlife Service listed the species as endangered. The decline in numbers has been attributed largely to loss of foraging habitat, particularly to habitat that is important during the breeding season.

When the DOE decided to restart L Reactor at the SRS, there was concern

that cooling water from this reactor would increase the water depth in the Steel Creek Delta and make this area unavailable to storks that nest in a rookery near Millen, GA and fly to the SRS to feed on aquatic prey. To replace the potentially lost foraging habitat, DOE created 14 hectares of ponds at the site of Kathwood Lake on the National Audubon Society's Silver Bluff Plantation Sanctuary in 1985. The ponds were stocked with fish and managed specifically as foraging areas for storks. DOE is providing research funds to SREL to ensure continued availability of adequate forage for this endangered species. In 1986, wood storks foraged in the ponds, for over two months and a maximum of 97 storks were recorded at any one time; in 1987, a maximum of 150 storks were counted; and in 1988, a maximum of 212 storks were counted in the ponds as shown in Figure 14-5, Vol. II. The patterns of storks at the ponds indicate that the ponds do indeed present appropriate stork foraging habitat. The procedures developed to manage the Kathwood ponds can be applied in other areas where stork foraging habitat is threatened.

Amphibian Studies Related to the Defense Waste Processing Facility

Carolina Bays on the SRS are used as breeding habitat by three closely related species of salamander: *Ambystoma opacum* (marbled salamander), *A. talpoideum* (mole salamander), and *A. tigrinum* (tiger salamander). Studies in FY-1988 focused on how these species adapt to natural variation in bay hydroperiod (i.e., the amount of time a site holds water each year), and how they may respond to human alteration of the habitat. The marbled salamander breeds in the bays in mid-autumn prior to pond-filling; when nests are flooded by winter rains, the eggs hatch. Female *A. opacum* at Ginger's Bay chose nest sites in low, heavily vegetated areas. Nests that were placed low were more successful than nests placed at middle or high elevations. This terrestrial mode of reproduction is energetically more expensive to adults than the more typical aquatic mode exhibited by *A. talpoideum*. The loss of non-polar lipids (the major energy store) during the reproductive season is greater for *A. opacum* than for *A. talpoideum*, and female *A. opacum* must invest more lipid per egg, probably due to the unpredictable length of the embryonic period.

Regardless of the mode of reproduction, there are years in which no species reproduces successfully, and recruitment from the larval stage into the adult population is zero (e.g., 1988 at many SRS sites). These years of catastrophic mortality obviously affect the population dynamics, but are unlikely to lead to local species' extinctions because of "storage effects." In *Ambystoma*, storage effects result from individual variation in age at first reproduction as well as in the timing of subsequent reproductions (if any). Thus, recruits from occasional successful years (generally "wet" years with hydroperiods of 6 to 9 months) are stored in the population, and may sustain the population through several years of little recruitment. However, human alteration of the hydrologic characteristics of a bay has potentially severe negative consequences. An activity such as ditching, which occurred at Sun Bay, may shorten the hydroperiod in all years so that few species are able to complete metamorphosis, and the storage effect only temporarily retards local extinctions. Alternatively, an artificially extended hydroperiod (e.g., the refuge ponds in S Area that were built as an experiment in mitigation of the loss of Sun Bay) may not allow breeding by *A. opacum*, and may reduce the reproductive success of other species due to high levels of predation in ponds that do not dry annually.

Life History Changes in Eastern Mosquitofish Induced by Thermal Environments

Eastern mosquitofish were sampled monthly for two years from an ambient and a thermally elevated pond on the SRS to determine the influences of extreme temperatures on life history patterns. Fish from the artificially hot environment reproduced all year, had higher reproductive investments (higher clutch sizes and reproductive biomass), and smaller offspring than did fish from the ambient environment, in which reproduction ceased from October through March. Likely selection pressures responsible for these changes in the thermal habitat include unpredictable food resources and higher mortality from thermal death and predation by fishes and birds. The extent to which these life history alterations are the result of adaptive genetic changes versus phenotypically plastic responses remains to be tested. Regardless, such flexibility in response to environmental perturbation helps to explain the extraordinary success of mosquitofish in altered environments around the world. The success of mosquitofish should not be used as a predictor of impacts of stress on other fish species; mosquitofish are unusual in this regard and most other fishes are much more environmentally sensitive.

TERRA-ENVIRONMENT STUDIES

Model Validation For Radionuclide Interception and Retention in Agricultural Crops

The accuracy of three simple radionuclide transfer models that predict the interception and retention of airborne particles by agricultural crops was tested using plutonium-bearing aerosols released to the atmosphere from the F-Area and H-Area nuclear fuel chemical separations facilities on the SRS. Plutonium concentrations in vegetation and grain were predicted from measured deposition rates and compared to concentrations observed in the field.

The models tested were (1) a Nuclear Regulatory Commission (NRC) model, which is designed for calculating doses-to-man from routine releases of reactor effluents, (2) a second model called FOOD, which is similar to the NRC model but also contains terms to predict radionuclide concentrations in grains, and (3) a third model called AGNS, which was developed as an extension of the NRC model and also predicts radionuclide concentrations in grains. None of the data used to test the models had been used in their design of the models, nor had any of the data been used to determine parameter values for the models.

The plutonium concentrations for vegetation predicted by the three models generally differed by lower than a factor of four; however, the predictions from the NRC and FOOD models were consistently less than those from the AGNS model. The NRC and FOOD models consistently underpredicted the observed concentrations. For both the NRC and FOOD models, seven of the ten observed concentrations were underpredicted by a factor of two or greater. The AGNS model was a more accurate predictor of vegetation concentrations than either the NRC or the FOOD model. It showed no overall bias in predicting plutonium concentrations, but did exhibit a wide range of "predicted to observed" ratios. The models were more accurate at predicting concentrations for grains.

Biogeochemistry of Coal Piles and Ash Basins

Eight watertable wells were sampled monthly over the past year in the vicinity of the 400-D Area coal pile and ash basins to assess whether coal-derived pollutants are moving through the soil and into nearby surface waters and groundwater. Preliminary indications are that all of the wells, except a nearby control well, have higher than normal levels for a number of inorganic contaminants. Sampling and data analysis are continuing, as are additional research studies that are designed to examine the chemical mechanisms controlling the release of contaminants from the coal pile and ash basins.

Transport and Speciation of Metals in the Environment

The chemical speciation and transport of heavy metals and radionuclides in aquatic and terrestrial systems continues to be a topic of great interest. Research at SREL has focused on the implementation of geochemical speciation models used in conjunction with advective-dispersion or convective-dispersion models to simulate transport and to estimate the time-dependent extent of migration. The partitioning of heavy metals between the solid and solution phases is a primary factor regulating their mobility in natural systems. Factors influencing this partitioning include metal complex distribution (speciation), the type of surface available (e.g. oxide, humic, phyllosilicate), and the specificity with which a given metal interacts with a given surface under a specified set of conditions. The approach to studying these factors and their interactions has been to examine the time-dependent nature of adsorption and competitive adsorption reactions to mineral phases commonly found in soils and sediments in obtaining information from which adsorption mechanisms may be deduced.

Impact of Fly Ash on Woody Swamp Species

Fly ash, a by-product of coal-powered electric generation, is enriched in boron. Although this element is essential for plant growth, it may be toxic at concentrations found in fly ash. The consequences of intentional or accidental release of this material into swamp ecosystems is unknown. Therefore, greenhouse experiments have been conducted to determine the effect of fly ash on the growth of water tupelo (*Nyssa aquatica*) and bald cypress (*Taxodium distichum*). Seedlings were grown under saturated to slight flooding to simulate natural swamp conditions. No significant effects on height, basal diameter, and biomass of leaves, stems, or roots were observed regardless of whether the fly ash was layered on or mixed with the soil.

Growth of water tupelo was reduced when the fly ash addition was $\geq 5\%$ (w/w) but fly ash did not reduce bald cypress growth. Fly ash rates less than 2.5% increased growth of water tupelo and bald cypress.

The effect of fly ash (greater than 2.5%) on water tupelo seedlings was typified by reduced height and diameter growth; pale yellow-green to white coloration of new leaves and death of the *apical meristem.* Damage was proportional to fly ash rate. Although the height of bald cypress was depressed in the 5% and 10% rate, the greatest biomass was at the highest fly ash (10%) rate.

Leaves of both species had similar boron concentrations. Control plants had leaf concentrations less than 25 mg/kg. Fly ash additions resulted in a dramatic increase in leaf boron concentration (14, 28, and 35 times the control for the 2.5, 5, and 10% treatments, respectively).

Water tupelo is less tolerant of fly ash amendments and would potentially be limited in an altered swamp ecosystem.

Effects of Hatch Date and Body Mass on Recruitment of Female Wood Ducks

Many factors affect the survival of offspring. Two important variables are time of hatching and size of body mass of the neonate. For example, young birds hatching early in the season often survive better than individuals hatching late. Body mass may be important because larger young often have greater lipid reserves and are able to survive longer without food. In this study, we examined the return of female wood ducks, marked as ducklings, to breeding areas. We tested effects of hatching date and body mass of ducklings at hatching on the return (i.e., recruitment) of females.

The study was conducted from 1982-88 on the SRS. Nest boxes were checked weekly during the breeding season. From 1982-87, day-old ducklings were weighed and tagged before they left the nest. Females nesting in the boxes were captured during incubation and tagged.

Return rates of tagged ducklings averaged 5% (2,945 ducklings were tagged) and rates for individual years were similar. Most females nested first as yearlings; however, a drought in 1985 delayed the return of females hatched in 1984. We found no evidence that ducklings hatched early in the season had a greater probability of returning to breed. There was also no relationship between the body mass of ducklings and their probability of returning. Our results suggest that hatch date affects recruitment more at northern latitudes where time for producing and rearing young is short.

Genetic Survey of the Endangered Red-Cockaded Woodpecker

A small population of the endangered red-cockaded woodpecker exists on the SRS. This population has declined steadily since monitoring began in 1977 and reached a low of four individuals in 1985. Research was initiated at that time to investigate the factors responsible for the population's decline and to determine the steps necessary to restore a viable population of red-cockaded woodpeckers at the SRS. A genetic survey was conducted from 1985 to 1987 to:

- compare levels of genetic variability of the red-cockaded woodpecker on the SRS to those of populations elsewhere in the south
- investigate the relationship between population size, genetic variability, and physical fitness
- develop guidelines for translocation of red-cockaded woodpeckers onto the SRS based on genetic structure of populations in the south

Results of this survey indicate that relative to other populations, the red-cockaded woodpeckers on the SRS exhibit normal levels of heterozygosity, but

Scientist study the small, red-cockaded woodpecker population on the SRS

slightly lower percent polymorphic loci and mean number of alleles per locus (measurements indicative of genetic variability). This slight decrease likely reflects the recent decline in number of individuals present in the population. There is no indication of reduced fitness level in the SRS population. Finally, the wide scale genetic survey indicates that red-cockaded woodpecker populations exhibit a greater degree of genetic variability among populations than other birds which have been studied. This suggests that caution must be used in moving birds among populations, so as not to disrupt locally adapted populations. Thus birds chosen for introduction onto the SRS are best chosen from populations occupying similar habitats in close geographic proximity to the SRS.

1988 HIGHLIGHTS

- Of the three radionuclide transfer models tested, the AGNS model was a more accurate predictor of vegetation concentrations than either the NRC or FOOD models. The latter models consistently underpredicted the observed concentrations.
- The uptake of radiocesium by free-living turtles and newly-arrived migratory waterfowl was best described by an S-shaped sigmoidal curve that has a significant early time lag in accumulation.
- In the Savannah River Swamp, cypress-tupelo seedling densities at the old-growth Georgia Power site were one-half those in 1986. However, densities at Stave Swamp were over 20 times higher than those in either 1985 or 1986.
- Significant changes in vegetation occurred in the submersed/floating-leafed zone between 1987 and 1988 in the revegetation area of L Lake. Three zones of vegetation have become established.
- No evidence was found that wood ducklings hatched early in the season had a greater probability of returning to breed, nor was there any relationship between the body mass of ducklings and their probability of returning.
- In 1988, a maximum of 212 storks were counted in the DOE-created ponds near Kathwood Lake. This is up from 97 storks in 1986, and 150 storks in 1987.
- Mean total suspended solids (TSS) levels following rain events in McQueen Branch near the Defense Waste Processing Facility (DWPF) were not significantly higher than levels measured in 1987; however, Crouch Branch, a second creek draining the DWPF site, had TSS levels higher than those in all other streams in 1988.

15
U.S. Forest Service Savannah River Forest Station Programs

SUMMARY—The forest management program, conducted by the Savannah River Forest Service (SRFS), not only produces timber but also contributes to environmental protection and research. Sitewide SRFS programs protect endangered species, provide quality habitats for native wildlife, protect soil and watershed values, and provide a healthy forest for environmental research.

The DOE Site Use Approval system coordinates more than 800 activities using SRS land for operations and research programs. The forest management activities described in this chapter deal with reforestation and pine seedling establishment, reclaiming eroded lands, and managing endangered species and their habitats.

At DOE's request, the USFS is preparing a Natural Resources Management Plan for the SRS to coordinate SRFS activities with other site contractors involved in natural resources research and management.

