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Volume I
Text

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Savannah River Site Environmental Report for 1989

Savannah River Site
Environmental Report for 1989

Westinghouse Savannah River Company
Savannah River Site
Aiken, SC 29808

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

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Savannah River Site Environmental Report for 1989 (U)

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Contents

PART IV—ENVIRONMENTAL MANAGEMENT AND RESEARCH PROGRAMS

Abbreviations and Acronyms

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
BBC	Balanced Biological Community
BDC	Beaver Dam Creek
BG	Burial Ground (Radioactive Waste Burial Ground)
BOD	biochemical oxygen demand
BSRI	Bechtel Savannah River Incorporated
CAAC	Clean Air Act Code
CCWS	Comprehensive Cooling Water Study
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act (Superfund)
CFR	Code of Federal Regulations
CL	confidence level
CLP	Contract Laboratory Program (EPA)
COD	chemical oxygen demand
CSRA	Central Savannah River Area
CS	Central Shops
CSWE	Central Services Works Engineering
CTS	Concentrate Transfer System
CWA	Clean Water Act (Federal)
DCG	Derived Concentration Guides
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, D.C.
DWPF	Defense Waste Processing Facility
DWS	Drinking Water Standards (EPA)
EA	Environmental Assessment
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
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
ERA	Environmental Resource Associates
ESS	Environmental Sciences Section (SRL)
ETS	Environmental Technology Section Division
ETF	Effluent Treatment Facility
ETI	Environmental Testing, Inc.
ETP	Effluent Treatment Plant
ETS	Environmental Technology Section (SRL)
FDA	Food and Drug Administration
FMC	Four Mile Creek
GDNR	Georgia Department of Natural Resources
GE	General Engineering Laboratories
GIS	Geographic Information System
GW/EMS	Environmental Monitoring Section-Groundwater Monitoring Group
HAZMAT	hazardous materials
HDEHP	Di-2-ethylhexyl phosphoric acid in toulene
HDM	H-Area dry monitoring wells

HEPA	high efficiency particulate air filter
HPIC	high pressure ionization chamber
HPGe	high purity germanium detector
HT	tritiated hydrogen
HWMW	Hazardous Waste/Mixed Waste Disposal Facilty
ICP/MS	inductively coupled plasma-mass spectrometer
ICRP	International Commission on Radiological Protection
IDMS	isotope dilution mass spectrometry
IGB	Indian Grave Branch
IWT	Interim Waste Technology (SRL)
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
MDC	minimum detectable concentration
MSS	multispectral scanner
MT	MetaTRACE, Inc.
MTF	Memorandum-to-File
MWMF	Mixed Waste Management Facility
NAAQS	National Ambient Air Quality Standards
NAI	Normandeau Associates, Inc.
NCRP	National Council on Radiation Protection and Measurements
NEPA	National Environmental Policy Act
NERP	National Environmental Research Park
NESHAP	National Emission Standards for Hazardous Air Polluants
NIST	National Institute of Standards and Technology
NOAA	National Oceanic and Atmospheric Agency
NPDES	National Pollutants Discharge Elimination System
NPL	National Priority List
NPR	New Production Reactor
NRC	Nuclear Regulatory Commission
NRDC	Natural Resources Defense Council
NSF	National Science Foundation
OHER	Occupational Health and Environmetnal Research (DOE)
OSHA	Occupational Safety and Health Administration
ORA	Operations Recreational Association
PAH	poly-cyclicaromatic hydrocarbons
PB	Pen Branch
PBF	Pen Branch fault
PCB	polychlorinated biphenyl
PE	Performance Evaluation samples (EPA)
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
RO	Reactor Operations
ROD	Record of Decision
RTF	Replacement Tritium Facility
RWBG	Radioactive Waste Burial Ground (formerly the Solid Waste Storage Facility--Burial Ground)
SARA	Superfund Amendments and Reauthorization Act
SBL	stable boundary layer
SCCP	South Carolina Coastal Plain
SCDHEC	South Carolina Department of Health and Environmental Control
SDWA	Safe Drinking Water Act
SEFES	Southeastern Forest Experimental Station
SI	International System of Units
SIRIM	Site Item Reportable Issue Management
SPOT	Satellite Pour l'Observation de la Terre (Earth Observation Satellite)

SREL	Savannah River Ecology Laboratory (University of Georgia)
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
TI	Teledyne Isotopes
TIMS	Thermal Ionization Mass Spectrometer
TIOA	Triisooctylamine
TDS	Total Dissolved Solids
TKN	total kjeldahl nitrogen
TLD	thermoluminescent dosimeter
TOC	total organic carbon
TOH	total organic halogens
TRAC	Tracking Radioactive Atmosphere Contaminants
TSC	Technical Support Center
TSP	total suspended particulates
TSS	total suspended solids
TRU	transuranic
UCF	Underground Counting Facility
ULLCF	Ultra-low-level Counting Facility
USF	Uranium Solidification Facility
USFS	U.S. Forest Service
USGS	U.S. Geological Survey
U3R	Upper Three Runs Creek
VAM3D	variably saturated code
VOC	volatile organic compound
WCAL	Weather Center Analysis Laboratory
WIND	Weather INformation and Display
WMin	waste minimization
WMT	Waste Management Technology
WP022	Water Pollution Study (EPA)
WSI	Wackenhut Services, Inc.
WSRC	Westinghouse Savannah River Company

Abstract

The purpose of this report is to meet three of the primary objectives of the Savannah River Site (SRS) environmental monitoring program. These objectives are to assess actual or potential exposures to populations from the presence of radioactive and nonradioactive materials from normal operations or nonroutine occurrences; to demonstrate compliance with applicable authorized limits and legal requirements; and to communicate results of the monitoring program to the public.

In 1989, the maximum committed dose to a hypothetical individual at the site perimeter from 1989 SRS atmospheric releases of radioactive materials was 0.31 mrem (0.0031 mSv). To obtain the maximum dose, an individual must reside at a point of highest exposure at the site perimeter for 24 hours per day, 365 days per year. The average committed dose from atmospheric releases to an individual at the site perimeter was 0.11 mrem (0.0011 mSv).

The maximum committed dose to an individual downriver from SRS who consumed Savannah River water was 0.12 mrem 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 dose is based on the assumption that the individual drinks 2 L (one-half gal) of water each day, 365 days per year.

In addition to monitoring for radioactive contaminants, the environment is also monitored for nonradioactive contaminants. Various state and federal permits regulate the sampling and analyses performed in the nonradiological monitoring program. In 1989, air emissions were within required standards and the NPDES compliance rate was 99.9%. Water quality studies were also performed on the Savannah River and on SRS streams throughout the year. Groundwater was continually monitored to identify and track contaminants, to comply with environmental regulations and DOE orders, and to support basic research projects.

Westinghouse Savannah River Company is also involved in various activities to bring the site into compliance with all applicable environmental regulations and DOE orders. These activities include closing waste sites, monitoring water temperatures in SRS streams, environmental restoration programs, and performing self-assessments to identify and correct areas of environmental noncompliance.

This 1989 report contains descriptions of radiological and nonradiological monitoring programs, it provides data obtained from these programs, and it describes various environmental research activities ongoing at the site. Also included are summaries of environmental management and compliance activities, a summary of National Environmental Policy Act activities, and a listing of environmental permits issued by regulatory agencies.

Preface

The *U. S. Department of Energy Savannah River Site Environmental Report for 1989* is designed to provide information to the public about the impact of SRS operations on the public and the environment. This report describes environmental surveillance and monitoring activities conducted at and around the Savannah River Site (SRS) during the calendar year 1989.

The SRS Environmental Report, published annually, is widely distributed to government officials, U. S. congressmen, universities, and other interested parties. Copies of the report are also placed in public reading rooms. Preparation and publication of the report is mandated by DOE Order 5400.1, Chapter II, with a publication deadline of June 1 of the following year.

Listed below are the objectives of this report:

- to provide detailed information about SRS and its environmental monitoring activities
- to report 1989 monitoring data for the SRS and surrounding environment
- to provide radiation dose estimates for surrounding populations and describe how the estimates were derived
- to summarize all significant environmental activities at SRS in one report
- to provide a historical document for reference and trending
- to show trend analyses, and when possible, to indicate increases and decreases in concentrations and/or discharges

Ensuring the radiation safety of the public in the vicinity of SRS was a foremost consideration in the design of the site and has continued to be a primary objective during the 35 years of SRS operation. 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 site. Data generated by the onsite surveillance program have been recorded in site 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.

Separate reporting of SRS's onsite and offsite environmental monitoring activities continued until 1985 when data from both 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 changed significantly during the years since site startup. This change is reflected in annual reports. Prior to the mid-1970s, the reports contained primarily radiological monitoring data. Beginning in the mid-1970s, the reports included expanded amounts of nonradiological monitoring data as those programs expanded. The nonradiological monitoring program is now as extensive as the radiological monitoring program.

This two-volume report is written for a wide audience with a variety of environmental interests. It is divided in such a way that readers may selectively read different sections of the report according to their specific interests.

Volume I summarizes environmental monitoring, research, and compliance activities at SRS and presents key figures, maps, and summary data tables. Volume II contains figures and detailed monitoring data tables. Both volumes are further divided into four parts—Environmental Monitoring Perspectives, Environmental Monitoring Methods, Environmental Monitoring Programs, and Environmental Management and Research Programs. The chapters within each part are arranged to describe the monitoring programs first by environmental media and then by type of monitoring.

Within Volume I, the abstract provides an overall picture of information contained in the report, while the executive summary provides highlights of pertinent information. A brief summary is presented at the beginning of each chapter, followed by the text. Highlights conclude each chapter. Each chapter also contains special highlighted summaries called "sidebars" to provide auxiliary explanations or additional information for important ideas or concepts. In addition, this report contains a glossary of technical terms, as well as an index, both located in the back matter of Volume I.

Executive Summary

The purpose of this report is to provide information about the impact of SRS operations on the public and the environment. The 1989 environmental report includes monitoring data from routine radiological and nonradiological environmental surveillance activities, summaries of environmental compliance programs in progress, a summary of National Environmental Policy Act activities, a listing of environmental permits issued by regulatory agencies, and summaries of site environmental research programs.