INTRODUCTION

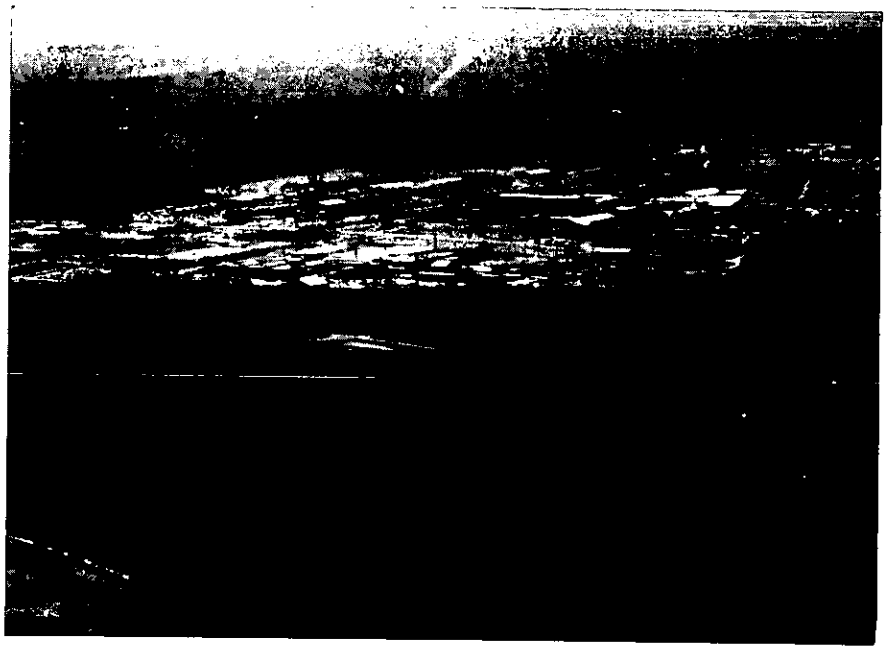
When the Atomic Energy Commission (AEC) allocated 300 square miles of land for the Savannah River Site, effective use of the public land under its control was necessary. To maintain and develop the land, a forest management program was initiated in 1952 through an interagency agreement with the United States Department of Agriculture Forest Service (USFS) and the AEC (now the Department of Energy). This program, conducted by the Savannah River Forest Station (SRFS), produces timber and contributes to environmental protection and research. The many sitewide SRFS programs play significant roles in protecting endangered species, providing quality habitats for native wildlife, protecting soil and watershed quality, and providing a healthy forest for environmental research.

FOREST MANAGEMENT

Planning for forest management is enhanced by preparing timber compartment prescriptions for one-tenth of the forest area each year. Prescriptions include a comprehensive collection of data required for vegetative manipulation, road maintenance, and coordination with other activities using SRS land. The DOE Site Use Approval system includes more than 800 activities using SRS land for programs including both operations and research. Data include timber stand types and conditions, and area inventories especially valuable for wildlife. Based on the prescriptions, timber sales are prepared and the trees to be sold and cut, are marked.

During 1988 the federal government received nearly $2 million for 22.9 million board feet of cut timber. Cut-over land was then quickly reforested. Before reforestation, land was cleared by burning, shearing and raking, drum chopping, and herbicide application. Pine seedlings were planted on nearly 2,700 acres during 1988.

On 540 of these acres, the SRFS planted longleaf pine. Although difficult to grow, longleaf pine is the native pine of SRS sandhill habitats and is preferred by the endangered red cockaded woodpecker. Superior tree seedlings are needed for successful survival of planted longleaf pines. The South Carolina Forestry Commission Nursery is under contract to DOE to use the most advanced technology identified by USFS researchers to grow seedlings for future planting at the SRS. Nurserymen, the forest industry, and regional tree farmers are closely watching the promising new technologies.



Reforestation is a major activity of the SRFS

SRFS thinned noncommercial stems on 156 acres using heavy-duty brush saws to allow the remaining trees to produce more valuable timber. On 569 acres, the competition of undesirable vegetation was reduced by applying selective herbicides.

Secondary roads used for the timber harvest are being upgraded to handle large trucks used for hauling tree-length sawtimber and pulpwood. During 1988, nearly nine miles of secondary roads were upgraded. The road banks were seeded with plants that provide food for wildlife and control erosion. Routine road maintenance was performed on 120 miles of roads.

Under a continuing program of reclaiming eroding land, 42 acres of bare areas were reshaped, subsoiled, and planted with legumes, grasses, hardwoods, and other wildlife food plants. These programs have proved very efficient in controlling erosion.

Endangered species and their habitats receive special consideration in the management of SRS forest lands. In 1988, southern bald eagles nested at SRS for the third consecutive year and three young were fledged successfully. A buffer zone established by SRFS prevented disturbance of the nesting birds. The SRFS Eagle Management Plan, which was prepared in 1987, called for the improvement of perching and nesting sites. During 1988, selected trees within six eagle management key areas were shaped and modified to provide perching and nesting sites.

The small SRS population of endangered red cockaded woodpeckers is the subject of an intensive research program testing the feasibility of translocating a few red cockaded woodpeckers to SRS forests. The move is designed to counteract possible inbreeding in the local population. In 1988, Southeastern Forest Experiment Station (SEFES) scientists continued their attempt to stabilize and expand the red cockaded woodpecker population at SRS through the translocation of individual birds as well as the translocation of a small colony. Although neither of the attempts were successful, valuable information was gained from the effort. Savannah River Ecology Laboratory (SREL) scientists continued to gather genetic information from other isolated populations of red cockaded woodpeckers for comparison with the data on SRS red cockaded woodpeckers. Cavity competitors, such as flying squirrels, were removed from the colonies. One of the eleven artificial cavities, built to make room for an increased population of woodpeckers was used by the endangered birds. In 1988, two red cockaded woodpecker clans nested successfully, and the known SRS population remained at 14 birds. The SEFES, in cooperation with SREL, held a workshop to discuss SRS experimental techniques used and experience gained from studies of red cockaded woodpeckers. Specialists who work with red cockaded woodpeckers throughout the southeast shared experiences and information.

Habitat for the red cockaded woodpeckers was improved on more than 150 acres of older pine forest by applying herbicide to weed out the competing scrub oak. Prescribed burning of 142 acres had a similar effect. On 307 acres, noncommercial and commercial thinning opened up the longleaf pine forest to the parklike condition the red cockaded woodpecker prefers for foraging and nesting.

Several wildlife species require control to protect forests, roads, and research sites. During 1988, trapping contractors removed 326 wild hogs from locations where the animals were causing damage.

Prescribed burning of 4,900 acres stimulated vegetation growth on the forest floor for wildlife food. Cool burns, conducted each winter under carefully selected weather conditions, also reduce fuel on the forest floor. This process serves to protect the forest against wildfires. Smoke management restrictions and dry periods during the winter limited the number of days available for burning. Acreage goals for prescribed burning will not be met until an aerial fire ignition program is implemented at SRS. Implementation is being considered for 1989. Fire danger was high during the spring and summer of 1988, but effective wildfire suppression by SRS employees and the USFS held eight wildfires to less than 100 acres.

At DOE's request, the USFS is preparing a Natural Resources Management Plan for the SRS. The plan will coordinate SRFS activities with other site contractors involved in natural resources research and management. In addition, the plan will describe an expanded role for the SRFS in management of SRS resources. The plan is scheduled for completion in 1989.

The Soil Conservation Service staff onsite provided specific information needed at SRS for plans on forest management, environmental research, environmental assessment, and facility siting. The Soil Conservation Service also prepared a Soil Survey Report which includes soil maps for the entire site. The report is scheduled to be published during 1989.

FOREST MANAGEMENT RESEARCH

SEFES scientists are conducting numerous studies that are anticipated to improve the overall forest management activities conducted at SRS. Among them are techniques being tested at SRS to produce seedlings for more successful reforestation. In one program the seedlings are prepared for their environment. Trees grow better if their feeder roots develop a symbiotic relationship with mycorrhizal fungi to facilitate absorption of water and nutrients. If seedlings in the nursery beds are inoculated with superior, selected fungi, then field performance will be enhanced.

In another program, lateral rooting of seedlings is promoted. Seedlings with more lateral roots show better field performance. Scientists use genetic selection to obtain families that have a higher percentage of lateral roots. Pruning the roots in the nursery bed also improves root morphology.

During 1988, 48 field studies, varying in age from one to 13 years and involving over 20,000 trees of longleaf pine, loblolly pine, sweetgum, and black walnut, were active at the SRS. Results were published in several research articles.

A new study, designed to investigate the effects of site preparation methods on pine seedling establishment and early growth was established in 1988.

In two large pine-field studies, certain common nursery practices (i.e. seedbed densities and top pruning) are being studied to determine their effect on lateral root development and mycorrhizal development and their influence on survival and early growth. Another study will measure the effect of removing pine straw from the forest floor on the growth and nutrition of trees. If changes are observed, scientists will determine if fertilization can compensate for the nutrients removed.

1988 HIGHLIGHTS

- During 1988 the federal government received nearly $2 million for 22.9 million board feet of cut timber from the SRS site. Pine seedlings were planted on nearly 2,700 acres during the same period.
- Nearly nine miles of secondary roads used for the timber harvest were upgraded to handle large trucks used for hauling tree-length sawtimber and pulpwood. Routine road maintenance was performed on 120 miles of roads.
- Southern bald eagles nested at SRS for the third consecutive year; three young were fledged successfully during 1988. Selected trees within six Eagle Management Key Areas were shaped and modified to provide perching and nesting sites.
- To protect forests, roads, and research sites, 326 wild hogs were trapped and removed from locations where they were causing damage.
- During 1988, 48 field studies involving over 20,000 trees of longleaf pine, loblolly pine, sweetgum, and black walnut were active at the SRS.

References

CAAC86 Radiation Shielding Information Center, 1986, "Code System for Implementation of Atmospheric Dispersion Assessment Required by the Clean Air Act," *Report CCC*-476, Oak Ridge, National Laboratory, Oak Ridge, TN.

DOE88 U. S. Department of Energy, 1988, External and Internal Dose Conversion Factors for Calculation of Dose to the Public, Report DOE/EH-0070&71, U. S. Department of Energy, Washington, D. C.

Du84 Dukes, E.K., 1984, The Savannah River Plant Environment, Report DP-1642, Savannah River Laboratory, Aiken, SC.

ENV Envirodyne Engineers, Inc., *Handbook for Analytical Quality Control,* St. Louis, MO.

EPA75 U.S. Environmental Protection Agency, 1975, "National Interim Primary Drinking Water Regulations," Title 40, *Code of Federal Regulations*, Part 141, Washington, D.C.

EPA85 U.S. Environmental Protection Agency, 1985, "National Emission Standards for Hazardous Air Pollutants: Standards for Radioactivity," Title 40, *Code of Federal Regulations*, Part 61, Washington, D.C.

Gi89 Gibbons, J. W., 1989, "Environmental Paradise and Paradox, " *South Carolina Wildlife*, Vol. 36 no. 2, March-April, 1989, pp. 44-49.

HPS80 Health Physics Society, 1980, "Upgrading Environmental Radiation Data," *Health Physics Society Committee Report HPSE*-1, prepared for the Office of Radiation Programs, U.S. Environmental Protection Agency, EPA 520/1-80-012, Washington, D.C.

Hu88 Hubbard, J. E., Stephenson, Steel, J. L., and Gordon, D. E., 1988, "Water Resource Management Planning Guide for the Savannah River Plant, Aiken, SC"

ICRP59 International Commission on Radiological Protection, 1959, *ICRP Publication* 2, (Oxford: Pergamon Press).

ICRP65 International Commission on Radiological Protection, 1965, "Principles of Environmental Monitoring Related to the Handling of Radioactive Materials," *ICRP Publication* 7, (New York: Pergamon Press).

ICRP68 International Commission on Radiological Protection, 1968, *ICRP Publication* 10, (Oxford: Pergamon Press).

ICRP77 International Commission on Radiological Protection, 1977, *ICRP Publication* 26, *Annals of the ICRP* 1(3):2-47.

ICRP78 International Commission on Radiological Protection, 1978, "Recommendations of the ICRP," *ICRP Publication* 26, *Annals of the ICRP* 1(3).

ICRP79 International Commission on Radiological Protection, 1979, "Limits for Intake of Radionuclides by Workers," *ICRP Publication* 30, *Annals of the ICRP* 3(4).

ICRP81 International Commission on Radiological Protection, 1981, "Limits of Inhalation of Radon Daughters by Workers," *ICRP Publication* 32, *Annals of the ICRP* 6(1).

Ka87 Kantelo, M.V., 1987, "Summary of I-129 Measurements in Ground and Surface Waters," Report DPST-87-820, Savannah River Laboratory, Aiken, SC.

Ku87 Kurzeja, R.J.; Taylor, R.W.; Sharma, J.; Burckhalter, L.T. 1987, "Environmental Effects of the July 31, 1987 Tritium Release From the Savannah River Plant," *Report DP*-1758, Savannah River Laboratory, Aiken, SC.

Mar84 Marter, W.L., 1984, "Environmental Dosimetry for Normal Operations at SRP," *Report DPST* 83-270 Rev. 1, Aiken, SC.

Mi80 Michel, J.; Moore, W.S. 1980, "Ra-228 and Ra-226 Content of Groundwater in Fall line Aquifers," *Health Physics, Vol.* 38, pp. 663-671.

Mk87 Mikol, S.C.; Burckhalter, L.T.; Todd, J.L.; Martin, D.K., 1987, *U.S. Department of Energy Savannah River Plant Environmental Report for 1987*, Report DPSPU-88-30-1, Savannah River Plant, Aiken, SC.

NCRP71 National Council on Radiation Protection and Measurements, 1971, "Basic Radiation Protection Criteria," *NCRP Report No.* 39, Washington, D.C.

NCRP78 National Council on Radiation Protection and Measurements, 1971, "A Handbook of Radioactivity Measurements Procedures, *NCRP No.* 58, Washington D.C.

NCRP79 National Council on Radiation Protection and Measurements, 1979, "Tritium in the Environment," *NCRP Report No.* 62, Washington, D.C.

NCRP87 National Council on Radiation Protection and Measurements, 1987, "Ionizing Radiation Exposure of the Population of the United States,"*NCRP Report No.* 93, Washington, D.C.

NCRP87b National Council on Radiation Protection and Measurements, 1987, "Recommendations on Limits for Ionizing Radiation Exposure," *NCRP Report No.* 91, Washington, D.C.

NUREG84 Office of Nuclear Reactor Regulations, 1984, *Lower Limit of Detection: Definition and Elaboration of a Proposed Position for Radiological Effluent and Environmental Measurements*, prepared by the National Bureau of Standards for the Division of Systems Integration, Office of Nuclear Reactor Regulations, U.S Nuclear Regulatory Commission, NCR FIN B8615.

Sag77 Sagendorf, J.F.; Goll, J.T., 1977, *XOQ/DOQ Program for Meteorological Evaluation of Routine Effluent Releases at Nuclear Power Stations*, U.S. Nuclear Regulatory Commission, Washington D.C., NUREG-0324 (Draft).

SCDHEC81 South Carolina Department of Health and Environmental Control, 1981, *Water Classification Standards System for the State of South Carolina*, Columbia, SC.

SCDHEC85 South Carolina Department of Health and Environmental Control, 1985, "Savannah River Plant, Aiken, Allendale, and Barnwell Counties," NPDES Permit 0000175, Columbia, SC.

Si80 Simpson, D.B; McGill, B.L., 1980, *Users Manual for LADTAP II - A Computer Program for Calculating Radiation Exposure to Man from Routine Release of Nuclear Reactor Liquid Effluents,* Oak Ridge National Laboratory, Oak Ridge, TN, NUREG/CR-1276 (ORNL/NUREG/TOMC-1).

St83 Stone, J.A., 1983, "Technical Summary of Groundwater Quality Protection Program at Savannah River Plant," *Report DPST*-83-829, Volume II, Savannah River Laboratory, Aiken, SC.

Tu83b Turcotte, M.D.S., 1983, "Georgia Fishery Study: Implications for Dose Calculations," *Report DPST*-83-319, Rev.1, Savannah River Laboratory, Aiken, SC.

USNRC73 U.S. Nuclear Regulatory Commission, 1973, "Methods for Estimating Atmospheric Transport and Dispersion of Gaseous Effluents in Routine Releases from Light-Water-Cooled Reactors," *Regulatory Guide* 1.111, Washington, D.C.

USNRC79 U.S. Nuclear Regulatory Commission, 1979, "NUREG 172," prepared by Battelle Pacific Northwest Laboratory for the U. S Nuclear Regulatory Commission.

Ze86 Zeigler, C.C.; Lawrimore, I.B.; Heath, E.M.; Till, J.E., 1986, *U.S. Department of Energy Savannah River Plant Environmental Report for 1986,* Report DPSPU-87-30-1, Savannah River Plant, Aiken, SC.

Glossary

a posteriori. Decisions and observations based on facts, experiment, or "after the fact" observations.

a priori. Decisions made before or without examination ("before the fact"); based on hypothesis or theory rather than on experiment or experience.

absorbed dose. The amount of energy deposited by radiation in a given amount of material. The unit of absorbed dose is the rad.

absorption. The process by which the number and energy of particles or photons entering a body of matter is reduced by interaction with the matter.

accuracy. The closeness of the result of a measurement to the true value of the quantity measured.

activity. (see radioactivity).

ALARA. The acronym, As Low As Reasonably Achievable, used to describe an approach to radiation exposure control or management whereby the exposures and resulting doses are maintained as far below the limits specified for the appropriate circumstances as social, economic, technical, and practical considerations permit.

alpha particle. A positively charged particle emitted from the nucleus of an atom having the same charge and mass as that of a helium nucleus (2 protons and 2 neutrons).

ambient air. The surrounding atmosphere, usually the outside air, as it exists around people, plants, and structures. It is not considered to include the air immediately adjacent to emission sources.

analyte. A constituent or parameter that is being analyzed.

anion. A negatively charged ion.

anneal, annealing. Maintenance of glass or metal at a specified temperature for a specific length of time, then gradually cooling. This treatment removes internal strains and eliminates distortions and imperfections. A more uniform material results.

aquifer. A saturated, permeable geologic unit that can transmit significant quantities of water under ordinary hydraulic gradients.

ash. Inorganic residue remaining after ignition of combustible substances.

assimilate. To take up or absorb into the body.

atom. Smallest particle of an element capable of entering into a chemical reaction.

atomic absorption spectrometry (AA). Chemical analysis performed by vaporizing a sample and measuring the absorbance of light by the vapor.

Atomic Energy Commission (AEC). A federal agency created in 1946 to manage the development, use, and control of nuclear energy for military and civilian application. It was abolished by the Energy Reorganization Act of 1974 and succeeded by the Energy Research and Development Administration (now part of the U.S. Department of Energy and the U.S. Nuclear Regulatory Commission).

attenuation. The process by which a beam of radiation is reduced in intensity when passing through some material. It is a combination of absorption and scattering processes.

beta particle. A negatively-charged particle emitted from the nucleus of an atom. It has a mass and charge equal to those of an electron.

biota. The animal and plant life of a particular region considered as a total ecological entity.

blank. A control sample that is identical, in principle, to the sample of interest, except that the substance being analyzed is absent. In such cases, the measured value or signal for the substance being analyzed is believed to be due to artifacts and should be subtracted from the measured value to give a net result reflecting the amount of the substance in the sample.

blind sample. A control sample of known concentration in which the expected values of the constituent are unknown to the analyst.

Brailsford pump. A surface water sampling device which is stationed on a stand above a stream. The device, which continuously samples stream water, consists of an all-plastic valveless piston driven by a Brailsford small electric motor. The variable pump speed is set normally at 0.75 gallons/day.

calibration. Determination of variance from a standard or accuracy of a measuring instrument to ascertain necessary correction factors.

Carolina Bay. A type of shallow depression commonly found on the coastal plains of the Carolinas. Carolina Bays are typically circular or oval. Some are wet or marshy, while others are dry.

carrier. A quantity of non-radioactive or non-labeled material having the same chemical composition as its corresponding radioactive or labeled counterpart. When mixed with the corresponding radioactive labeled material, (to form a chemically inseparable mixture), the carrier permits chemical (and some physical) manipulation of the mixture with less label or radioactivity loss than would be true for the undiluted label or radioactivity.

cation. Positively charged ion.

Central Savannah River Area (CSRA). A 12-county area in Georgia and South Carolina surrounding Augusta, GA. SRS is included in the CSRA.

chain-of-custody. A record that documents sample collection, transport, analysis, and disposal.

chlorocarbon. A compound of carbon and chlorine, or carbon, hydrogen, and chlorine, such as carbon tetrachloride, chloroform, tetrachloroethylene, etc.

collective dose equivalent/collective effective dose equivalent. The sums of the dose equivalents or effective dose equivalents of all individuals in an exposed population within an 80-km radius, and expressed in units of person-rem (or person-sievert). When the collective dose equivalent of interest is for a specific organ, the units would be organ-rem (or organ-sievert). The 80-km distance is measured from a point located centrally with respect to major facilities or DOE program activities.

committed dose equivalent. The predicted total dose equivalent to a tissue or organ over a 50-year period after known intake of a radionuclide into the body. It does not include contributions from external dose. Committed dose equivalent is expressed in units of rem (or sievert).

committed effective dose equivalent. The sum of the committed dose equivalents to various tissues in the body, each multiplied by the appropriate weighting factor. Committed effective dose equivalent is expressed in units of rem (or sievert).

community evenness. A measure of the degree to which the total number of individuals in a collection are evenly apportioned among taxa.

concentration. The amount of a substance contained in a unit volume or mass of a sample.

confluence. The point at which two or more streams meet; the point where a tributary joins the main stream.

contamination. The deposition of unwanted radioactive material on the surfaces of structures, areas, objects, or personnel.

control chart. A statistical tool used to demonstrate whether or not a specific process is within acceptable standards or limits of performance.

control limits. A statistical tool used to define the bounds of virtually all values produced by a system in statistical control.

cosmic radiation. Radiation with very high energies, originating outside the earth's atmosphere. Cosmic radiation is one source contributing to natural background radiation.

count. The signal that announces an ionization event within a counter; a measure of the external radiation of an object or device.

counter. A general designation applied to radiation detection instruments or survey meters that detect and measure radiation.

counting geometries. A well defined sample size for which a counting system has been calibrated.

curie (Ci). A unit of radioactivity. One curie is defined as 3.7×10^{10} (37 billion) disintegrations per second. Several fractions and multiples of the curie are in common usage:

kilocurie (kCi) -10^{3}Ci, one thousand curies; 3.7×10^{13} disintegrations per second.
millicurie (mCi) -10^{-3} Ci, one-thousandth of a curie; 3.7×10^{7} disintegrations per second.
microcurie (μCi) -10^{-6} Ci, one-millionth of a curie; 3.7×10^{4} disintegrations per second.
nanocurie (nCi) -10^{-9} Ci, one-billionth of a curie; 37 disintegrations per second.
picocurie (pCi) -10^{-12} Ci, one-trillionth of a curie; 0.037 disintegrations per second.
femtocurie (fCi) -10^{-15} Ci, one-quadrillionth of a curie; 0.000037 disintegrations per second.
attocurie (aCi) -10^{-18} Ci, one-quintillionth of a curie; 0.000000037 disintegrations per second.

daughter. A nuclide formed by the radioactive decay of another nuclide, which is called the parent.

DCG. (see derived concentration guide).

decay, radioactive. The spontaneous transformation of one radionuclide into a different radioactive or nonradioactive nuclide, or into a different energy state of the same radionuclide.

derived concentration guide (DCG). The concentration of a radionuclide in air or water that, under conditions of continuous exposure for one year by one exposure mode (i.e. ingestion of water, submersion in air or inhalation), would result in either an effective dose equivalent of 0.1 rem (1mSv) or a dose equivalent of 5 rem (50 mSv) to any tissue, including skin and lens of the eye. The standards for radionuclides in air and water are given in DOE Order 5480.1A.

deep dose equivalent. The dose equivalent in tissue at a depth of 1 cm resulting from external (penetrating) radiation.

detector. Material or device (instrument) that is sensitive to radiation and can produce a signal suitable for measurement or analysis.

diatoms. Unicellular or colonial algae of the class Bacillariophyceae, having siliceous cell walls with two overlapping, symmetrical parts. Diatoms represent the predominant periphyton (attached algae) in most water bodies and have been shown to be reliable indicators of water quality.

diatometer. Diatom collection equipment consisting of a series of microscope slides in a holder that is used to determine the amount of algae in a water system.

disintegration, nuclear. A spontaneous nuclear transformation (radioactivity) characterized by the emission of energy and/or mass from the nucleus of an atom.

dose. The energy imparted to matter by ionizing radiation. The unit of absorbed dose is the rad, equal to 0.01 joules per kilogram for irradiated material in any medium.

dose commitment. The dose which an organ or tissue would receive during a specified period of time (i.e. 50 or 100 years) as a result of intake (as by ingestion or inhalation) of one or more radionuclides from one year's release.

dose equivalent. The product of the absorbed dose (rad) in tissue and a quality factor. Dose equivalent is expressed in units of rem (or sievert) (1 rem=0.01 sievert).The dose equivalent to an organ, tissue, or whole body in a year will be that received from the direct exposure plus the 50-year committed dose equivalent received from radionuclides taken into the body during the year.

dosimeter. A portable detection device for measuring the total accumulated exposure to ionizing radiation.

dosimetry. The theory and application of the principles and techniques involved in the measurement and recording of radiation doses. Its practical aspect is concerned with the use of various types of radiation instruments with which measurements are made.

effective dose equivalent. An estimate of the total risk of potential health effects from radiation exposure. It is the sum of the committed effective dose equivalent from internal deposition and the effective dose equivalent from external penetrating radiation received during a calendar year. The

committed effective dose equivalent is the sum of the individual organ committed dose equivalents (50 year) multiplied by weighting factors that represent the proportion of the total random risk that each organ would receive from uniform irradiation of the whole body.

effluent. A liquid or gaseous waste discharge to the environment.

effluent monitoring. The collection and analysis of samples or measurements of liquid and gaseous effluents for purposes of characterizing and quantifying the release of contaminants, assessing radiation exposures of members of the public, and demonstrating compliance with applicable standards.

eluate. The liquid resulting from removing the trapped material from an ion-exchange resin.

elute. To remove absorbed ions from an ion exchange resin.

environmental surveillance. The collection and analysis of samples of air, water, soil, foodstuffs, biota, and other media to determine environmental quality of some industry or community. It is commonly performed at sites containing nuclear facilities.

erosion. The process in which exposed geologic materials are worn away by the action of wind or water.

exposure (radiation). The incidence of radiation on living or inanimate material by accident or intent. Background exposure is the exposure to natural background ionizing radiation. Occupational exposure is that exposure to ionizing radiation which takes place during a person's working hours. Population exposure is the exposure to the total number of persons who inhabit an area.

external radiation. Exposure to ionizing radiation when the radiation source is located outside the body.

fauna. The population of animals at a given area, environment, formation, or time span.

flora. The population of plants at a given area, environment, formation, or time span.

gamma ray. High-energy, short-wavelength electromagnetic radiation emitted from the nucleus of an atom. Gamma radiation frequently accompanies the emission of alpha or beta particles. Gamma rays are identical to x-rays except for the source of the emission.

gamma spectrometry. A system consisting of a detector, associated electronics, and a multichannel analyzer that is used to analyze samples for gamma-emitting radionuclides.

gas-flow proportional counter. A device or instrument in which an appropriate atmosphere is maintained in the counter tube by allowing a suitable gas to flow slowly through the sensitive volume thereby allowing ionization to occur.