The Savannah River Site occupies a large area of approximately 300 square miles along the Savannah River, principally in Aiken and Barnwell counties of South Carolina. The primary function of SRS is to produce plutonium, tritium, and other special nuclear materials for national defense, for other governmental uses, and for some civilian purposes. From January 1 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

Applicable Dose Standards

Applicable DOE radiation standards for the protection of the public in the vicinity of SRS are given in draft DOE order 5400.xx (finalized in 1990 as DOE Order 5400.5). The Environmental Protection Agency (EPA) limits for doses from the atmospheric pathways, contained in 40 CFR 61, Subpart H [EPA85], also apply. These standards are summarized in Table ES-1 (following page). EPA drinking water standards, which apply to concentration of radionuclides in drinking water at downriver water treatment plants, are given in Appendix E.

Dose from Atmospheric Releases

As shown below in Figure ES-1, the maximum committed dose to a hypothetical individual residing on the SRS boundary from 1989 SRS atmospheric releases of radioactive materials was 0.31 mrem (0.0031 mSv) or 0.31% of the DOE guide of 100 mrem/yr (1 mSv) for annual exposure to an individual. The collective 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 17 person-rem (0.17 person-Sv). Releases of tritium, primarily tritium oxide, accounted for greater than 80% of the offsite collective dose from SRS atmospheric releases.

Dose from Releases to Surface Waters

Releases of radioactivity to surface waters also contributed to the radiation doses of offsite persons. The committed dose to a hypothetical, maximally-exposed individual from SRS releases of radioactivity

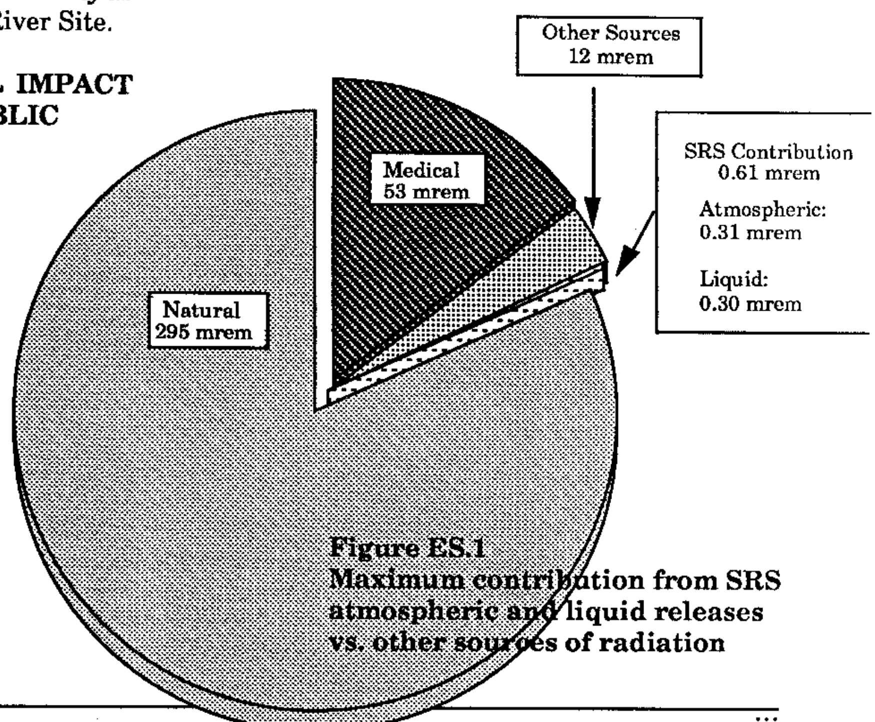


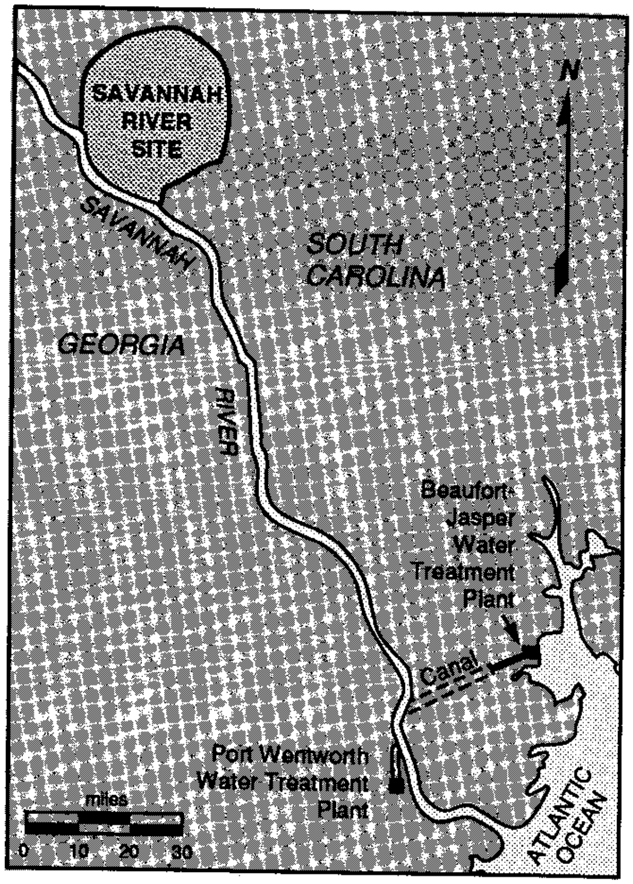
Figure ES.1
Maximum contribution from SRS atmospheric and liquid releases vs. other sources of radiation

to the Savannah River was 0.30 mrem (0.003 mSv). This dose would result from the consumption of water and fish from the river just downriver from SRS, and from swimming, boating, and shoreline activities.

Offsite doses are also received by people consuming water supplied by the two water treatment plants on the Savannah River located downriver of SRS, in Beaufort and Jasper counties in South Carolina, and in Port Wentworth, GA. The committed dose to an individual who consumed Savannah River water at a maximum rate of 2 L per day was 0.12 mrem (0.0012 mSv). The 1989 collective dose commitment from liquid releases was 4.8 person-rem (0.048 person-Sv).

Perspective

Table ES-2 (right) summarizes the individual and collective doses from SRS and other sources, while Table ES-3 (page xvi) compares the individual doses to applicable standards and natural radioactivity. The annual dose from natural radiation averages 295 mrem (2.95 mSv) per year [NCRP87a]. Figure ES-1 (page xiii) graphically shows the sources of an individual's radiation dose, the percentage each source contributes, and SRS's maximum contribution from both atmospheric and liquid releases.



Water treatment plants downriver of SRS

Table ES-1. DOE Revised Interim Radiation Dose Limits[a]

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

	Effective dose equivalent[c]	
	mrem/year	**mSv/year**
Annual exposure	100	1
Occasional annual exposure[d]	500	5

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] DOE established new Radiation Dose Limits in DOE Order 5400.5, which was promulgated February 8, 1990 and supersedes DOE Order 5480.1A. For the *SRS Environmental Report for 1989*, the limits given in this table were in effect during 1989 and will be referenced throughout the report.
[b] "Routine DOE operations" means normal planned operations and does not include nonroutine releases.
[c] Effective dose equivalent is expressed in rem (or mrem) and the corresponding value of Sv (or mSv).
[d] A subsidiary limit of effective dose equivalent in a year. A dose higher than 100 mrem but not higher than 500 mrem may occur, provided the dose averaged over a lifetime does not exceed the principal limit of 100 mrem.

Table ES-2. Individual and Collective (Population) Doses - 1989				
Location/Source	**Calculated Individual Dose, mrem[a]**		**Calculated Collective Dose**	
			Size	**person-rem[a]**
SRS Boundary	**Average**	**Maximum**		
SRS Atmospheric Releases	0.11	0.31[b]	-	-
SRS Liquid Releases	-	0.30[c]	-	-
Within 80 km of SRS				
Dose From Atmospheric Releases	0.03[d]	-	555,100	16.9
Water Treatment Plants Downriver of SRS				
Beaufort-Jasper Plant	0.06	0.12	51,000	3.0
Port Wentworth Plant	0.06	0.12	20,000	1.2
River Fish and Recreation				
Consuming River Fish	-	-	555,100	0.6
Recreation	-	-	555,100	<0.1
SRS Releases Total				21.7

Other Sources[g]	**Annual Dose,mrem**		**Collective Dose, person-rem**
Natural Radioactivity[e]			
Cosmic Radiation	27		
External Terrestrial	28		
Internal	40		
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 site 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 4-5 (page 85, Chapter 4)
[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.

Table ES-3
Comparison of Calculated Doses from SRS Operations with Applicable Standards and Natural Radiation Sources

Committed Dose (mrem)		Atmospheric Dose Standards (mrem)	% of Standard
Maximum Individual	0.31	25 (NESHAP)	1.2
		100 (DOE)	0.31
		295 (Natural)	0.11
Committed Dose (mrem)		**Liquid Dose Standards (mrem)**	**% of Standard**
<u>Site perimeter</u> Maximum Individual	0.30	4 (EPA)	7.5
		100 (DOE)	0.30
		295 (Natural)	0.10
<u>Downriver from SRS</u> Maximum Consumption (2 L water/day)	0.12	4 (EPA)	3.0
		100 (DOE)	0.12
		295 (Natural)	0.04

ENVIRONMENTAL MONITORING PROGRAM

In 1989, over 331,000 radiological and nonradiological analyses were performed. In addition, over 1.7 million nonradiological 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.

While the radiological monitoring program experiences 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 is now as large as the radiological program. The majority of the growth in the nonradiological monitoring program has occurred in groundwater monitoring.

Air Monitoring

Small amounts of particulate alpha and beta-gamma radioactivity were released to the atmosphere from SRS facilities. However, concentrations in air in the area surrounding SRS are generally obscured by contributions from worldwide fallout. Concentrations of tritium released to the atmosphere from SRS operations were routinely detected in the air, with these concentrations decreasing with increasing distance from the site.

Continuous measurements of ambient radiation levels at 454 locations at and around SRS were made with thermoluminescent dosimeters (TLDs). As observed in previous years, ambient radiation measurements taken at each location at the site boundary and up to 100 miles away from SRS showed little variability throughout the year.

Atmospheric emissions of sulfur dioxide, oxides of nitrogen, and particulate matter less than 10 microns from the five onsite coal-fired power plants were within applicable standards in 1989. 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 compliance of the 291-F stack.