Geiger-Mueller (GM) counter. A highly sensitive, gas-filled radiation detector which operates at voltages sufficiently high to produce ionization. The counter is used primarily in the detection of gamma radiation and beta emission. It is named for Hans Geiger and W. Mueller who invented it in 1928.

genetic selection. A descent with modification due to differing survival rates among young who vary in fitness according to genetic background.

grab sample. A full sample collected instantaneously using a glass or plastic bottle placed below the water surface to collect surface water samples. Grab samples are also called dip samples.

half-life, biological. The time required for a biological system, such as that of a human, to eliminate by natural processes half the amount of a substance (such as a radioactive material) that has entered it.

half-life, radiological. The time required for half of a given number of atoms of a specific radionuclide to decay. Each nuclide has a unique half-life.

head reversal. The hydrologic phenomenon in which a deeper formation has a higher water pressure than a more shallow formation in the same location. This condition results in a tendency for groundwater to flow upward from the deeper media to the more shallow formation.

HEPA. The acronym for High Efficiency Particulate Air filter.

hydrology. The science dealing with the properties, distribution, and circulation of natural water systems.

in-situ. In its original place; field measurements taken without removing the sample from its origin.

internal dose factor. A factor used to convert intakes of radionuclides to dose equivalents.

Ion. An atom or compound that carries an electrical charge.

ion exchange. Process in which a solution, containing soluble ions is passed over a solid ion exchange column which removes the soluble ions by exchanging them with labile ions from the surface of the column. The process is reversible so that the trapped ions can be removed (eluted) from the column and the column can be regenerated.

irradiation. Exposure to radiation.

isotopes. Forms of an element having the same number of protons in their nuclei but differing in the number of neutrons.

long-lived isotope - A radionuclide that decays at such a slow rate that a quantity of it will exist for an extended period (half-life is greater than three years).

short-lived isotope - A radionuclide that decays so rapidly that a given quantity is transformed almost completely into decay products within a short period (half-life is two days or less).

liquid scintillation cocktail. A solution combined with a radioactive sample which converts the energy of the particle emitted during radioactive decay into light, which is detected by a liquid scintillation counter.

liquid scintillation counter. The combination of phosphor, photomultiplier tube, and associated circuits for counting light emissions produced in the phosphors.

lower limit of detection (LLD). The smallest concentration/ amount of analyte that can be reliably detected in a sample at a 95% confidence level.

macrophyte. A plant that can be observed with the naked eye.

marinelli beaker. A 1-L beaker molded to fit around a germanium detector to optimize geometry.

maximally exposed individual. A hypothetical individual who remains in an uncontrolled area and would, when all potential routes of exposure from a facility's operations are considered, receive the greatest possible dose equivalent.

microbes. Microscopic organisms.

migration. The natural travel of a material through the air, soil, or groundwater.

milli-roentgen (mR). A measure of x-ray or gamma radiation. The unit is one-thousandth of a roentgen.

minimum detectable concentration (MDC). The smallest amount or concentration of a radioelement that can be distinguished in a sample by a given measurement system in a preselected counting time at a given confidence level.

monitoring. Process whereby the quantity and quality of factors that can affect the environment and/or human health are measured periodically in order to regulate and control potential impacts.

mrem. The dose equivalent which is one-thousandth of a rem.

natural radiation. Radiation arising from cosmic and other naturally occurring radionuclide (such as radon) sources that are present in the environment.

nonroutine radioactive release. Unplanned or non-scheduled release of radioactivity to the environment.

nonstochastic effects. Biological effects in which the severity in affected individuals varies with the magnitude of the dose above a threshold.

nuclide. An atomic nucleus specified by its atomic weight, atomic number,and energy state. A radionuclide is a radioactive nuclide.

outfall. The end of a drain or pipe that carries wastewater or other effluents into a ditch, pond, or river.

paddlewheel sampler. A sampling device, constructed of a Lexan® wheel, suspended on two pontoons and anchored in streams and rivers.

part per million (ppm). A unit measure of concentration equivalent to the weight/volume ratio expressed as mg/L.

part per billion (ppb). A unit measure of concentration equivalent to the weight/volume ratio expressed as μg/L or ng/ml.

person-rem. Collective dose to a population group. For example, a dose of one rem to 10 individuals results in a collective dose of 10 person-rem.

pH. A measure of the hydrogen ion concentration in an aqueous solution. Acidic solutions have a pH from 0 to 6, basic solutions have a pH greater than 7, and neutral solutions have a pH of 7.

planchet. A small, round, lipped, metal dish that is used to mount samples for radiological analyses.

population dose commitment. (see collective dose equivalent)

precision. The closeness of approach of a value of similar or replicate results to a common value in a series of measurements.

process water. Water which is an integral part of the system process as opposed to cooling water, for example, which is segregated from the process.

pulse height analysis. A spectroscopy technique in which the voltage (height) of an electronic pulse from a detector is related to the energy of the detected radiation.

quality assurance. A system of activities whose purpose is to provide the producer or user of a product or service the assurance that it meets defined standards of quality with a stated level of confidence.

quality control. Regulatory process through which actual quality performance is measured, compared with standards, and improved if necessary to meet the needs of the user.

quality factor. The factor by which the absorbed dose (rad) is multiplied to obtain a quantity that expresses, on a common scale for all ionizing radiation, the biological damage to exposed persons. It is used because some types of radiation, such as alpha particles, are more biologically damaging than others.

quench. (a) The reduction of the signal from a liquid scintillation cocktail due to chemical or color interferences; (b) a process by which a gas (usually a halogen) is added to a detector to inhibit avalanche ionizations.

rad. The unit of absorbed dose.

radiation detection instruments. Devices that detect and record the characteristics of ionizing radiation.

Radioactive Waste Burial Ground (RWBG). A place for burying unwanted radioactive material to prevent escape of radioactivity. The surrounding water acts as a shield. Such material is placed in watertight, noncorrodible containers so that it cannot leach out and invade underground water.

radioactivity. The spontaneous emission of radiation, generally alpha or beta particles, or gamma rays, from the nucleus of an unstable isotope.

radioisotopes. Radioactive isotopes.

radionuclide. An unstable nuclide capable of spontaneous transformation into other nuclides by changing its nuclear configuration or energy level. This transformation is accompanied by the emission of photons or particles.

reagent. Any substance used in a chemical reaction to detect or measure another substance or to convert one substance into another by means of the reaction which it causes.

reagent blank. A control sample which is used to determine the background of each reagent or solvent used in a given method of analysis. They are composed of all constituents that will contact the sample except the sample itself.

reclamation. The recovery of wasteland, desert, etc. by ditching, filling, draining, or planting.

reference material. A material or substance with one or more properties that is sufficiently well established and is used for the calibration of an apparatus, the assessment of a measurement method, or for assignment of values to materials.

reforestation. The process of planting new trees on land once forested.

regression analysis. A collection of statistical techniques that serve as a basis for drawing inferences about relationships among quantities in a scientific system.

rem. The unit of dose equivalent (rad x quality factor). Dose equivalent is frequently reported in units of millirem (mrem) which is one-thousandth of a rem.

resin. An organic polymer used as an ion-exchange material.

routine radioactive release. A planned or scheduled release of radioactivity to the environment.

screen zone. In well construction, the section of a formation that contains the screen, or perforated pipe that allows water to enter the well.

seepage basin. An excavation that receives wastewater. Insoluble materials settle out on the floor of the basin and soluble materials seep with the water through the soil column where they are removed partially by ion exchange with the soil. Construction may include dikes to prevent overflow or surface runoff.

self-absorption. Absorption of radiation by the sample itself, preventing detection by the counter.

sensitivity. The capability of methodology or instrumentation to discriminate between samples having differing concentrations or containing varying amounts of analyte.

sievert (Sv). The SI (International System of Units) of dose equivalent, 1 Sv=100 rem.

slurry. A suspension of solid particles (sludge) in water.

source. A point or object from which radiation emanates.

source check. A preparation with a known amount of radioactivity used to check the radiation detector instrument performance.

spike. The addition of a known amount of reference material containing the analyte of interest to a blank sample.

spill. Any unintentional discharge to the environment. Environment is broadly defined as any water, land, or ambient air.

SRS stream. Any natural stream on the SRS site. Surface drainage of the site is via these streams to the Savannah River.

stable. Not radioactive or not easily decomposed or otherwise modified chemically.

stack. A vertical pipe or flue designed to exhaust airborne gases and suspended particulate matter.

standard deviation. An indication of the dispersion of a set of results around their average.

standard reference material (SRM). A reference material distributed and certified by the National Institute of Standards and Technology.

stochastic effects. Biological effects, whose probability, rather than the severity, is a function of the magnitude of the radiation dose without threshhold (i.e., stochastic effects are random in nature).

substrate. The substance, base, surface, or medium in which an organism lives and grows.

Superfund reportable spill. A spill to the environment that exceeds reportable quantities as defined by CERCLA (Comprehensive Environmental Response Compensation and Liability Act).

surface water. All water on the surface of the earth, as distinguished from groundwater.

tank farm. An installation of interconnected underground tanks for storage of high-level radioactive liquid wastes.

taxa richness. The abundance of any rank such as a particular species, family, or class.

thermoluminescent dosimeters (TLDs). A device used to measure external gamma radiation levels.

total suspended particulates. Refers to the concentration of particulates in suspension in the air irrespective of the nature, source, or size of the particulates.

transect. A line across an area being studied. The line is composed of points where specific measurements or samples are taken.

tritium (H-3). The hydrogen isotope with one proton and two neutrons in the nucleus. It emits a low-energy beta particle (0.0186 MeV max) and has a half-life of 12.5 years.

turbidity. A measure of the concentration of sediment or suspended particles in solution.

uncontrolled area. Any area to which access is not controlled for the purpose of protecting individuals from exposure to radiation and radioactive materials. The area beyond the boundary of the Savannah River Site is an uncontrolled area.

variation. The divergence in the structural or functional characteristics of an organism from those that are considered typical of the group to which it belongs.

watershed. The region draining into a river, river system, or body of water.

weighting factor. A value used to calculate dose equivalents. It is tissue-specific and represents the fraction of the total health risk resulting from uniform, whole-body irradiation that could be contributed to that particular tissue. The weighting factors used in this report are recommended by the ICRP (Publication 26).

worldwide fallout. Radioactive debris from atmospheric weapons tests that has been deposited on the earth's surface after being airborne and cycling around the earth.

Appendix A: Listing of Environmental Monitoring Reports

ONSITE REPORTS

Reports of the routine environmental monitoring program at SRS have been prepared periodically since before SRS construction in 1951. The monitoring report numbering system and titles have been changed several times over the years to reflect the evolving progress in the concepts of environmental monitoring. The amount of detailed information contained in the reports also varies from time to time, and probably reflects the relative importance and emphasis given to topics by different authors.

Except for July–December 1953, reports were issued semi-annually from 1951 to 1962, and annually beginning in 1963. Attempts to find a report for July–December 1953 have been unsuccessful. The onsite report was discontinued in 1985 when the onsite and offsite reports were merged into a single publication.

Some of the monitoring reports originally contained secret information, primarily radioactive release values that could be related to production rates. The secret information in these reports was deleted in the mid-1970s, and a deleted version (DEL) of the report was issued.

Listed below are onsite environmental reports since 1951.