The quality of air at SRS was monitored at several locations around the site to measure particulate matter less than 10 microns, 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 all site streams located on SRS are continuously sampled to monitor radioactivity released in effluent water from SRS facilities. In

1989, no measurable differences were detected between upriver and downriver gross 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 1989. Low levels of ^{137}Cs were also measured downriver from SRS.

The SRS stream with the highest concentration of radionuclides in 1989 was Four Mile Creek (FMC). These elevated concentrations are due to releases of radioactive materials in effluents from process facilities and from migration from seepage basins. Maximum activities of gross alpha and nonvolatile beta in FMC were 9.0 pCi/L and 300 pCi/L, respectively. The maximum concentrations of tritium in FMC was 2,200 pCi/mL. Higher concentrations of tritium were also measured in Upper Three Runs Creek (U3R) during 1989. The Effluent Treatment Facility (ETF) and stormwater runoff from parts of F and H Areas discharge into the creek. The higher concentrations of tritium result primarily from startup of the ETF process. Tritium concentrations at U3R-2A, which monitors the ETF effluent, averaged 17,000 pCi/mL, with a maximum of 80,000 pCi/mL. After dilution, the maximum concentration of tritium entering the river, measured at Road A, was 26.2 pCi/mL.

SRS liquid effluents are regulated by the South Carolina Department of Health and Environmental Control (SCDHEC) under the National Pollutant Discharge Elimination System (NPDES). In 1989, 76 active, permitted outfalls were monitored. Nine of the 6,859 analyses performed exceeded permit limits.

The Savannah River is extensively monitored for chemicals, physical properties, and metals. Chemical and biological water quality standards for the Savannah River are specified in the requirements of the state of South Carolina for Class B streams.

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 South Carolina, as stated in consent order 84-4-W between SCDHEC and DOE.

Groundwater Monitoring

SRS monitors groundwater quality for radioactive and nonradioactive constituents to identify any contamination that may occur as a result of site operations. Approximately 80 waste sites, operating facilities, and spill sites have monitoring wells. Monitoring was performed at 1,240 wells in 1989. In 1989, over 214,300 analyses were performed under the groundwater monitoring program.

Environmental Monitoring of Other Media

Air and water are the principal dispersal media for SRS radioactive releases. However, the SRS environmental monitoring 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 the public.

Concentrations of radioactivity were measured in milk, food, drinking water, wildlife, rainwater, soil, sediment, and vegetation. 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]. In most cases, when tritium is present, it is attributed to SRS operations.

In the nonradiological monitoring program for drinking water, no confirmed positive concentrations of chlorocarbons were detected in monthly analyses of drinking water from the domestic water wells in A-Administration/M Areas during 1989. However, 1,1,1-trichloroethane was detected in four semiannual samples. The maximum concentration of 5.87 mg/L measured at the River 1G pump station was below the EPA drinking water standard of 200 mg/L.

Nonroutine Occurrences

Special radiological sampling and analyses programs are instituted in response to unplanned releases of radioactivity to the environment. In 1989, special sampling programs were initiated following three atmospheric tritium releases, six liquid tritium releases, four releases involving other radionuclides, a tornado, and an oily film covering a delaying basin. The largest atmospheric release occurred when 1,100 Ci of tritium were released from an H-Area facility. The largest liquid release occurred when 534 Ci of tritium were released to Pen Branch from K Area.

Special Surveys

In addition to the routine monitoring of the environment on and around SRS, special surveys are performed throughout the year to evaluate radioactivity levels and monitor the effects of SRS effluents on the environment. Some surveys are conducted to evaluate new technologies. The following special surveys were conducted in 1989:

- Savannah River Swamp Survey
- Pond B Survey
- Savannah Harbor Sediment Survey
- Dry Monitoring Wells Survey in F- and H-Area Waste Management Facilities
- Academy of Natural Sciences of Philadelphia—River Quality Surveys
- Isco/Paddlewheel Sample Comparison

SAVANNAH RIVER SITE ENVIRONMENTAL MANAGEMENT AND COMPLIANCE PROGRAMS

SRS must operate in compliance with applicable environmental regulations established by various federal and state statutes and regulations. For this reason, a major effort at SRS has been to bring the site into compliance with these applicable standards and regulations.

Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)
In December 1989, SRS was officially included on the National Priority List. This means that SRS has been identified by the EPA as a site with significant contamination, and that SRS has priority status for remediation activities. Discussions are under way between the South Carolina Department of Health and Environmental Control (SCDHEC) and DOE to develop agreements on satisfying the remediation requirements and other requirements of the law.

Two CERCLA reportable releases occurred in 1989. The first release occurred in F Area when acidic wastewater containing trace quantities of radioactivity leaked from a broken terra-cotta pipe. The second release was discovered in H Area from piping used to transfer waste from a processing area into a waste storage tank. The contaminated soil from both releases was excavated and disposed in a low-level waste burial ground.

Clean Air Act and Clean Water Act
In 1989, SRS had 13 air quality permits that covered 130 point sources for air emissions. All facilities are currently being assessed to ensure that all release points have been identified and are permitted. SRS monitors liquid effluent discharges from 76 outfalls permitted under the National Pollutant Discharge and Elimination System program.

Resource Conservation and Recovery Act (RCRA)
Currently, 262 waste sites are located on SRS, including active and inactive waste sites and contaminated sites. In 1989, five groundwater units were being investigated or treated for contamination. Ten waste sites are currently being closed. Seventy-nine waste site are currently under the RCRA facility investigation (RFI) program.

The National Environmental Policy Act (NEPA)
The NEPA group of the Environmental Protection Section at SRS performed 237 reviews in 1989 to evaluate the potential environmental impacts of proposed federal actions and to examine alternatives to those actions. In December 1989, an Environmental Assessment for the planned Consolidated Incineration Facility in H Area was submitted to DOE for review.

ENVIRONMENTAL MANAGEMENT AND RESEARCH PROGRAMS

Savannah River Laboratory Programs

The Environmental Sciences and Environmental Technology sections of the Savannah River Laboratory (SRL) conduct numerous environmental research and management projects that cover a wide range of environmental topics. In 1989, special research projects included airborne and aqueous effluent studies, dosimetry of SRS reactors, and development of ultra-low-level mass spectrometry facilities and emergency response capabilities. Research also focused on determining the nature and distribution of SRS contaminants and outlining possible remediation plans.

Listed below are two of the environmental management projects in which SRL was also involved to help meet permit or environmental impact statement requirements.

- developing the IMPACT computer system that will improve the quality of SRS environmental assessment
- demonstrating compliance with Section 316(a) of the Clean Water Act for K-Reactor discharges into Pen Branch; for the 400-D Area outfall into Beaver Dam Creek; and L-Reactor effluents into L Lake/Steel Creek

National Environmental Research Park Program

The National Environmental Research Park (NERP) program was established in 1972 to study the environmental impact of human activities. Ten research projects were conducted under the National Environmental Research Park program in 1989. In two of these projects, the Savannah River Ecology Laboratory herbarium collection was upgraded and a potentially rare and endangered species of freshwater clam from SRS was studied.

Savannah River Ecology Laboratory Programs

SREL has conducted independent environmental research studies of the SRS environment since 1952. These research programs have since evolved into three divisions—biogeochemical ecology, wildlife and stress ecology, and wetlands ecology.

In 1989, biogeochemical ecology studies focused on chemical speciation, cycling of radionuclides, contaminants in coal piles and ash basins, and microbial activity in L Lake. Specific wildlife and stress ecology programs included biodiversity, populations, and genetics research. Wetlands ecology programs included the set-asides program and community succession and development studies.

U. S. Forest Service Savannah River Forest Station Programs

The Savannah River Forest Station directs the forest management program at SRS to protect endangered species, to provide quality habitats for native wildlife, to protect soil and watershed quality, and to provide a healthy forest for environmental research. SRFS carried out 52 forest-related studies during 1989, in the areas of biological diversity, reforestation techniques, and old pine-field studies.

The populations of the endangered red-cockaded woodpecker and the Southern bald eagle were also the subjects of intensive research projects. As a result of SRFS efforts, the red-cockaded woodpecker population increased from 14 to 18 birds in 1989.

During 1989, the federal government received nearly $2.4 million for 20.7 million board feet of cut timber from the site. Pine seedlings were planted on over 2,700 acres during the same period.

Part I

Environmental Monitoring Perspectives

Introduction and Program Overview

Objectives and Rationale for Environmental Monitoring at SRS

Perspectives on Environmental Contaminants and Risk

Introduction and Program Overview

DESCRIPTION OF THE SAVANNAH RIVER SITE

Location

The Savannah River Site (SRS) occupies an area of approximately 300 square miles adjacent to the Savannah River, principally in Aiken and Barnwell counties of South Carolina. The site is approximately 25 miles southeast of Augusta, GA and 20 miles south of Aiken, SC. The 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. Augusta has a population of more than 250,000 [DOC88].

Various industrial, manufacturing, and farming operations are conducted in areas surrounding the site. Major industrial and manufacturing facilities in the area include textile mills, plants producing various polystyrene foam and paper products, chemical processing plants, and a commercial nuclear power plant.

Farming is diversified around the area and includes crops such as cotton, soybeans, corn, and small grains. Livestock production for market is also expanding.

Meteorology

The SRS 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. With the exception of the Savannah River, there are no unusual topographic features to exert significant influences on the general climatology.

Summers are hot and humid, with temperature elevations often reaching the upper 90s (°F). Thundershowers are most prevalent during the summer months and contribute about 33% to the annual total rainfall.

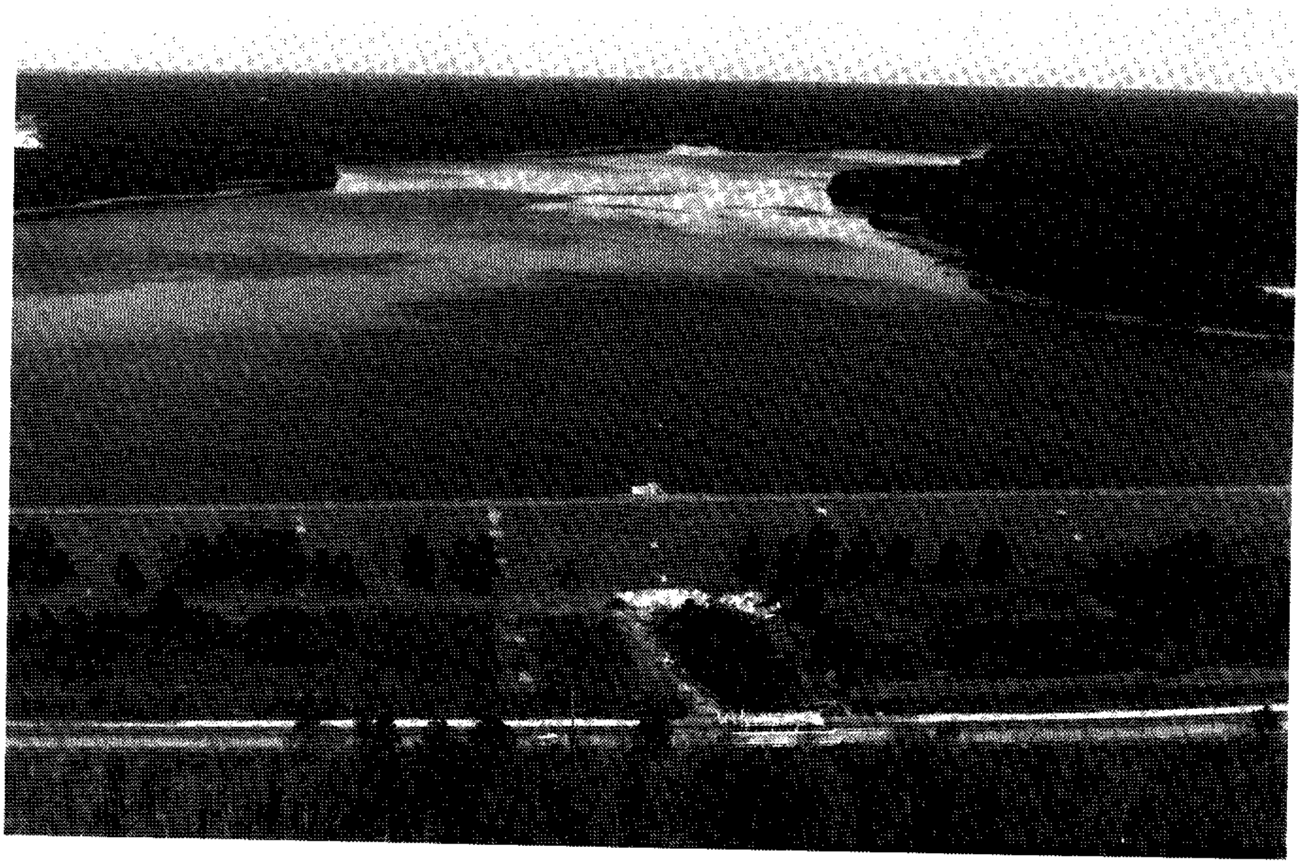
Fall is characterized by cool mornings with warm afternoons. Average daily temperatures in the fall range from a high of 76°F to a low of 50°F. On average, approximately 9 in. or 19% of the annual total rainfall occurs during the fall.

Winters are usually mild, with cold weather lasting from late November to March. Temperatures remain above freezing about 80% of the time. There is occasional snowfall, which usually remains an average of three days. Winter rainfall contributes about 21% to the annual total rainfall.

Spring is the most variable season of the year with an average temperature of 65°F. There is an occasional cold snap in March. Tornadoes, although infrequent, occur most often in the spring. Spring rainfall represents about 27% of the annual total.

Typical Climate of SRS

- **Summer**
  - Hot and humid
  - Temperatures reach upper 90s(°F)
  - 33% of annual rainfall
- **Fall**
  - Cool mornings, warm afternoons
  - Temperatures range 76° to 50°F
  - 19% of annual rainfall
- **Winter**
  - Mild; lasting November–March
  - Temperatures normally above 32°F
  - 21% of annual rainfall
- **Spring**
  - Most variable; cold snap in March
  - Temperatures average 65°F
  - 27% of annual rainfall



Par Pond is a 2,640 acre man-made lake on SRS that supports a variety of water fowl

Water Resources

The Savannah River flows along the western boundary of SRS for approximately 35 miles and is used as a drinking water supply for approximately 71,000 persons downriver at Port Wentworth, GA, and near Hardeeville, SC (Beaufort and Jasper counties). The Savannah River is also used for commercial and sport fishing, boating, and other recreational activities downriver from SRS.

SRS uses water from the Savannah River for site operations. River water is used to supply cooling water for reactors when they are operating. In addition, the drinking water system in D Area is supplied with treated surface water taken from the Savannah River.

Five major streams on SRS feed into the Savannah River: Upper Three Runs Creek, Four Mile Creek, Pen Branch, Steel Creek, and Lower Three Runs Creek. These streams are not used as commercial sources of water, but they do receive effluents from various operations onsite.

Land Resources

Most of the site's environs are rural. Approximately 40% of the countryside is forested with longleaf and loblolly pines, sweet gum, maple, birch, and various oak-hickory hardwood trees. SRS maintains a forest management program to contribute to environmental protection and research. In addition, the Savannah River Forest Station provides the federal government with cut timber from SRS.

Major plant communities on SRS include cypress-gum and lowland hardwood swamps, sandhills, old agricultural fields, and aquatic and semiaquatic areas. These habitats range from very sandy, dry hilltops to continually flooded swamps.

SRS is populated with more than 50 species of mammals. Deer, feral hogs, beavers, rabbits, foxes, raccoons, and opossums are examples of wildlife found on the site. SRS is home to more than 50 species of reptiles and amphibians including turtles, alligators, lizards, snakes, frogs, and salamanders. In addition, over 200 species of birds occur on SRS.

The site provides refuge for many endangered and threatened species including red-cockaded woodpeckers, wood storks, and the American alligator. Research projects are continually conducted to protect and increase the populations of these species.

In 1972, SRS was designated as a National Environmental Research Park. Since then, various research projects have been conducted at the site. In 1989, the government increased the amount of protected land onsite for research from over 800 acres to approximately 12,000 acres.

For more details on SRS and the surrounding area, see "The Savannah River Plant Environment" [Du84].

DESCRIPTION OF SRS OPERATIONS AND FACILITIES

SRS's primary function is to produce plutonium, tritium, and other special nuclear materials for national defense, other governmental uses, and some civilian purposes. Major facilities located on SRS include five nuclear reactors, a fuel and target fabrication facility, two chemical separations plants, a nuclear fuel production facility, and the Savannah River Laboratory (SRL), a process development laboratory that supports production operations on the site.

Many other facilities necessary to support SRS operations are also located onsite. The following sections of this chapter present brief descriptions with respect to the facilities' function and status. On the following page, Table IP-1 summarizes the operational status of the major SRS and support facilities. Figure IP-1 (below) shows the various operating areas of SRS.

SRS Operations

All five SRS reactors were inoperative during 1989. In 1988, K, P, and L reactors were shut down for maintenance and safety upgrades. C Reactor was shut down for repairs in 1985. The fifth reactor, R Reactor, was permanently shut down in 1964.

Nuclear fuels, targets, and other reactor components are manufactured in the fuel and target fabrication facility, also called Raw Materials. The reactors at SRS are fueled with uranium. Heavy water that is circulated in a closed system through heat exchangers moderates and cools the reactors. 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.

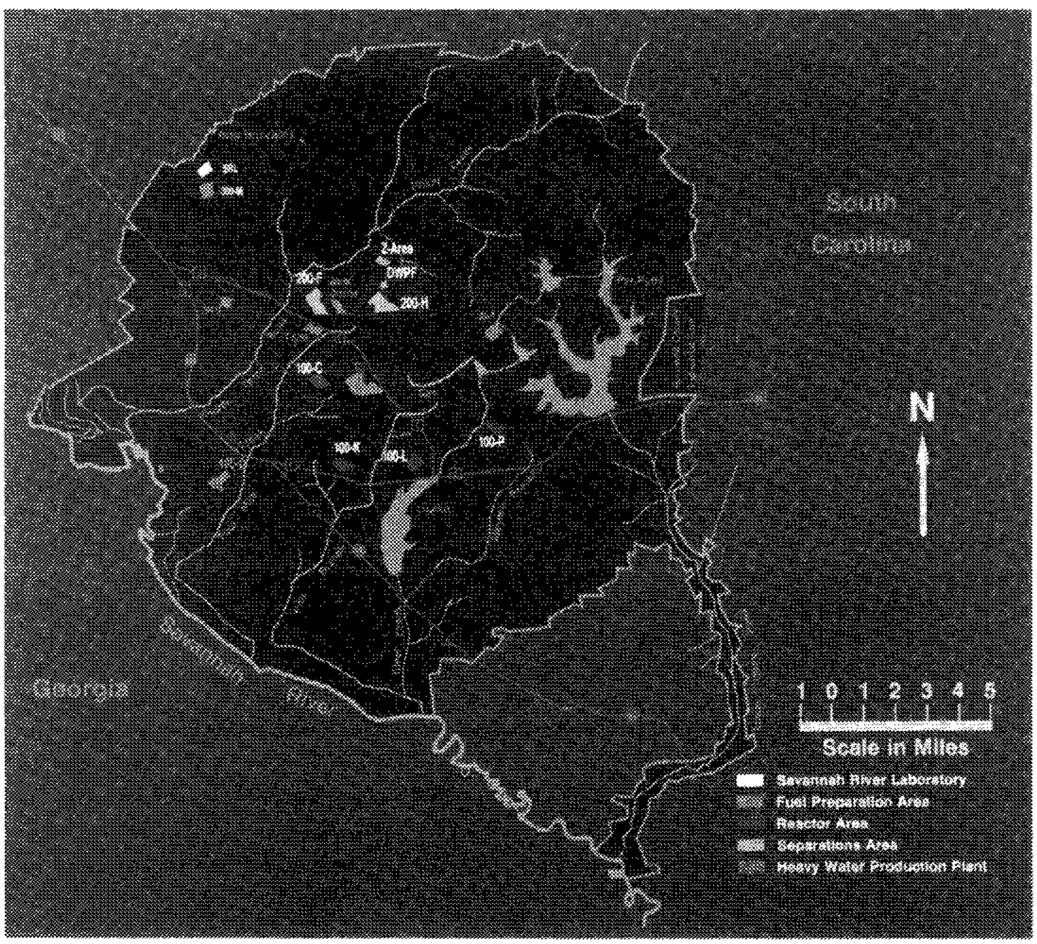


Figure IP-1. The Savannah River Site consists of five major areas

Table IP-1.
Operating Status for SRS Facilities during 1989

Area	Status of Operation*
Reactor Areas	
C Area	Process down 100%
K Area	Process down 100%
L Area	Process down 100%
P Area	Process down 100%
Separations Area	
H-Area Plutonium Process	Process down 100%
Chemical Separation Facility	Process operational 10%
Tritium Facilities	One process operational 40%
RBOF Facility	Normal operation
Waste Compactor	Process operational 25%
Beta-gamma Incinerator	Process down 100%
Waste Management Facility	Normal operation
F-Area Plutonium Process	Process operational 29%
Chemical Separation Facility	Process operational 30%
Plutonium Fabrication Facility	Process down 100%
A Line	Process operational 40%
Naval Fuel Materials Facility	Normal operation
Laboratory Facility	Process operational 50%
Laboratory Facility	Normal operation
Tank Farms (F and H Areas)	Normal operation
Effluent Treatment Facility	Normal operation
Raw Materials	
Fuel Fabrication Facility	Process operational 35%
Fuel Fabrication Facility	Process down 100%
Laboratory Facility	Normal operation
Defense Waste Processing Facility	Process down 100%
Savannah River Laboratory	Normal operation