Number	Period	Title
DP27	Jun 1951–Jan 1953	Natural Radioactivity Content of the Savannah River Plant
DPSPU 54-11-12	Jan–Jul 1953	Works Technical Department Data Record, Health Physics Site Survey Data
No report	Jul–Dec 1953	
DP92	Jan–Jul 1954	Radioactivity in the Environment of the Savannah River Plant
DPSP 55-25-34	Jul–Dec 1954	Semi-Annual Progress Report-Regional
DPSP 56-25-13	Jan–Jun 1955	Semi-Annual Progress Report-Regional
DPSP 56-25-54 (DEL)	Jul–Dec 1955	Health Physics Regional Monitoring
DPSP 56-25-4 (DEL)	Jan–Jun 1956	
DPSP 57-25-15 (DEL)	Jul–Dec 1956	
DPSP 57-25-43 (DEL)	Jan–Jun 1957	
DPSP 58-25-17 (DEL)	Jul–Dec 1957	
DPSP 58-25-38 (DEL)	Jan–Jun 1958	
DPSPU 59-11-23	Jul–Dec 1958	
DPSPU 59-11-30	Jan–Jun 1959	
DPSPU 60-11-9	Jul–Dec 1959	
DPSP 60-25-26 (DEL)	Jan–Jun 1960	
DPSP 61-25-4 (DEL)	Jul–Dec 1960	
DPSP 62-25-2 (DEL)	Jan–Jun 1961	
DPSP 62-25-9 (DEL)	Jul–Dec 1961	
DPSP 63-25-3 (DEL)	Jan–Jun 1962	
DPSP 63-25-10 (DEL)	Jul–Dec 1962	
DPSPU 64-11-12	Jan–Dec 1963	Environmental Monitoring at the Savannah River Plant

DPST 65-302	Jan–Dec 1964	Environmental Monitoring at the Savannah River Plant
DPST 66-302	Jan–Dec 1965	
DPST 67-302	Jan–Dec 1966	
DPST 68-302	Jan–Dec 1967	
DPST 69-302	Jan–Dec 1968	
DPST 70-302	Jan–Dec 1969	
DPST 71-302	Jan–Dec 1970	
DPSPU 72-302	Jan–Dec 1971	
DPSPU 73-302	Jan–Dec 1972	
DPSPU 74-302	Jan–Dec 1973	
DPSPU 75-302	Jan–Dec 1974	
DPSPU 76-302	Jan–Dec 1975	
DPSPU 77-302	Jan–Dec 1976	
DPSPU 78-302	Jan–Dec 1977	
DPSPU 79-302	Jan–Dec 1978	
DPSPU 80-302	Jan–Dec 1979	
DPSPU 81-302	Jan–Dec 1980	
DPSPU 82-302	Jan–Dec 1981	
DPSPU 83-302	Jan–Dec 1982	
DPSPU 84-302	Jan–Dec 1983	
DPSPU 85-302	Jan–Dec 1984	

DEL–reissue of reports with secret information deleted.

OFFSITE REPORTS

Results of the environmental monitoring program that affected the offsite environment have been reported to the public since 1959. These reports contained data from the site boundary and beyond. The offsite report was discontinued in 1985 when the onsite and offsite reports were merged into a single publication. A listing of the offsite reports follows:

Number	Period	Title
No document number	Jan–Dec 1959	The Effect of the Savannah River Plant on Environmental Radioactivity
	Jan–Mar 1960	
	Apr–Jun 1960	
	Jul–Sep 1960	
	Oct–Dec 1960	
	Jan–Mar 1961	
	Apr–Jun 1961	
	Jul–Sep 1961	
DPSPU 62-30-11	Oct–Dec 1961	
DPSPU 62-30-24	Jan–Jun 1962	
DPSPU 63-30-12	Jul–Dec 1962	
DPSPU 63-30-1	Jan–Jun 1963	
DPSPU 64-30-1	Jul–Dec 1963	
DPSPU 64-30-2	Jan–Jun 1964	
DPSPU 65-30-1	Jul–Dec 1964	
DPST 65-30-2	Jan–Jun 1965	
DPST 66-30-1	Jul–Dec 1965	

DPST 66-30-2	Jan–Jun 1966	The Effects of the Savannah River Plant on Environmental Radioactivity
DPST 67-30-1	Jul–Dec 1966	
DPST 67-30-2	Jan–Jun 1967	
DPST 68-30-1	Jul–Dec 1967	
DPST 68-30-2	Jan–Jun 1968	
DPST 69-30-1	Jul–Dec 1968	
DPST 69-30-2	Jan–Jun 1969	
DPST 70-30-1	Jul–Dec 1969	
DPST 70-30-2	Jan–Jun 1970	
DPST 71-30-1	Jul–Dec 1970	
DPST 71-30-16	Jan–Jun 1971	
DPSPU 72-30-1	Jan–Dec 1971	Environmental Monitoring in the Vicinity of the Savannah River Plant
DPSPU 73-30-1	Jan–Dec 1972	
DPSPU 74-30-1	Jan–Dec 1973	
DPSPU 75-30-1	Jan–Dec 1974	
DPSPU 76-30-1	Jan–Dec 1975	
DPSPU 77-30-1	Jan–Dec 1976	
DPSPU 78-30-1	Jan–Dec 1977	
DPSPU 79-30-1	Jan–Dec 1978	
DPSPU 80-30-1	Jan–Dec 1979	
DPSPU 81-30-1	Jan–Dec 1980	
DPSPU 82-30-1	Jan–Dec 1981	
DPSPU 83-30-1	Jan–Dec 1982	
DPSPU 84-30-1	Jan–Dec 1983	
DPSPU 85-30-1	Jan–Dec 1984	Savannah River Plant Environmental Report

ENVIRONMENTAL REPORTS (COMBINED ONSITE AND OFFSITE)

In 1985, the onsite and offsite environmental monitoring reports were merged into a single publication. A listing of these reports follows:

Number	Period	Title
DPSPU 86-30-1	Jan–Dec 1985	Savannah River Plant Environmental Report
DPSPU 87-30-1	Jan–Dec 1986	Savannah River Plant Environmental Report
DPSPU 88-30-1	Jan–Dec 1987	Savannah River Plant Environmantal Report

Appendix B: Environmental Permits

PERMIT NUMBER	TYPE	TITLE
0080-0060-CF	AIR	1000 KW Emergency Diesel Generator, 654-1T
0080-0060-CE	AIR	300 KW Emergency Diesel Generator, 654-T
0080-0066-CA	AIR	2000 KW Emergency Diesel Generator, 292-S
0080-0042-CA	AIR	400 KW Emergency Power Diesel Generator, 773-A
0080-0045-CA	AIR	200 KW Emergency Diesel Generator, 254-5F #1
0080-0045-CA	AIR	175 KW Emergency Diesel Generator, 772-F #1
O/P-02-285	AIR	Uranium Dissolution, 221-F (Pending Enforcement Action Resolution)
0080-0045-CH	AIR	350 KW Emergency Diesel Generator, 241-19F
0080-0045-CD	AIR	315 KW Emergency Diesel Generator, 221-FB
0080-0045-CA	AIR	415 KW Emergency Diesel Generator, 772-1F
0080-0045-CF	AIR	300 KW Emergency Power Diesel Generator, 254-9F
0080-0046-0	AIR	400 LBS/HR Type "O" Waste Incinerator, Baghouse and Hepa Filters (Beta-Gamma Incinerator)
0080-0046-CA	AIR	300 KW Emergency Power Diesel Generator, 221-HB
0080-0046-CC	AIR	1000 KW Emergency Power Diesel Generator, 221-H
0080-0047-CA	AIR	225 KW Emergency Power Diesel Generator
0080-0055-CB	AIR	400 Gallon/Minute Air Stripper
0080-0066-CD	AIR	84 Ton/Hr Cem Storage Silo, Baghouse
0080-0060-CA	AIR	300 KW Emergency Power Diesel Generator, 673-T
0080-0060-CC	AIR	300 KW Emergency Power Diesel Generator, 672-T
0080-0060-CB	AIR	20 LBS/HR Shirco incinerator, Hepa Filters, 677-T
0080-0060-CD	AIR	Process to Decompose Tetraphenylborate into Aqueous and Organic Portions, 682-T
0080-0046-CJ	AIR	455 KW Emergency Diesel Generators, 720-H
0080-0046-CG	AIR	765 KW Emergency Power Diesel Generator, 233H
0080-0046-CD	AIR	Alt Tanks 48H and 49H (In-Tank Precipitation Air Quality Control Permit)
0080-0046-CE	AIR	150 KW Emergency Power Diesel Generator, 241-96H
0080-0046-CF	AIR	1000 KW Emergency Power Diesel Generator
0080-0046-CH	AIR	Fuel Processing Facility (FPF) with Hepa Filters
0080-0046-CI	AIR	400 and 500 KW Emergency Power Diesel Generators, 254-8H, 254-9H
0080-0042-CC	AIR	455 KW Emergency Diesel Generators, 720-2A
0080-0042-CB	AIR	250 KW Emergency Power Diesel Generator
0080-0042-CA	AIR	150, 400, 200 KW Emergency Power Diesel Generators, 703-A, 503-2A, 751-A
0080-0042-CB	AIR	250 KW Diesel Driven Electric Driven Generator, 754-4A
0080-0045-CI	AIR	FMF Cement and Flyash Silos and Baghouse
0080-0045-CJ	AIR	455 KW Emergency Diesel Generators, 720-F
0080-0066-CC	AIR	187 KW Emergency Power Diesel Generator, 980-S
0080-0047-CA	AIR	225 and 365 KW Emergency Power Diesel Generators, 105-K, 183-K

0080-0080-CG	AIR	Silo to Store Cement, with Baghouse
0080-0080-CA	AIR	425 KW Emergency Power Diesel Generator
0080-0048-CA	AIR	225 and 365 KW Emergency Power Diesel Generators, 105-L, 183-2L
P/C-02-358	AIR	Fuel Materials Facility (FMF) (Inc. Batch Mixer Vent Emissions)
P/C-02-359	AIR	FMF Waste Treatment Facility
P/C-02-360	AIR	1483 KW Emergency Diesel Generator
P/C-02-364	AIR	Batch Process Filtration Unit and Scrubber
0080-0043-CA	AIR	225 and 365 Emergency Power Diesel Generators, 105-C, 183-2C
0080-0055-CA	AIR	50 GPM Air Stripper
0080-0066-CB	AIR	DWPF Vitrification Process, 221-S
0080-0079-0	AIR	180 KW Emergency Power Diesel Generator, Atta Facility
0080-0080-CB	AIR	Three Fly Ash Silos with Baghouse
0080-0080-CC	AIR	Weigh Hopper with Baghouse
0080-0080-CD	AIR	Two Premix Air Blenders with Baghouse
0080-0080-CE	AIR	Premix Feed Bin with Baghouse
0080-0055-CC	AIR	200 KW Emergency Power Diesel
0080-0045-CB	AIR	175 KW Emergency Diesel Generator, 772-F #2
0080-0080-CH	AIR	Substitute Slag for Cement to be stored in Silo (Z-Area, Modification to 0080-0080-CA)
0080-0080-CJ	AIR	Low Point Drain Tank Vent with Hepa Filter (Z-Area)
0080-0080-CI	AIR	Modification of Permit 0080-0080-CF to Include VOC Emissions From Stack (Z-Area)
0080-0042-CB	AIR	200 KW Emergency Power Diesel Generator, Bldg. 254-5F #2
0080-0080-CF	AIR	Grout Mixer with Baghouse
P/C-02-361	AIR	Nine Finishing Processes for FMF
0080-0045-CH	AIR	350 KW Emergency Power Diesel Generator
O/P-02-271	AIR-VOID	71.7 MMBTU/HR Coal Boiler #1, Cyclones, 284-F
O/P-02-272	AIR-VOID	71.7 MMBTU/HR Coal Boiler #2, Cyclones, 284-F
O/P-02-273	AIR-VOID	71.7 MMBTU/HR Coal Boiler #3, Cyclones, 284-F
O/P-02-274	AIR-VOID	71.7 MMBTU/HR Coal Boiler #4, Cyclones, 284-F
0080-0045-CE	AIR-VOID	600 KW Emergency Power Diesel Generator, 221-F
0080-0066-CA	AIR-VOID	270 CU YDS/HR Concrete Batch Plant
0080-0045-CD	AIR-VOID	315 and 1025 KW Emergency Diesel Generator, 292-2F
N/A	AIR-VOID	12 LBS/HR Pilot Plant Incinerator
0080-0080-CA	AIR-VOID	Storage Silo and Baghouse, 425 KW Emergency Power Diesel Generator
LS-233-W	DOMESTIC WATER	Temporary Domestic Water for F/H ETF Construction Office
LS-232-W	DOMESTICWATER Facilities	Temporary Domestic Water for FPF & RTF
404618	DOMESTIC WATER	705-C Domestic Water
404608	DOMESTIC WATER	717-K Domestic Water
204198	DOMESTIC WATER	Replace Domestic Deepwell, 905-66H
204138	DOMESTIC WATER	Replace Domestic Deepwell, 905-94K
203638	DOMESTIC WATER	Replace Allendale Barricade Well
203628	DOMESTIC WATER	Replace Pistol Range Well
LS-238-W	DOMESTIC WATER	ECF/CAS Security Upgrade Facilities, H-Area