* Status of operation refers to the period that the facility was operating during the year.
Normal operation - facilities operated all year
Process operational - facilities operated for the percentage of time stated.
This information was obtained from Health Protection Operations managers in each facility.

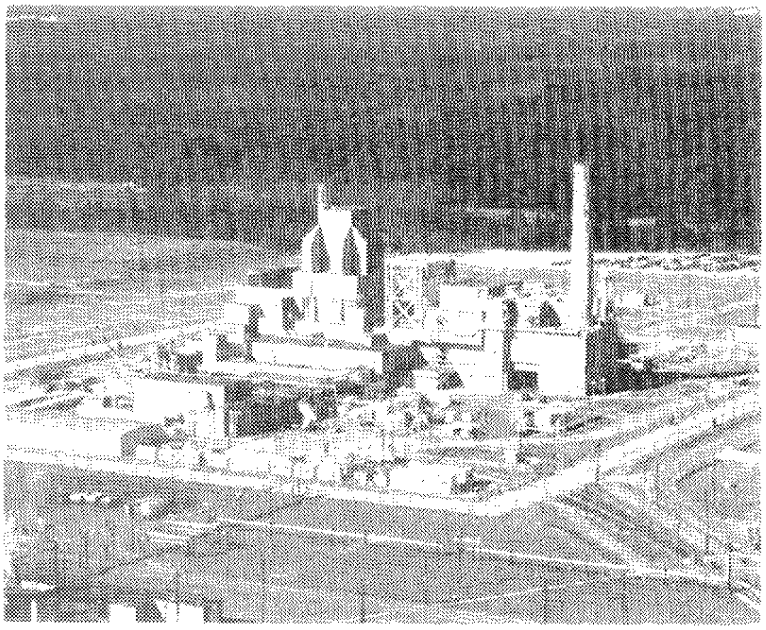
Heat exchanger cooling water does not pass directly through the reactors. Therefore, it is not subject to direct neutron activation. The heat exchanger cooling water from P Reactor is returned to Par Pond, some of which overflows to Lower Three Runs Creek. L and K Reactors use Savannah River water as a heat exchanger coolant. 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 processed in the chemical separations areas. Uranium, ^{238}Pu, and ^{239}Pu are separated from each other and from fission products by complex chemical processes. These areas also have facilities for purifying and packaging tritium and for storing fission-product wastes.

The Naval Fuel Materials Facility, located in F Area, began producing uranium fuel for the U.S. Navy in late 1988. The facility converts a special enriched uranium into a material that can be used to manufacture reactor cores that power the nuclear fleet. Although approximately 40% of the Navy's major combat fleet is nuclear powered, the decreased demand for nuclear fuel resulted in shut down of the Naval Fuel Materials Facility in September 1989. The facility is currently in a non-operational back-up status.

SRS Support Facilities

The Defense Waste Processing Facility (DWPF) is a major construction effort currently underway at SRS. This facility will be the nation's first high-level radioactive waste glassification plant. DWPF will accept high-level radioactive waste currently stored in waste tanks in F and H Areas, mix the waste with glass frit, 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 will be



P Reactor is one of three reactors shut down for maintenance and safety upgrades

suitable for storage in an offsite geologic repository. The DWPF glass form and the geologic repository will effectively isolate the nuclear waste from the environment. The scheduled startup date for DWPF operation is 1992.

The Effluent Treatment Facility (ETF), located on the south side of H Area, began operation in 1988. This facility collects and treats water previously discharged to the F- and H-Area seepage basins. ETF receives routine process wastewater, contaminated canyon facility cooling water, and tank farm storm water. ETF removes all the radioactive and nonradioactive contaminants, except tritium, from process effluents, allowing the water to be discharged to Upper Three Runs Creek. The ETF process eliminated the use of seepage basins, which adversely impacted the quality of groundwater.

The Z-Area Saltstone Facility is designed to process and dispose of the decontaminated salt solution supernates from the F- and H-Area storage tanks and the ETF concentrate. The decontaminated salt solution is immobilized with solidifying agents such as slag, fly ash, and cement and disposed of in concrete vaults. During 1989, equipment checks and cold runs were completed for the facility.

The Replacement Tritium Facility (RTF), a one-acre underground facility located in H Area, is currently under construction. The purpose of RTF is to replace most extraction and purification operations presently performed in the existing Tritium facilities, which have been in operation since 1958. RTF and the existing Tritium facilities will operate concurrently for approximately one year. The RTF is designed to minimize tritium losses to the environment. Multiple systems will exist to protect the environment, personnel in the facility, and the tritium process itself. Operation of RTF will reduce waste generation at SRS and atmospheric tritium releases. The scheduled date for RTF operation is 1992.

DESCRIPTION OF ENVIRONMENTAL PROGRAMS

Environmental Monitoring

The Environmental Monitoring Section (EMS) of the Environmental and Health Protection Department (EHP) conducts extensive radiological and nonradiological environmental monitoring programs at and around SRS. In 1989 over 331,000 radiological and nonradiological analyses were performed on over 35,000 samples. In addition, over 1.7 million nonradiological measurements were made at ambient air quality monitoring stations, and over 460,000 water quality readings were taken from monitors in Beaver Dam Creek and Steel Creek.

Radiological Monitoring Program

Each year, the site performs radiological monitoring by collecting and analyzing samples from a 30,000-square-mile area in the vicinity of SRS. Within this 30,000-square-mile area, many different types of samples are routinely collected and analyzed for radioactivity. In addition, ambient gamma radiation levels are monitored within an 8,000-square-mile area of SRS. Table IP-2 on the following page lists the types of samples collected and analyzed in the radiological monitoring program.

In the radiological monitoring program, EMS performed approximately 100,000 analyses on 25,000 samples during 1989. Approximately 554,000 samples have been collected and 2,072,500 analyses have been performed since the program began in 1951.

Nonradiological Monitoring Program

The nonradiological monitoring program is primarily confined to SRS and is designed to monitor the

Table IP-2
Types of Samples Analyzed in the Radiological Monitoring Program

Air	**Wildlife**
Thermoluminescent Dosimeters	fish
Surface Water	crabs/oysters
rivers	deer/ hogs
streams	furbearers
seepage basins	(i.e., opossums, foxes, raccoons)
Groundwater	turtles
Milk	ducks
Food	**Rainwater**
(i.e., eggs, chickens, meats, fruits, grains, collards)	**Soil**
Drinking Water	**Sediment**
	Vegetation

concentrations of various nonradiological constituents onsite. Some samples from offsite locations are analyzed to obtain background analytical data. Offsite analyses also serve as a backup to ensure detection of nonradiological constituents if released. In 1989, over 231,000 analyses were performed on over 10,000 samples. Table IP-3 (below right) lists the types of samples analyzed in the nonradiological monitoring program.

Although the nonradiological ambient air monitoring program is coordinated by EMS, routine operation of the program is subcontracted to an offsite company. Instruments at the onsite stations monitor for sulfur dioxide, oxides of nitrogen, ozone, and particulate matter less than 10 microns.

SRS has monitored site stream wastewater discharges and their effects on Savannah River water quality since the early 1950s. The inhouse nonregulatory water quality program 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 31 constituents are analyzed at each sample location. The Analytical Laboratories Department in 400-D Area performs coliform bacteria analyses for this program.

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 Department of Energy (DOE). Temperature and dissolved oxygen measurements are taken daily in Steel Creek. Temperature, conductivity, pH, oxidation/reduction potential, and dissolved oxygen readings are made every five minutes in Beaver Dam Creek.

The Division of Environmental Research of the Academy of Natural Sciences of Philadelphia (ANSP) also monitors the quality of Savannah River by conducting surveys of the aquatic environment and water quality both upriver and downriver from SRS. These studies have been conducted since 1951.

EMS coordinates the National Pollutant Discharge Elimination System (NPDES) liquid effluent monitoring program for SRS, while the analyses are subcontracted to commercial laboratories certified by SCDHEC. EMS collects NPDES samples and administers the analytical subcontracts. The Environmental Protection Section (EPS) reviews and reports data to SCDHEC through DOE. In 1989, over 6,800 routine analyses were performed on 76 active outfalls at the site.

Sample collection, laboratory analysis, and data handling for the nonradiological groundwater monitoring program (nonregulatory and regulatory) are subcontracted to offsite companies with contracts administered by EMS. EPS and Operating Depart-

Table IP-3
Types of Samples Analyzed in the Nonradiological Monitoring Program

- **Air**
- **Surface Water**
  - rivers
  - streams
- **Groundwater**
- **Drinking Water**
- **Sediment**
  - rivers
  - streams
- **Fish**

ments review and report groundwater data to SCDHEC to fulfill regulatory requirements. Approximately 214,300 analyses were performed during 4,626 sampling events in 1989.