200279	DOMESTIC WATER	Install Domestic Deepwell 905-120-P (Well - P-Area)
401118	DOMESTIC WATER	Domestic Water for NWTF
LS-178-W	DOMESTIC WATER	Computer Repair Building Domestic Water, 722-5A
203427	DOMESTIC WATER	Sodium Hypochlorite System, 280-F
203467	DOMESTIC WATER	Sodium Hypoclorite System, 280-H
LS-187-W	DOMESTIC WATER	ETF-F Lift Station Domestic Water
411357	DOMESTIC WATER	ETF-H Lift Station Domestic Water
LS-185-W	DOMESTIC WATER	Domestic Water Main, 901-A
205217	DOMESTIC WATER	Upgrade Instrumentation 280-1, F/H Areas
405556	DOMESTIC WATER	Domestic Water System, 200-H
LS-54-W	DOMESTIC WATER	Domestic Water Line, 707-H
212745	DOMESTIC WATER	DWPF Domestic Water Wells 1 and 2
402186	DOMESTIC WATER	DWPF Domestic Water Distr. System
401446	DOMESTIC WATER	Production Control Facility for 200 Area Process 772-1F
408285	DOMESTIC WATER	Domestic Water Service for Sanitary Waste Treatment Facility, TNX
LS-23-W	DOMESTIC WATER	DWPF TC Emergency Water Supply
203786	DOMESTIC WATER	Drinking Water Well 905-114G, 681-3G
LS-43-W	DOMESTIC WATER	Technical Area Water Main Bypass, 773-14A
411995	DOMESTIC WATER	Water Distribution System, 340-M, 341-M
LS-82-W	DOMESTIC WATER	Domestic Water for Sanitary Treatment Facility, U-Area
LS-81-W	DOMESTIC WATER	Domestic Water for Construction Office Bldg., C Area
LS-56-W	DOMESTIC WATER	Domestic Water Supply for Chemical Feed Facilities In G&H Areas (H)
LS-55-W	DOMESTIC WATER	Domestic Water Supply for Chemical Feed Facilities In G&H Areas (G)
LS-61-W	DOMESTIC WATER	Domestic Water Line to feed DWPF Sanitary Treatment Plant
LS-60-W	DOMESTIC WATER	Domestic Water Line for 704-S Administration Bldg. DWPF
LS-57-W	DOMESTIC WATER	Domestic Water Line Relocation & Service Line Install, Bdg. 735-11A
41225	DOMESTIC WATER	3/700 A-Area Water Line from New Domestic Wells
208866	DOMESTIC WATER	Domestic Water Well for Aiken Barricade Gate House (701-5G)
400347	DOMESTIC WATER	Domestic Water Headers, TNX Area
LS-115-W	DOMESTIC WATER	Water Line, Crafts & Engineers, CAB/Central Shop
LS-106-W	DOMESTIC WATER	DWPF Auxiliary Pump PIT Water Lines, S-511
410406	DOMESTIC WATER	Drinking Water System, 777-A
210657	DOMESTIC WATER	Drinking Water Well And Distribution System, 905-39F
LS-139-W	DOMESTIC WATER	Replacement Tritium Facility Domestic Water, 233-H, 249H
400367	DOMESTIC WATER	Fuel Production Facility Water System, 225H
111626	DOMESTIC WATER	Upgrade Gaseous Chlorination Facility, D/G Areas
406137	DOMESTIC WATER	Interim Storage and Redrumming FAC., Domestic Water, 709-1G, 709-2G
LS-118-W	DOMESTIC WATER	Water Line, 719-4A
LS-119-W	DOMESTIC WATER	Water Line, 730-M
400737	DOMESTIC WATER	Water Line, DWPF, Z-Area
205877	DOMESTIC WATER	Augusta Barricade Water Well, 905-116G

405566	DOMESTIC WATER	Domestic Water System, 200-F
208425	DOMESTIC WATER	Atta Domestic Water System
LS-25-W	DOMESTIC WATER	Chemical Feed Facility Water System, 100-C
408595	DOMESTIC WATER	Domestic Water Line, Construction Office Building, 300-M
409955	DOMESTIC WATER	Helicopter Facility Domestic Waterline
207005	DOMESTIC WATER	Activated Carbon Treatment System, 3/700 Area
LS-59-W	DOMESTIC WATER	Water System, DWPF Ice House
402925	DOMESTIC WATER	DWPF Temporary Domestic Water
206575	DOMESTIC WATER	Domestic Water Deepwells and Distribution Line, A-Area
201715	DOMESTIC WATER	Domestic Deepwell, Railroad Classification Yard, 905-107G
209454	DOMESTIC WATER	TNX Domestic Water System and Well
409484	DOMESTIC WATER	Water Line, Reactor Simulator Facility, 707-C
LS-11-W	DOMESTIC WATER	Water Line, Naval Fuels Mater Facility, 247-F
LS-7-W	DOMESTIC WATER	Water Line, Naval Fuels Mater Facility, 221-17F, 221-18F
LS-8-W	DOMESTIC WATER	Water Line, 703-4A, 703-6A, 703-34A
208434	DOMESTIC WATER	Domestic Water System, Barricades, 701-8G, 701-12G, 701-13G
202915	DOMESTIC WATER	Water Supply and Well System, DWPF Construction Support Area
402874	DOMESTIC WATER	Segregated Domestic Water Supply, 300/700 Area, Phase I
403434	DOMESTIC WATER	Segregated Domestic Water Supply, 300/700 Area, Phase II
48061	DOMESTIC WATER	Temporary Water System, 905-104L, 904-105L
200092	DOMESTIC WATER	Deep Wells, 905-104L, 904-105L
LS-4-W	DOMESTIC WATER	Water Line, Office Bldg., 703-41A
LS-1-W	DOMESTIC WATER	Water Line, Tritium Facilities Support Bldg., 235-H
405184	DOMESTIC WATER	Water Line, 773-41A, 773-42A
412917	DOMESTIC WATER	Drinking Water System, ETF, 241-84H, 241-81H
208177	DOMESTIC WATER	Phosphate Feed System, B-Area
LS-265-W	DOMESTIC WATER	Domestic Water Supply for Equipment Storage & Health Protection (HP) Facility 221-25F (F-Area)
LS-264-W	DOMESTIC WATER	Central Shops Construction Div. Quality Office Bldg.
411337	DRINKING WATER	Install Sodium Hypochlorite System, 780-A
IWP-219	IND. SOLID WASTE	200-F Erosion Control Site
IWP-211	IND. SOLID WASTE	200-H Erosion Control Site
IWP-210	IND. SOLID WASTE	D-F Steamline Erosion Control Site
IWP-087A	IND. SOLID WASTE	Sanitary Landfill Expansion
IWP-212	IND. SOLID WASTE	Coal-Ash Waste Landfill, 100-P Area
IWP-217	IND. SOLID WASTE	Z-Area Saltstone Disposal Facility (Solid Waste) - Modification
IWP-175	IND. SOLID WASTE	Experimental Sewage Sludge Application Sites (Road F, 1953 Sandy, Kato Road, Par Pond, K-Area, 40 Acre Hardwood, Lower)
13,734	IND. WASTEWATER	Industrial Wastewater pH Control System, 211-H
13,735	IND. WASTEWATER	Industrial Wastewater PH Control System, 211-F
13,978	IND. WASTEWATER	TNX ION Exchange Facility
13,286	IND. WASTEWATER	Portable Chromium Removal System, SRL

14,068	IND. WASTEWATER	M-Basin Closure Wastewater Treatment Facility (M-Area Basin)
14,020	IND. WASTEWATER	Mercury and Organic Removal Facility for F&H ETF
14214	IND. WASTEWATER	Batch Mixer System-FMFWastewater Treatment Facility Mod.
14,379	IND. WASTEWATER	Upper Three Runs Creek Diffuser (For F&H ETF - Outfall H-016)
14218	IND. WASTEWATER	NPDES Outfall Structures F-012 & F-013 (Flow Monitoring Weir Box Structures)
14219	IND. WASTEWATER	NPDES Outfall Structures H-017 & H-018 (Monitoring Weir Box Structures)
14520	IND. WASTEWATER	F&H ETF Tank 50 As-Built
14,100	IND. WASTEWATER	Repair Ash Basin Dike 488-1D
13,457	IND. WASTEWATER	L-Tank Mercury Removal
12,773	IND. WASTEWATER	L-Lake Thermal Barrier Curtain
12,683	IND. WASTEWATER	Z-Area Saltstone MFG. FAC.
12,782	IND. WASTEWATER	Replacement Tritium Facility Process Sewer
LS-186-S	IND. WASTEWATER	FPF Process Sewer Line
13,105	IND. WASTEWATER	ETF Process Sewer Lines, F/H-Area
13,154	IND. WASTEWATER	Flow Measurement Device, L Area
12,922	IND. WASTEWATER	Naval Fuel Facility Modifications
12,894	IND. WASTEWATER	Filtrate Hold Tank Covers, M Area
12,870	IND. WASTEWATER	Effluent Treatment Facility - F/H Area (ETF)
12,622	IND. WASTEWATER	Organics Removal Facility, TNX
12,633	IND. WASTEWATER	Effluent Treatment Plant, TNX (ETP)
11,413	IND. WASTEWATER	DWPF Chemical Treatment Facility, S-Area
11,411	IND. WASTEWATER	DWPF Treated Effluent Line
11,588	IND. WASTEWATER	Powerhouse Effluent Diversion to Ash Basins, D/H Areas
11,589	IND. WASTEWATER	Powerhouse Effluent Diversion to Ash Basins, K & P Areas
12,888	IND. WASTEWATER	Metallurgical Laboratory Neutralization Facility, 723-A
10,389	IND. WASTEWATER	M-Area Drain Line
10,469	IND. WASTEWATER	735-11A Lab Bldg. Process Sewer System Neutralization Facility
10,358	IND. WASTEWATER	S-Area Oil Separator
10,253	IND. WASTEWATER	M-Area 330 GPM Air Stripper
9886	IND. WASTEWATER	M-Area 50 GPM Air Stripper
10,349	IND. WASTEWATER	672-T TNX Process Sewer to Outfall X-008
10,949	IND. WASTEWATER	Trade Waste Flow Equalization Tank, 607-18A
10,920	IND. WASTEWATER	SREL Wastewater Disinfection Facility
10,765	IND. WASTEWATER	Wastewater Neutralization Facility, 704-U
11,497	IND. WASTEWATER	Production Control Facility Sanitary/Process Sewer, 772-1F
11,406	IND. WASTEWATER	Fire Brigade Training Facilities Oil Separator, 411-D
11,971	IND. WASTEWATER	Carbon Bed Piping for Organics Removal Demonstration Proj.-TNX
11,498	IND. WASTEWATER	Flow Monitoring Station for NPDES Outfall - L-007
13,354	IND. WASTEWATER	D-Area Neutralization Facility, 483-1D
13,355	IND. WASTEWATER	F-Area Neutralization Facility, 280-1F
13,356	IND. WASTEWATER	H-Area Neutralization Facility, 280-H

13,357	IND. WASTEWATER	K-Area Neutralization Facility, 183-2K
12,973	IND. WASTEWATER	P-Area Neutralization Facility, 183-2P
LS-112-S	IND. WASTEWATER	Fire Training Facility Process Sewer, 904-D
11,760	IND. WASTEWATER	Wastewater For PCB Clean-Up, 320-M
10,696	IND. WASTEWATER	Interim Sludge Storage Tank, M-Area
LS-42-S	IND. WASTEWATER	Inert L Facility Loading Dock Sewer Relocation, 234-H
10,955	IND. WASTEWATER	DWPF Concrete Batch Plant Wastewater Treatment Pond, S Area
10,778	IND. WASTEWATER	Wastewater Treatment Facility, Naval Fuel (FMF)
10,475	IND. WASTEWATER	Non-Contact Cooling Water Diversion, 300-M Area
9974	IND. WASTEWATER	Concrete Batch Plant, S-Area
10,287	IND. WASTEWATER	Liquid Effluent Treatment Facilities, 300-M (LETF)
7289	IND. WASTEWATER	"As Built" Wastewater Treatment Facilities, A and M Areas
7290	IND. WASTEWATER	"As Built" Wastewater Treatment Facilities, F-Area
7291	IND. WASTEWATER	"As Built" Wastewater Treatment Facilities, H-Area
7292	IND. WASTEWATER	"As Built" Wastewater Treatment Facilities, P Area
7293	IND. WASTEWATER	"As Built" Wastewater Treatment Facilities, K Area
7294	IND. WASTEWATER	"As Built" Wastewater Treatment Facilities, C Area
7295	IND. WASTEWATER	"As Built" Wastewater Treatment Facilities, D Area
7296	IND. WASTEWATER	"As Built" Wastewater Treatment Facilities, CS Area
13,431	IND. WASTEWATER	Flume at M-004 Outfall
13,456	IND. WASTEWATER	L-Tank "As Built"
SC 88-D-005	IND. WASTEWATER	F/H ETF Diffuser (Permit Application to S.C. Water Resources Commission - SCWRC)
14,338	IND. WASTEWATER	H-Z Inter-Area Salt Solution Transfer Line (H-Area - Z Area) (As-Built Permit to Transfer Solution From Tank-50 in H Area)
14624	IND. WASTEWATER	As Built Process Sewer Lines Between 200 H & F Areas to F/H ETF
84-2Z-209	MAIN. DREDGING	Maintenance Dredging in Raw Water Intake Canal on Savannah River - South Carolina Water Resources Commission (SCWRC)
84-2Z-209	MAINT. DREDGING	Maintenance Dredging in Raw Water Intake Canal (681-5G) On Savannah River - Corps of Engineers (COE)
LS-10-S	SAN. WASTE	Sanitary Sewer System, Naval Fuels Material Facility, 248-F
14,407	SAN. WASTEWATER	Increased Sanitary Wastewater Treatment Capcity, 607-15D (D Area)
10,131-P	SAN. WASTEWATER	Septic Tank and Drain Field for RTF Construction Engineers Office
10,132-P	SAN. WASTEWATER	Septic Tank and Drain Field for FPF Construction Engineers Office
9998	SAN. WASTEWATER	Septic Tank And Drain Field for F&H ETF
LS-227-S	SAN. WASTEWATER	705-C Sanitary Sewer
LS-228-S	SAN. WASTEWATER	717-K Sanitary Sewer
LS-239-S	SAN. WASTEWATER	ECF/CAS Security Upgrade Facilities, F-Area
LS-240-S	SAN. WASTEWATER	3/700 Area Security Upgrade, Building 720-2A
LS-256-S	SAN. WASTEWATER	Grinder Pump for F-Area EQ. Basin (Macerator) (607-18F)