Drinking water analyses for residual chlorine as well as for other chemical constituents are subcontracted to offsite laboratories by the Power Operations Department. Total coliform analysis of drinking water is performed onsite in D Area by the Analytical Laboratories Department. Chlorocarbon analyses are performed on duplicate drinking water samples by both the Analytical Laboratories Department and an offsite laboratory. EPS reviews and reports the required regulatory data to SCDHEC through DOE.

River and stream water and sediment are analyzed for pesticides and herbicides by an offsite laboratory.

EMS normally performs mercury analyses in fish each year. In 1989, 400 mercury analyses were performed on 254 fish samples.

Organizational Involvement

Many SRS organizations are involved in the environmental monitoring program to ensure regulatory compliance, to research the impacts of SRS operations on the environment, and to provide additional support for the monitoring program. Various organizations involved with SRS environmental monitoring programs are summarized in Table IP-4 (below).

Table IP-4.
SRS Monitoring Programs and Organizational Involvement

Radiological Programs	Organizations Involved
Environmental Monitoring (air, surface water, groundwater, food, drinking water, wildlife, rainwater, soil, vegetation, sediment)	Environmental Monitoring Section SRL/Environmental Sciences Section Health Protection Operations
Nonradiological Programs	**Organizations Involved**
Air Monitoring	Environmental Monitoring Section Environmental Protection Section Operating Departments
Water Quality Monitoring	Environmental Monitoring Section Analytical Laboratories Department 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
Drinking Water Monitoring	Environmental Monitoring Section Power Operations Department Environmental Protection Section Analytical Laboratories Department

EPS is responsible for the oversight and coordination of site programs to protect the environment and ensure regulatory compliance.

DESCRIPTION OF ENVIRONMENTAL RESEARCH AND SERVICE

In 1972, SRS was designated as the first National Environmental Research Park (NERP). Scientists from universities and other organizations use the site as an outdoor laboratory to study the environmental impact of man's activities. Approximately 10 research projects were conducted at the SRS under the NERP program in 1989.

In addition to NERP programs, other research programs are conducted each year at SRS. Many of these activities are described in Chapters 12 through 16 of this report. Onsite 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 (USFS) has planted pine seedlings on nearly 97,000 acres of the site 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 USFS sitewide 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.

Environmental Advisory Committee

The Environmental Advisory Committee meets quarterly to review SRS environmental programs and to make recommendations. The committee consists of six consultants who are nationally recognized experts in their respective fields of biology, ecology, hydrogeology, and health physics.

In September 1989, a member of the Environmental Advisory Committee and a senior member of the SRL staff convened a conference, "Integrated Environmental Management," which brought together scientists and professionals from around the country to develop and identify approaches for managing complex environmental issues. Specific emphasis was placed on the following issues:

- management of the Savannah River
- long-term land-use management of SRS
- endangered species and biodiversity protection

Results of the conference are being compiled into a book that discusses each of the above issues. The book will be published in 1990.

Environmental Data Exchange

Since 1987, representatives from the South Carolina Department of Health and Environmental Control (SCDHEC), Georgia Department of Natural Resources (GDNR), Georgia Power Company, Chem-Nuclear, Department of Energy (DOE), and Savannah River Site (SRS) have discussed in informal meetings mechanisms for routine exchange and comparison 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.

A desire to continue the data exchange program in a formal, rather than an informal manner, led to discussion for developing a Memorandum of Understanding (MOU) between participating organizations in 1989. The MOU will define the purpose of the data exchange program and provide direction to the committee so that member organizations can derive desired benefits. Listed below were features discussed while preparing the MOU:

- program purpose
- desired benefits
- guidelines for the use of exchanged data
- types of information or topics to be discussed at meetings

- administrative functions (e.g., hosting and organizing responsibilities)
- committee membership

Goals for the 1990 data exchange program include approval and acceptance of the MOU by member-organization management, and development of a program to establish data comparability.

Environmental Outreach

WSRC expanded its community outreach programs during 1989. The site began a formal program to encourage and facilitate tours, and it expanded the Speakers Bureau. During the year, over 1,300 visitors toured SRS and the Speakers Bureau made 83 presentations to 8,812 individuals. Many of the tours and speeches included information on environmental issues at SRS.

Under the outreach tour program, SRS hosted representatives from several groups with environmental concerns—Greenpeace, Physicians for Social Responsibility, the South Carolina Energy Research Foundation, and the Savannah Nuclear Dialog.

Media executives, editors, and news reporters from major and local televisions, radio stations and newspapers, as well as environmental agency representatives from South Carolina and Georgia, were invited to SRS through the outreach program for a review of the site's environmental activities and research.

Objectives and Rationale for Environmental Monitoring at SRS

SAVANNAH RIVER SITE ENVIRONMENTAL MONITORING PROGRAM OBJECTIVES

The objectives of the Savannah River Site (SRS) environmental monitoring program were developed from recommendations of the International Commission on Radiological Protection [ICRP84]. These objectives are listed below.

Primary Objectives

- To assess actual or potential exposures to critical groups and populations from the presence of radioactive and nonradioactive materials from normal operations or accidents;
- To demonstrate compliance with authorized limits and legal requirements;
- To verify the adequacy of the facility containment of effluent radioactivity and the effectiveness of effluent control;
- To notify the proper officials of unusual or unforeseen conditions and, where appropriate, to activate a special environmental monitoring program;
- To effectively communicate the results of the monitoring program to the public.

Secondary Objectives

Secondary objectives of environmental monitoring include the following:

- To provide accurate information in an expedient manner to local, state, and federal agencies and to the general public for evaluating environmental quality and public safety;
- To provide information on monitoring methods and instrumentation to the public to ensure their active participation in the monitoring program;
- To maintain an accurate, continuous record of the environmental effects of Savannah River Site operations;
- To determine concentrations of radioactive and nonradioactive contaminants in the environmental media to assess the immediate and long-term consequences of normal and accidental releases;
- To distinguish the contributions to environmental contamination and environmental effects from the operation of the Savannah River Site from contributions from other sources;
- To revise the environmental monitoring program in response to changing conditions in transfer pathways;
- To provide site-specific data for risk assessment and uncertainty analyses for human populations in the vicinity of SRS;
- To conduct scientific studies of the transfer pathways of radioactive and nonradioactive contaminants in the environment.

The sections that follow describe how these objectives are being met at SRS through the implementation of a comprehensive environmental monitoring program.

RATIONALE FOR ENVIRONMENTAL MONITORING

In order to meet the objectives of the SRS environmental monitoring program, many thousands of samples are collected and analyzed for radioactive and nonradioactive contaminants. In designing this monitoring program, it is important to justify that the samples that will be taken, together with their analyses, will contribute to achievement of the monitoring objectives. The justification of planned sampling locations, sample media, sampling frequencies, and analyses to be performed is called the "rationale for monitoring."

The development of the rationale for monitoring is a dynamic process. The types, frequencies, and locations of environmental measurements are reviewed routinely to determine if a need for monitoring remains. 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. Important factors which form the basis for this rationale include environmental regulations, public concern, measurement capabilities, and environmental modeling.

Environmental Regulations

One basis for environmental monitoring is the requirements of various environmental regulations and DOE orders. Many of the laws governing waste management and releases of materials to the environment contain specific requirements for monitoring to show compliance with law. In cases where such laws or standards apply to the SRS, the appropriate sampling and analyses will be added to the SRS environmental monitoring program. For example, the discharge of operational effluents through outfalls is permitted by the National Pollutant Discharge Elimination System (NPDES). The SRS NPDES permit, administered by the South Carolina Department of Health and Environmental Control (SCDHEC), delineates the required monitoring and applicable standards. Samples must be taken and analyses performed to meet these requirements.

Public Concern

Distributing information about the environmental performance of SRS to members of the surrounding public is one of the objectives of environmental monitoring. In some instances, public concern may be an important element in the decision to perform specific environmental monitoring. Public concern is often generated for releases of any radioactive or nonradioactive contaminant which may be transported toward surrounding residences or schools. Thus, such locations of concern are typically monitored when far-field monitoring, away from the site, is required.

Concern may also be generated for releases of radionuclides with very long half-lives, that will remain in the environment for many years. Thus, monitoring may be performed for ^{99}Tc and ^{14}C, with half lives of 213,000 years and 5,730 years, respectively, although the potential dose contributions to humans may be extremely low.

Measurement Capabilities

Many of the radioactive and nonradioactive materials released from SRS exist in such low concentrations when they are dispersed in the environment that they are not readily measured using conventional monitoring procedures. Thus, the measurement capabilities become determining factors in the rationale for monitoring certain materials. In these cases, it is still important to determine the quantities of the substances in the environment.

One solution is to monitor the source of the contamination or the release where higher concentrations may be more readily assessed before dispersion in the environment. Environmental modeling can be used to calculate the expected concentrations of the contaminant in various media in the environment. Smaller numbers of environmental samples may be obtained to verify the accuracy of the modeling.

Future Direction: Environmental Modeling

Environmental models are mathematical representations of real phenomena that simulate transport in the environment and estimate internal and external exposure to individuals. Computer codes are generally used in modeling to efficiently calculate the resulting radiation dose. The SRS facilities maintain meteorological and computing capabilities that are applicable to environmental modeling. Chapter 3 of this report, "Calculating Offsite Radiation Doses," includes a brief discussion of the important environmental models used at SRS.

As discussed in Chapter 3, these models are generally used to determine transport of radionuclides in the environment and then to predict doses to the offsite population. The next logical step is to use modeling techniques to optimize the extensive environmental monitoring program for radioactive and nonradioactive contaminants. The use of models will be extremely important in expanding the rationale for monitoring in the future.

Predictions of the models can be extremely beneficial in determining the placement of measuring devices in the environment, and in identifying important pathways and contaminants that should be given priority in a monitoring scheme. Modeling can also contribute to the optimization of resource allocation for sampling and analysis efforts, and to verification that a sampling network will perform adequately. These environmental monitoring activities can be better implemented with the help of environmental models.

As part of its routine updating of the site environmental monitoring program, SRS is beginning to use environmental models as part of their sampling program. The site is only in the initial stages of using these techniques, but a number of possibilities can already be seen for future application. The methods could be used in the design of monitoring programs for air, surface waters, and groundwaters, among others.

For illustrative purposes, some examples of the potential use of models for the development of monitoring rationale are given in the remainder of this chapter. Many of the underlying principles that form the rationale for monitoring at the Savannah River Site are described.

The examples given focus primarily on monitoring radioactive contaminants. This is only because the majority of effort in the uses of models has been for radionuclides. Most of these techniques, with modification, can also be applied to monitoring nonradioactive contaminants. In fact, monitoring nonradioactive contaminants may be increasingly important in the future, as the potential environmental effects are examined. Models may be useful for balancing the radionuclide monitoring with the monitoring of nonradioactive contaminants.

Monitoring for Accidental Atmospheric Releases

Atmospheric dispersion models can be used to assist in determining the optimum distance between thermoluminescent dosimeter (TLD) monitoring stations at a given distance from the source. The TLD monitoring network is used to make integrated measurements of the intensity of gamma radiation levels at and around SRS. In the event of a significant unplanned release of radioactivity from the site, the network would provide a quick and reliable method of determining external gamma radiation doses to population groups within about 50 miles (80 km) of SRS.

Theoretically, the spread of a plume can be predicted using a mathematical model, the accuracy of which is significantly influenced by site-specific conditions. The Gaussian plume model can be used to estimate the spread of the plume as a function of distance downwind and atmospheric stability class. The dispersion is a function of the release height, the distance downwind, the horizontal and vertical dispersion coefficients, and the atmospheric stability class. Pasquill stability classes used typically range from class A, very unstable conditions, to class F, very stable conditions.

A computer code was developed at SRS to calculate the width of the plume based on a specified percentage of the centerline (CL) concentration as a function of the downwind distance and the stability class. The width of the plume for a 50% of centerline concentration refers to the width of that part of the plume which has a contaminant concentration at least 50% of the concentration at the centerline (the maximum concentration). Figure OR-1 (below) illustrates this concept of plume width for 30% and 50% of centerline

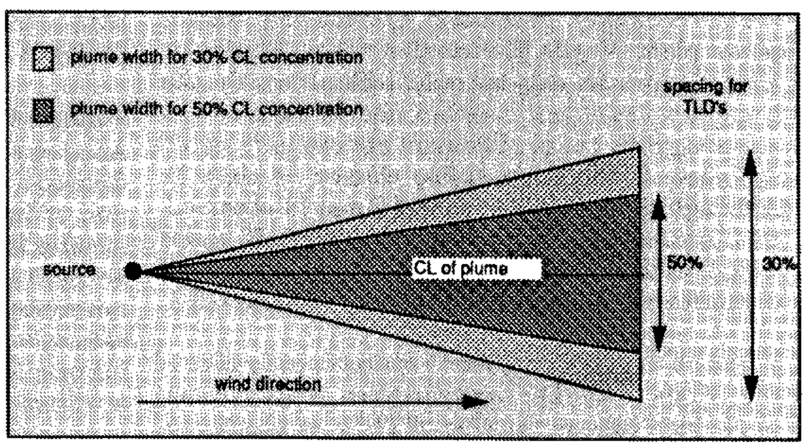


Figure OR-1. A computer code is used to calculate plume width as distances from the release source increase

Table OR-1
Width of the Gaussian Plume for 30% and 50% of Centerline (CL) Concentration Downwind Distance and Stability Class Function

Stability Class	Distance Downwind Miles (km)		Plume Width in Miles (km) 50% CL		30% CL	
D	1.3	(2)	0.20	(0.33)	0.26	(0.43)
	2.5	(4)	0.37	(0.59)	0.49	(0.78)
	5.0	(8)	0.68	(1.10)	0.90	(1.40)
	7.5	(12)	0.94	(1.50)	1.20	(1.90)
	10	(16)	1.10	(1.80)	1.50	(2.30)
E	1.3	(2)	0.15	(0.23)	0.19	(0.30)
	2.5	(4)	0.27	(0.42)	0.35	(0.56)
	5.0	(8)	0.49	(0.78)	0.64	(1.00)
	7.5	(12)	0.66	(1.05)	0.88	(1.40)
	10	(16)	0.78	(1.25)	1.00	(1.70)
F	1.3	(2)	0.10	(0.17)	0.14	(0.22)
	2.5	(4)	0.19	(0.30)	0.25	(0.40)
	5.0	(8)	0.34	(0.55)	0.45	(0.72)
	7.5	(12)	0.46	(0.74)	0.61	(0.97)
	10	(16)	0.56	(0.89)	0.73	(1.20)

concentrations as distance from the release source increases. The calculated data are summarized above in Table OR-1, showing the plume width for three stability classes, D, E, and F.

All of the facilities that release radioactivity at SRS, except for the Fuel Fabrication and Savannah River Laboratory facilities on the northern side of the site in A/M Areas, are 7.5 miles (12 km) or greater from the site boundary. In addition, a commercial nuclear power plant (Vogtle Electric Generating Station) is located approximately one mile (1.6 km) from the site boundary on the southwestern side. In the area surrounding SRS, the predominant atmospheric stability class, of the more stable classes, is class D. Although stability classes E and F may be observed, their occurrence is infrequent. Classes A, B, and C would result in greater dispersion than class D at all distances, and thus were not included in Table OR-1.

Based on the ability to detect approximately 50% of the plume centerline concentration from a short, unplanned release, spacing of TLDs at about one-mile intervals around the site boundary provides adequate coverage. However, around the Fuel Fabrication-Savannah River Laboratory Area and the Vogtle Electric Generating Station, the spacing interval should be approximately 0.25 miles (0.4 km) within 2 miles (3.2 km) of the facilities.

It is emphasized that these theoretical calculations do not include site-specific information and therefore do not consider important physical properties of atmospheric dispersion such as plume meander and terrain effects. Although these calculations are idealistic, they provide a rationale for locating monitoring points as a function of downwind distance.

Monitoring for Routine Atmospheric Releases

Another example of using environmental models to develop a rationale for monitoring is the determination of important pathways and radionuclides to monitor for atmospheric releases from SRS. Models are used at SRS to calculate the dispersion and environmental transport of radionuclides released to the atmosphere, and the radiation doses to persons living near the site, from these releases. These models are discussed in Chapter 3.

The results can be used in the design of an environmental monitoring program to ensure that radionuclides and exposure pathways of highest potential dose are adequately monitored and to optimize the allocation of monitoring resources.

In 1988, SRS used these models to calculate the average radiation dose to a resident at the SRS boundary [Da89]. The distributions of dose by exposure pathway and radionuclide are shown below in Table OR-2.

Pathway analyses of 1988 SRS atmospheric releases indicate that the significant contributions to the average committed dose to an individual at the site perimeter are through inhalation (39%), consumption of vegetation (26%), immersion (21%), meat consumption (8%), and milk consumption (7%). This distribution is not surprising because the largest contributor to dose is tritium, which permeates all environmental media. Based on the potential doses to individuals, these data indicate the need for greater environmental monitoring efforts toward contaminants in air, vegetation, milk, and meat products. These media can be monitored with air sampling stations (air), environmental TLDs (air), and analyses of food product samples (vegetation, milk, and meat). These data also indicate that deposition of radionuclides on the ground is an insignificant pathway for doses to humans, and thus sampling efforts directed at measuring ground deposition can reasonably be reduced.

Based on the same modeling analysis, the principal radionuclide contributors to the average dose to an individual at the site perimeter are tritium (about 66%), ^{41}Ar (17%), ^{129}I (9%), isotopes of Kr and Xe (4%), and ^{14}C (2%). Consequently, these data indicate the need for greater monitoring efforts for tritium, ^{41}Ar, ^{129}I, Kr, Xe, and ^{14}C, and lesser efforts for monitoring other radionuclides. There may be reasons for monitoring other radionuclides. In fact, tritium is monitored extensively at and around the SRS. On the other hand, ^{41}Ar is monitored extensively at the sources, with some support monitoring around the site. (Argon-41 is very difficult to monitor at low concentrations in the environment, and thus modeling is typically used to estimate downwind concentrations.)

In the actual application of modeling data, a thorough analysis would be performed, including an examination of similar data for many years, trends of the data, and estimates of releases due to accidents.

Table OR-2
Modeled Average Individual Doses at the Site Boundary From Atmospheric Releases in 1988[a]

By Pathway

Pathway	Average Individual Dose, mrem[b]	% 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[b]	% 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] Reference Da89.
[b] Committed effective dose equivalent.

Monitoring Surface Waters

Models can also be used to perform a similar analysis for optimization of surface water monitoring. Models of radionuclide dispersion in surface waters can be used to calculate doses to members of the surrounding population, with the doses broken down by exposure pathway and radionuclide. Monitoring efforts can be adjusted to provide monitoring for pathways, sample media, and radionuclides contributing the most significant doses. Surface water models can also identify the environmental media and sampling points where the concentration of dissolved contaminants should be highest.

For example, in surface water modeling, sediments may be important sinks for certain radionuclides and some nonradioactive contaminants. Thus, sediments may represent long-term indicators of environmental quality for some contaminants, and consequently should be monitored regularly.

The extent to which a contaminant is adsorbed to sediments or desorbed to the surrounding water is typically modeled using the concept of equilibrium distribution coefficient (K_d). The distribution coefficient is the ratio of the contaminant concentration in the sediments to the concentration of the contaminant in the water at equilibrium conditions. Values of K_d can be estimated with theoretical models or can be measured, but are very site-specific parameters.

After determining the contaminants of concern for surface water releases, the K_d values should be modeled or measured. Then, the appropriate monitoring media (water or sediments) can be chosen based on the K_d values. Contaminants with very high K_d values are expected to deposit and mostly remain adsorbed on the sediments. Thus, sampling and analysis of the sediments should be performed. Contaminants with very low K_d values are expected to remain dissolved in the water, and water sampling and analysis are indicated. As examples, cerium, cesium, and plutonium typically have fairly large K_d values and may accumulate in sediments, whereas tritium and ^{14}C typically have small K_d values and would remain mostly in the water.

Monitoring Groundwater

Modeling of the dispersion of contaminants in groundwater can also be performed. Groundwater modeling is typically more difficult because many site-specific parameters are required in order to obtain accurate results. In addition, groundwater sampling is more complicated than other sampling, because monitoring wells must be constructed. However, models can still be useful for developing the rationale for groundwater monitoring.

First, it is important to consider the probability of release of contaminants to groundwater (source term). There is a significant difference between the emphasis that should be given to groundwater monitoring for a reactor containment vessel which typically does not release radionuclides to groundwater versus facilities which use earthen basins for disposal of radioactive or hazardous liquid waste.