14,321	SAN. WASTEWATER	Interim Sodium Hypochlorite Dis. for SREL Waterfowl Lab
14,322	SAN. WASTEWATER	Interim Sodium Hypochlorite Dis. for 607-18G
14,315	SAN. WASTEWATER	Interim Sodium Hypochlorite Dis. for 607-7F & 607-21F
14,314	SAN. WASTEWATER	Interim Sodium Hypochlorite Dis. for 607-7P & 607-23P
14,312	SAN. WASTEWATER	Interim Sodium Hypochlorite Dis. for 607-17K
14,316	SAN. WASTEWATER	Interim Sodium Hypochlorite Dis. for 607-7H & 607-21H
14,317	SAN. WASTEWATER 2S	Interim Sodium Hypochlorite Dis. for 831-1S &832-
14,324	SAN. WASTEWATER	Interim Sodium Hypochlorite Dis. for 607-40T
14,319	SAN. WASTEWATER	Interim Sodium Hypochlorite Dis. for 607-1B
14,323	SAN. WASTEWATER	Interim Sodium Hypochlorite Dis. for 607-17F (NF)
14,313	SAN. WASTEWATER	Interim Sodium Hypochlorite Dis. for 607-17L
14,311	SAN. WASTEWATER	Interim Sodium Hypochlorite Dis. for 607-7C
14,320	SAN. WASTEWATER	Interim Sodium Hypochlorite Dis. for 607-9A
14,318	SAN. WASTEWATER	Interim Sodium Hypochlorite Dis. for 607-15D
13,156	SAN. WASTEWATER	716-2A Sanitary Sewer
LS-168-W	SAN. WASTEWATER	A-Area Sanitary Sewer
13,157	SAN. WASTEWATER	Computer Repair Building Sanitary Sewer, 722-5A
13,430	SAN. WASTEWATER	Sanitary Sewage Treatment Facility, 607-21F
13,173	SAN. WASTEWATER	Sanitary Sludge Land Application, K Area and Par Pond Borrow Pits
12,695	SAN. WASTEWATER	Replacement Tritium Facility Sanitary Sewer
13,175	SAN. WASTEWATER	Flow Equalization Basin, Building 607-22A
LS-158-S	SAN. WASTEWATER	Sanitary Sewer, 3/700 Construction Facility
12,910	SAN. WASTEWATER	Sanitary Treatment Facility, H Area
LS-149-S	SAN. WASTEWATER	Sanitary Sewer, TNX-ETP
LS-52-S	SAN. WASTEWATER	Sanitary Sewer, 707-H
10,906	SAN. WASTEWATER	Sanitary Sewer, 341-M
10,530	SAN. WASTEWATER	TNX Sanitary Wastewater Treatment Plant, 607-4G
10,499	SAN. WASTEWATER	DWPF Sanitary Sewer System, 200S
LS-35-S	SAN. WASTEWATER	Sanitary Sewer Relocation, Bldg. 735-11A
10,314	SAN. WASTEWATER	DWPF Construction Site Sanitary Sewer System
LS-62-S	SAN. WASTEWATER	717-F Sanitary Sewer Relocation for DWPF
8928	SAN. WASTEWATER	FMF Sanitary Waste Treatment Plant
LS-53-S	SAN. WASTEWATER	Sanitary Sewer Line, Construction Office Building, M Area
11,847	SAN. WASTEWATER	Effluent Weir for Sanitary Treatment System, TNX
11,615	SAN. WASTEWATER	Sanitary Treatment Plant - U-Area
9888	SAN. WASTEWATER	DWPF Sanitary Waste Treatment Plant
9983	SAN. WASTEWATER	Sanitary Treatment Plant, 100-C Area
LS-3-S	SAN. WASTEWATER	Sanitary Sewer System, Office Bldg., 703-41A
LS-2-S	SAN. WASTEWATER	Sanitary Sewer Line, Tritium Facilities Support Bldg., 235-H
9694	SAN. WASTEWATER	Sanitary Sewer System, 773-41A, 773-42A
9326	SAN. WASTEWATER	Sanitary Wastewater Treatment Plant, F, H, P & G Areas
LS-275-S	SAN. WASTEWATER	Sanitary Sewer for Equipment Storage & Health Protection (HP) Facility, 221-25F (F-Area)
13,291	SAN. WASTEWATER	H-Area Septic Tank & Tile Field (Commercial Toilet Trailer)

12,076	SOLID WASTE	Sanitary Sludge Land Application, F&H Area Borrow Pits
GW-02-894	UNDERGD. STORAGE	Gasoline Station Building 715-2G & Gas TK Replacement, Plantwide (UST)
LS-98-S	SAN. WASTEWATER	Sanitary Sewer Addition, S Area
12,453	SAN. WASTEWATER	Bromide Feed System, 607-18F
12,452	SAN. WASTEWATER	Bromide Feed System, 607-19L
10,825	SAN. WASTEWATER	Sanitary Sewer Lift Station, 607-19-A
11,847	SAN. WASTEWATER	Effluent Weir, TNX
11,442	SAN. WASTEWATER	Lift Station - Force Main, 241-82H
LS-32-S	SAN. WASTEWATER	Sanitary Sewer Line, Wackenhut Bldg., TC/U Area
10,521	SAN. WASTEWATER	Chemical Feed Facility, A Area
10,522	SAN. WASTEWATER	Chemical Feed Facility, F Area
10,523	SAN. WASTEWATER	Chemical Feed Facility, H Area
10,524	SAN. WASTEWATER	Chemical Feed Facility, P Area
10,525	SAN. WASTEWATER	Chemical Feed Facility, G Area
10,526	SAN. WASTEWATER	Chemical Feed Facility, D Area
10,236	SAN. WASTEWATER	Lift Station, Change Station Facility, 241-58H
9940	SAN. WASTEWATER	Sanitary Sewer System, Reactor Simulator Facility, 707-C
8881	SAN. WASTEWATER	Flow Equalization Basin, 700-A
LS-78-S	SAN. WASTEWATER	Sanitary Sewer Line for Construction Office Building, C Area
LS-80-S	SAN. WASTEWATER	Sanitary Sewer Line - Receiving & Stores Warehouse Const. Central Shops
LS-79-S	SAN. WASTEWATER	Sanitary Sewer Line - Electrical Office Bldg., Const. Central Shops
11,407	SAN. WASTEWATER	Sanitary Waste Transfer Station 321-M Change Room Renovation
13,155	SAN. WASTEWATER	Naval Fuels Flow Measurement Device; Outfall F-003(A)
14,443	SAN. WASTEWATER	Septic Tank and Tile Field, H Area
LS-134-S	SAN. WASTEWATER	DWPF Sanitary Sewer Line Modification
9256P	SAN. WASTEWATER	Septic Tank and Tile Field, Landfill Monitoring Bldg. 642-G
12,725	SAN. WASTEWATER	F-Area STP-Phase III, 607-F
12,498	SAN. WASTEWATER	F-Area STP-Phase III
LS-206-S	SAN. WASTEWATER	Sewer Pipe and Manhole, 704-1T TNX
8611-P	SAN. WASTEWATER	Septic Tank and Tile Field, CS Area, 709-1G
13,717	SAN. WASTEWATER	Wastewater Treatment Facility, Z Area (Septic Tank System)
12,383	SAN. WASTEWATER	Fuel Production Facility Sanitary Sewer, 225-H
LS-129-S	SAN. WASTEWATER	Sanitary Sewer, 719-4A
12,386	SAN. WASTEWATER	Sanitary Sewer, 730-M

Appendix C: Savannah River Site Historical Environmental Highlights

1950 - Original Du Pont Contract Awarded in August

1951 - Began Onsite Environmental Monitoring

1951 - Started Forest Management

1951 - Began Biological Monitoring of the Savannah River by the Academy of Natural Sciences Of Philadelphia

1952 - Began The University Of Georgia Ecology Studies At SRS

1953 - Began Use of Environmental Technical Standards Based on Recommendations of Standards-Setting Organizations such as NCRP, ICRP, FRC, AED

1959 - Began Distribution of Annual Environmental Monitoring Report to the Public

1960 - Established Radionuclide Release Guides for Specific SRS Streams

1961 - Established University of Georgia-Operated Savannah River Ecology Laboratory

1964 - Related Release Guides to Potential Dose and Technical Standards Containing Release Guides for all SRS Streams Were Established to Stay Under the Dose Limit

1964 - Established Release Guides For I-131 from all SRS Stacks

1965 - Started Controlled Deer Hunts

1971 - Formed Environmental Analysis and Planning Division Which Reported Directly to Du Pont Management

1971 - Developed a Radioactivity Emission Inventory

1972 - Provided Radioactive Dose Calculations for Offsite Public from SRS Releases in Annual Environmental Monitoring Report for the First Time

1972 - Prepared a Report on SRS Thermal Distributionsin SRS Waters and in the Savannah River

1972 - Du Pont Site Technical Standards Took "As Low As Reasonably Achievable" Approach for Environmental Releases and this was Applied to Release Guides on an Annual Basis Thereafter

1972 - Du Pont Site Technical Standard Set for Offsite Dose to Maximum Individual Of 10 mrem/year to Whole Body, Gonads and Bone Marrow, 30 mrem/year to Gi Tract, Bone Thyroid and all other Organs

1972 - Developed an Applied Research Plan for SRL/SRS

1972 - Became The First National Environmental Research Park within DOE

1973 - Formed an Environmental Research Organization within SRL

1973 - Formed a Central Environmental Committee

1974 - Performed First Epidemological Studies of Populations Surrounding the Site

1974 - Began Improving Meteorological Input to Site Emergency Capabilities

1975 - Published a Report Outlining the Needs for Environmental Monitoring of Nonradioactive Materials

1975 - Began Studies on Tritiated Gas Cycling in Forest Ecosystems

1976 - Conducted Studies on Uptake of Plutonium by Agricultural Crops

1977 - Conducted Dye Studies onsite Creeks to Obtain Transport and Dispersion Parameters

1978 - Added Automated Forecast Meteorology to Site Emergency Response Capability through Collaboration with the National Weather Service

1979 - Developed an Understanding of The Ecology of the Legionnaires Disease Bacterium

1980 - Developed a Computer Model of Heavy Gas Dispersion

1983 - Formed a Du Pont Environmental Advisory Committee for the Site

1985 - Completed the TRAC Mobile Laboratory

1985 - Merged the On-And Offsite Environmental Monitoring Reports and included Highlights Of Site Wide Environmental Studies In the Annual Public Report

1985 - Completed the Ultra-Low-Level Underground Counting Laboratory

1986 - Standardized And Verified Methods of Calculating Dose to Public through Environmental Pathways

1986 - Published DOE Strategic Environmental Plan

1988 - Published a Draft DOE Environmental Implementation Plan

Index

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	(rad)	rad	10^{-2} Gy
dose equivalent	sievert	Sv	J/kg^{-1}
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File(WSRC-RP-89-59-1, REFERENCES)
BSF-ISG-89-0014

May 4, 1989

Ms. W. F. Perrin, Technical Information Officer
U. S. Department of Energy
Savannah River Operations Office
Aiken, SC 29801

Dear Ms. Perrin:

REQUEST FOR APPROVAL TO RELEASE SCIENTIFIC/TECHNICAL INFORMATION

The attached document(s) is (are) submitted for approval for external release. Please complete Part II of this letter and return the letter to the undersigned, by: 05/19/89 Patent clearance is requested and received via direct communication between DOE Patent Counsel and AED Patent Reviewer. The document has ~~not~~ been reviewed for classification and UCNI. The document is ~~classified~~/unclassified and contains no/~~may contain/contains~~ UCNI. (Strike words that do not apply.)

C. J. Banick Classification Officer
C. J. Banick

I. DETAILS OF REQUEST FOR RELEASE

WSRC-RP-89-59-1, (REFERENCES), "SAVANNAH RIVER SITE ENVIRONMENTAL REPORT FOR 1988 REFERENCES," By D. Martin, A. Davis, J. Todd, and C. Hetrick.

References to be included in the overall package (15 Chapters) being sent to OSTI for distribution to the general public.

Technical questions pertaining to the contents of the document should be addressed to the author(s) or

G. Hayes
Health Protection
Savannah River Site

Questions concerning processing of this document should be addressed to the AED Classification Officer & Patent Reviewer at Extension 5-2606.

II. DOE-SR ACTION

DATE RECEIVED BY TIO 5-8-89

✓ Approved as written
___ Remarks

___ Not approved as written, ___ revise and resubmit to DOE
___ Approved upon completion of changes marked on document

W. F. Perrin
W. F. Perrin, Technical Information Officer, DOE-SR

Date 5-8-89

SR 25-82-W(4-89)

Westinghouse
Savannah River Company

CC: W. F. Perrin, DOE-SR (3)
J. S. Roberts, 703-A
D.Martin,735-11A
J.E.Sellers,703-43A
File(WSRC-RP-89-59-1ABBREVIATE/ACRON.
ABSTRACT, PREFACE,
RATIONALE, PERSPECTIVE
GLOSSARY, INDEX, CHAP. 14)
BSF-ISG-89-0002

P.O. Box 616
Aiken. SC 29802

April 26, 1989

Ms. W. F. Perrin, Technical Information Officer
U. S. Department of Energy
Savannah River Operations Office
Aiken, SC 29801

Dear Ms. Perrin:

REQUEST FOR APPROVAL TO RELEASE SCIENTIFIC/TECHNICAL INFORMATION

The attached document(s) is (are) submitted for approval for external release. Please complete Part II of this letter and return the letter to the undersigned, by: 05/11/89 Patent clearance is requested and received via direct communication between DOE Patent Counsel and AED Patent Reviewer. The document has ~~not~~ been reviewed for classification and UCNI. The document is ~~classified~~/unclassified and contains no/~~may contain/contains~~ UCNI. (Strike words that do not apply.)

C. J. Barick Classification Officer
C. J. Barick

I. DETAILS OF REQUEST FOR RELEASE

WSRC-RP-89-59-1, ABBREVIATIONS/ACRONYMS, ABSTRACT, PREFACE, RATIONALE, PERSPECTI VE, GLOSSARY, INDEX, AND CHAPTER 14, "SAVANNAH RIVER SITE ENVIRONMENTAL REPORT FOR 1988" By A. Davis, D Martin, J. Todd, and C. Hetrick.

ABBREVIATIONS/ACRONYMS, ABSTRACT, PREFACE, RATIONALE, PERSPECTIVE, GLOSSARY, INDEX, AND CHAPTER 14, "SAVANNAH RIVER SITE ENVIRONMENTAL REPORT FOR 1988," to be included in the overall package (15 Chapters) being sent to OSTI for distribution to the general public.

Technical questions pertaining to the contents of the document should be addressed to the author(s) or

G. Hayes, Manager
Health Protection
Savannah River Site

Questions concerning processing of this document should be addressed to the AED Classification Officer & Patent Reviewer at Extension 5-2606.

II. DOE-SR ACTION

DATE RECEIVED BY TIO 4-26-89

✓ Approved as written
___Remarks

___Not approved as written,___revise and resubmit to DOE
___ Approved upon completion of changes marked on docum

M. J. Perrin
W. F. Perrin, Technical Information Officer, DOE-SR

Date 5-5-89

OSR 25-82-W(4-89)

Westinghouse
Savannah River Company

P.O. Box 616
Aiken, SC 29802

CC: W. F. Perrin, DOE-SR (1)
J. S. Roberts, 703-A
D.Martin,735-11A
J.E.Sellers,703-43A
File(WSRC-RP-89-59-1, SEE BELOW)
BSF-ISG-89-0011

May 1, 1989

Ms. W. F. Perrin, Technical Information Officer
U. S. Department of Energy
Savannah River Operations Office
Aiken, SC 29801

Dear Ms. Perrin:

REQUEST FOR APPROVAL TO RELEASE SCIENTIFIC/TECHNICAL INFORMATION

The attached document(s) is (are) submitted for approval for external release. Please complete Part II of this letter and return the letter to the undersigned, by: 05/10/89 Patent clearance is requested and received via direct communication between DOE Patent Counsel and AED Patent Reviewer. The document has ~~not~~ been reviewed for classification and UCNI. The document is ~~classified~~/unclassified and contains no/~~may contain/contains~~ UCNI. (Strike words that do not apply.)

C. J. Banick Classification Officer
C. J. Banick

I. DETAILS OF REQUEST FOR RELEASE

WSRC-RP-89-59-1, "SRS ENVIRONMENTAL REPORT FOR 1988, (COVER, TITLE PAGE, ACKNOWLEDGMENTS, TABLE OF CONTENTS, CHAPTER 11, DISTRIBUTION LIST)," By A. Davis, D Martin, J. Todd, and C. Hetrick.

SRS ENVIRONMENTAL REPORT FOR 1988, (COVER, TITLE PAGE, ACKNOWLEDGMENTS, TABLE OF CONTENTS, CHAPTER 11, DISTRIBUTION LIST)" to be included in the overall package (15 Chapters) being sent to OSTI for distribution to the general public.

Technical questions pertaining to the contents of the document should be addressed to the author(s) or

G. Hayes, Manager
Health Protection
Savannah River Site

Questions concerning processing of this document should be addressed to the AED Classification Officer & Patent Reviewer at Extension 5-2606.

II. DOE-SR ACTION DATE RECEIVED BY TIO 5-1-89

✓ Approved as written
___Remarks
___Not approved as written,___revise and resubmit to DOE
___ Approved upon completion of changes marked on document

W. F. Perrin Date 5-8-89
W. F. Perrin, Technical Information Officer, DOE-SR

OSR 25-82-W(4-89)

Westinghouse
Savannah River Company

CC: W. F. Perrin, DOE-SR (3)
J. S. Roberts, 703-A
D. Martin, 735-11A
J. Sellers, 703-43A
File(WSRC-RP-89-59-1, CHAP. 6 & 12, VOL. I & II)

P.O. Box 616
Aiken, SC 29802

April 24, 1989

Ms. W. F. Perrin, Technical Information Officer
U. S. Department of Energy
Savannah River Operations Office
Aiken, SC 29801

Dear Ms. Perrin:

REQUEST FOR APPROVAL TO RELEASE SCIENTIFIC/TECHNICAL INFORMATION

The attached document(s) is (are) submitted for approval for external release. Please complete Part II of this letter and return the letter to the undersigned, by: 05/09/89 Patent clearance is requested and received via direct communication between DOE Patent Counsel and AED Patent Reviewer. The document has ~~not~~ been reviewed for classification and UCNI. The document is ~~classified/~~unclassified and contains no/~~may contain/contains~~ UCNI. (Strike words that do not apply.)

C. J. Banick Classification Officer
C. J. Banick

I. DETAILS OF REQUEST FOR RELEASE

WSRC-RP-89-59-1, CHAPTERS 6 & 12, VOLUME I & TABLES FOR CHAPTERS 6 & 12, VOLUME II, "SAVANNAH RIVER SITE ENVIRONMENTAL REPORT FOR 1988,"
By A. Davis, D Martin, J. Todd, and C. Hetrick.

Chapters 6 and 12, Volume I and Tables for Chapters 6 & 12, Volume II to be included in the overall package (15 Chapters) being sent to OSTI for distribution to the general public.

Technical questions pertaining to the contents of the document should be addressed to the author(s) or

G. Hayes, Manager
Health Protection
Savannah River Site

Questions concerning processing of this document should be addressed to the AED Classification Officer & Patent Reviewer at Extension 5-2606.

II. DOE-SR ACTION

DATE RECEIVED BY TIO 4-24-89

✓ Approved as written
___ Remarks
___ Not approved as written, ___ revise and resubmit to DOE
___ Approved upon completion of changes marked on document

3 photos have been returned to the author.
(1) Tracking Van (2) Underground Sodium Iodide Detector
(3) Woodstorks.

W. F. Perrin
W. F. Perrin, Technical Information Officer, DOE-SR

Date 5-8-89

OSR 25-82-W(4-89)

Westinghouse
Savannah River Company

CC: W. F. Perrin, DOE-SR (3)
D. Martin, 735-11A
J. E. Sellers, 703-43A
File(WSRC-RP-89-59-1, CHAP. 1 & 2)

April 18, 1989

Ms. W. F. Perrin, Technical Information Officer
U. S. Department of Energy
Savannah River Operations Office
Aiken, SC 29801

Dear Ms. Perrin:

REQUEST FOR APPROVAL TO RELEASE SCIENTIFIC/TECHNICAL INFORMATION

The attached document(s) is (are) submitted for approval for external release. Please complete Part II of this letter and return the letter to the undersigned, by: 05/03/89 Patent clearance is requested and received via direct communication between DOE Patent Counsel and Patent Reviewer. The document has ~~not~~ been reviewed for classification and UCNI. The document is ~~classified~~/unclassified and contains no/~~may contain/contains~~ UCNI. (Strike words that do not apply.)

C. J. Banick Classification Officer
C. J. Banick

I. DETAILS OF REQUEST FOR RELEASE

WSRC-RP-89-59-1 CHAPTERS 1 & 2, "SAMPLE COLLECTION, ANALYTICAL PROCEDURES AND DATA ANALYSIS," By D Martin and D. Stevenson.

A report being sent to OSTI for distribution to the general public. The attached covers Chapters 1 and 2. Subsequent portions of the document will be submitted as they are completed

Technical questions pertaining to the contents of the document should be addressed to the author(s) or

G. Hayes, Manager
Health Protection
Savannah River Site

Questions concerning processing of this document should be addressed to the AED Classification Officer & Patent Reviewer at Extension 5-2606.

II. ~~DOE-SR~~ ACTION

DATE RECEIVED BY TIO 4-18-89

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___Remarks

___Not approved as written, ___revise and resubmit to DOE
___Approved upon completion of changes marked on document

W. F. Perrin
W. F. Perrin, Technical Information Officer, DOE-SR

Date 5-8-89

OSR 25-8; WSRC-RP-89-

Westinghouse
Savannah River Company

P.O. Box 616
Aiken, SC 29802

CC: W. F. Perrin, DOE-SR (3)
J. S. Roberts, 703-A
D. Martin, 735-11A
J. Sellers, 703-43A
File(WSRC-RP-89-59-1, CHAP. 3, 4, 5, 7, 9, 13, 15, APPENDIXES, INTRODUCTION, EXECUTIVE SUMMARY)

7

April 24, 1989

Ms. W. F. Perrin, Technical Information Officer
U. S. Department of Energy
Savannah River Operations Office
Aiken, SC 29801

Dear Ms. Perrin:

REQUEST FOR APPROVAL TO RELEASE SCIENTIFIC/TECHNICAL INFORMATION

The attached document(s) is (are) submitted for approval for external release. Please complete Part II of this letter and return the letter to the undersigned, by: 05/10/89 Patent clearance is requested and received via direct communication between DOE Patent Counsel and AED Patent Reviewer. The document has ~~not~~ been reviewed for classification and UCNI. The document is ~~classified~~/unclassified and contains no/~~may contain/contains~~ UCNI. (Strike words that do not apply.)

C. J. Banick Classification Officer
C. J. Banick

I. DETAILS OF REQUEST FOR RELEASE

WSRC-RP-89-59-1, CHAPTERS 3, 4, 5, 7, 9, 13, & 15 , APPENDIXES A, B, & C, INTRODUCTION AND PROGRAM OVERVIEW AND EXECUTIVE REVIEW , VOLUME I, "SAVANNAH RIVER SITE ENVIRONMENTAL REPORT FOR 1988," By A. Davis, D Martin, J. Todd, and C. Hetrick.

CHAPTERS 3, 4, 5, 7, 9, 13, & 15 , APPENDIXES A, B, & C, INTRODUCTION AND PROGRAM OVERVIEW AND EXECUTIVE REVIEW , VOLUME I, "SAVANNAH RIVER SITE ENVIRONMENTAL REPORT FOR 1988," to be included in the overall package (15 Chapters) being sent to OSTI for distribution to the general public.

Technical questions pertaining to the contents of the document should be addressed to the author(s) or

G. Hayes, Manager
Health Protection
Savannah River Site

Questions concerning processing of this document should be addressed to the AED Classification Officer & Patent Reviewer at Extension 5-2606.

II. DOE-SR ACTION

DATE RECEIVED BY TIO 4-24-89

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W. F. Perrin
W. F. Perrin, Technical Information Officer, DOE-SR

Date 5-8-89

OSR 25-82-W(4-89)

Westinghouse
Savannah River Company

CC: W. F. Perrin, DOE-SR (3)
J. S. Roberts, 703-A
D. Martin, 735-11A
J. Sellers, 703-43A
File(WSRC-RP-89-59-1, CHAP. 8 & 10, VOL. I & II)

April 21, 1989

Ms. W. F. Perrin, Technical Information Officer
U. S. Department of Energy
Savannah River Operations Office
Aiken, SC 29801

Dear Ms. Perrin:

REQUEST FOR APPROVAL TO RELEASE SCIENTIFIC/TECHNICAL INFORMATION

The attached document(s) is (are) submitted for approval for external release. Please complete Part II of this letter and return the letter to the undersigned, by: 05/08/89 Patent clearance is requested and received via direct communication between DOE Patent Counsel and AED Patent Reviewer. The document has ~~not~~ been reviewed for classification and UCNI. The document is ~~classified~~/unclassified and contains no/~~may contain/contains~~ UCNI. (Strike words that do not apply.)

C. J. Banick Classification Officer
C. J. Banick

I. DETAILS OF REQUEST FOR RELEASE

WSRC-RP-89-59-1, CHAPTERS 8 & 10, "SAVANNAH RIVER SITE ENVIRONMENTAL REPORT FOR 1988," By A. Davis, D Martin, J. Todd, and C. Hetrick.

This ~~concludes~~ Includes Chapters 8 and 10 of a total of 15 Chapters, Volumes I and II Figures for Volume II pertaining to Chap 8 + 10 being sent to OSTI for distribution to the general public.

Technical questions pertaining to the contents of the document should be addressed to the author(s) or

G. Hayes, Manager
Health Protection
Savannah River Site

Questions concerning processing of this document should be addressed to the AED Classification Officer & Patent Reviewer at Extension 5-2606.

II. DOE-SR ACTION

DATE RECEIVED BY TIO 4-21-89

✓ Approved as written
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___ Approved upon completion of changes marked on document

W. F. Perrin
W. F. Perrin, Technical Information Officer, DOE-SR

Date 5-8-89

OSR 20-85 W-3-83