In addition, a groundwater monitoring program should focus on those contaminants which are the best indicators of leakage or contaminant movement. Based on the lowest values of K_d, the most mobile radionuclides are tritium, ^{14}C, ^{99}Tc, and ^{129}I. Many volatile organic compounds, such as the solvent trichloroethylene, are also very mobile in groundwater. At SRS, tritium oxide (tritium in the form of water) is the most abundant groundwater source-term radionuclide, in addition to being the radionuclide with the smallest K_d factor. Therefore, groundwater monitoring well samples are analyzed routinely for tritium oxide, and tritium oxide is used as the primary indicator of groundwater movement. Samples are also analyzed for the source contaminants that are most mobile for the specific area of the site being monitored.

Perspectives on Environmental Contaminants and Risk

SUMMARY—The purpose of this section is to provide basic information on the sources of exposure to radiation and hazardous chemicals, and to outline the general process of risk assessment, especially as it applies to these materials. This information will help provide readers with a perspective for judging risks associated with releases of radionuclides and chemicals at the Savannah River Site (SRS).

The chapter includes a review of the basic sources of radiation to which the general public is normally exposed including natural background radiation and man made sources. A total average annual effective dose equivalent of 360 mrem (3.6 mSv)/year to members of the U.S. population is contributed by these sources, according to the latest BEIR V report. The process of risk assessment is described, as it is used in determining the probability of health effects from exposure to low doses of radiation. The risk estimates from the most recent BEIR committee report are given. A discussion of exposures to hazardous chemicals and the risk assessments for hazardous chemicals concludes the chapter.

SOURCES OF RADIATION

All human beings are exposed to sources of ionizing radiation which include naturally occurring sources and man-made sources. The following sections provide brief descriptions of these radiation sources. The estimates of contributions to the average dose to individuals were obtained from a recent report of the National Council on Radiation Protection and Measurements [NCRP87]. Figure PR-1, located on the following page, shows the contributions of various sources to the average dose to an individual. Chapter 3 of this report, "Calculating Offsite Radiation Doses," defines the terms and units for expressing radiation doses.

Natural Background 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 occurs from sources both external and internal to the body. This naturally occurring radiation is often referred to as the natural background radiation.

Cosmic Radiation

Energetic charged particles from outer space continuously hit the earth's atmosphere. These particles and the secondary particles and photons they create are ionizing radiation called cosmic radiation. Because the atmosphere provides some shielding against cosmic radiation, the intensity of this radiation increases with altitude above the earth's surface. The average annual dose equivalent to people in the U.S. from cosmic radiation is about 28 mrem.

Terrestrial Radiation

Terrestrial radiation refers to radiation emitted from radioactive materials, primarily ^{40}K, thorium, and uranium, in the earth's rocks and soils. The average annual dose, from terrestrial gamma radiation, is about 28 mrem in the U.S. This annual dose varies geographically across the U.S., from about 16 mrem at the Atlantic and Gulf coastal plains to about 63 mrem at the eastern slopes of the Rocky Mountains.

Internal Radiation

Natural radionuclides in the environment enter the body by ingestion of foods, milk, and water, and by inhalation. These radionuclides follow the same

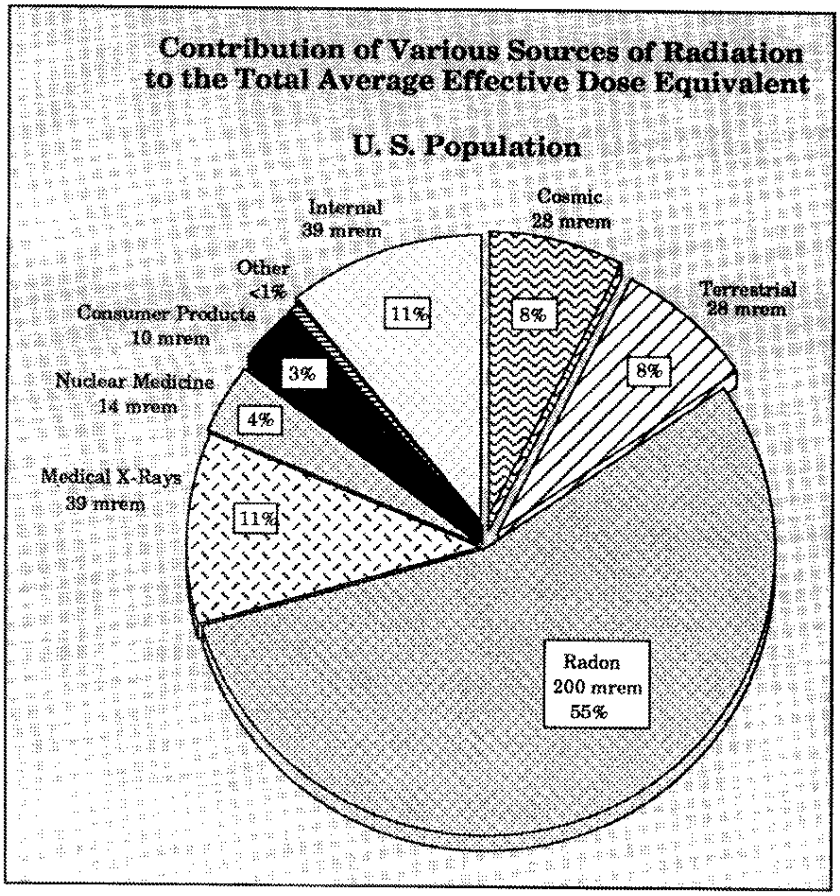


Figure PR-1. A variety of radiation sources contributes to the total average effective dose equivlaent

metabolism in the body 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 decay series; as well as ^{40}K, ^{87}Rb, and ^{14}C. The major contributors to the annual dose equivalent for internal radionuclides are the short-lived decay products of radon (mostly ^{222}Rn), which contribute an average dose of about 200 mrem per year. The average dose from other internal radionuclides is about 39 mrem per year, which is predominantly attributed to ^{40}K.

Consumer Products

A wide range of consumer products also contain sources of ionizing radiation. In some of these products, like smoke detectors and airport x-ray baggage inspection systems, the radiation is essential to the performance of the device. In other products, such as televisions and tobacco, the radiation occurs incidentally to the product function. The average annual dose to an individual is about 6 to 12 mrem.

Medical Diagnosis and Therapy

Radiation is one of the important tools of diagnostic medicine and of cancer treatment. Exposure to patients is deliberate, and the purpose of these medical and dental uses 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 thus not normally irradiated uniformly.

In nuclear medicine examinations, the distribution of internally administered radionuclides is not uniform throughout the body. In these cases, 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 effective dose equivalent to all individuals from all medical examinations is 53 mrem (about 39 mrem for diagnostic x-rays and 14 mrem for nuclear medicine procedures). The actual doses to individuals who receive such medical exams is much higher than these values; not everyone receives such exams each year.

Other Sources

There are a few sources of radiation that contribute a minor dose to individuals in the U.S. About 1,320,000 people were engaged in radiation work in 1980, with an average dose of 110 mrem per year. Thus, for the population average dose to an individual, the contribution is less than 1 mrem per year. The dose to individuals in the U.S. from nuclear fuel cycle facilities, such as uranium mines, mills, fuel processing plants, nuclear power plants, and transportation routes, has been estimated at much less than 1 mrem per year.

Very small doses to individuals occur due to radioactive fallout from atmospheric atomic bomb tests, which have now been suspended; emissions of radioactive materials from other nuclear facilities, such as

DOE facilities; emissions from certain mineral extraction facilities; and transportation of radioactive materials. The combination of these sources contributes less than 1 mrem per year to the average dose to an individual.

RISK ASSESSMENT

The purpose of risk assessment is to estimate the hazard to humans from materials or activities in the environment around them. The risk assessment process may be a simple, intuitive evaluation that a particular action represents an acceptable risk compared to the benefit (crossing a street with heavy noon traffic to have lunch). Or it may be sophisticated, involving estimation of all possible risks and environmental pathways from a complex facility to a human population. For example, risk assessment may require many steps to determine:

- how much material is released from a facility
- how the material is transported throughout the environment
- how the material is ingested or inhaled by humans, and concentrated in bodily organs
- what health effects these materials may cause in the body

Risks are evaluated using data from annual safety studies or epidemiological data, and can be expressed as the number of deaths or injuries to a certain population for a specified period of time. Presently, formal risk assessment is characterized by the calculation—through the use of equations and mathematical models—of a numeric risk such as the number of deaths per million persons per year of exposure to a material.

PERSPECTIVES ON RADIATION RISK

This section of the chapter will describe the process of obtaining a reasonable risk estimate for radiation. The goal of radiation risk assessment is to examine the known effects that radiation has upon both the individual and population exposed, then to estimate probable effects of additional exposure. Recent risk estimates for radiation doses will be presented. Finally, various levels of radiation dose will be described and compared.

Potential Health Effects of Radiation Exposure

More information has been accumulated on the health effects of exposures to ionizing radiation than on any other hazard. Although disagreement exists on the effects of low doses of radiation, higher doses of radiation present a clear hazard. In general, radiation effects can be characterized as stochastic or nonstochastic. Nonstochastic effects have a clear causal relationship between exposure to radiation and the observed effect, and are usually believed to have a threshold dose below which no effects are induced by radiation (see curve C, Figure PR-2, on the following page). Cataract induction by radiation is one example of a nonstochastic effect.

Stochastic effects are those effects that occur in a statistical manner, described by a probability of an effect from a given dose. Furthermore, stochastic effects are typically thought to have no threshold, with the result of exposure to radiation being an increase in the probability of occurrence of the effect.

For radiation, stochastic effects include most kinds of cancer induction and all genetic effects. However, cancers caused by radiation are no different from tumors or cancers that occur "normally" in a population. If cancer does develop after exposure to a carcinogen like radiation, it is not absolutely clear that the cancer was caused by the radiation. Instead, the probability that the cancer was caused by radiation can be estimated.

Dose-Response Relationships

In radiation risk assessment, the doses from occupational exposure to radioactive materials or from exposures to the general population are sufficiently low that the only health effects that need to be considered are stochastic effects, those that occur probabilistically. Because the effects of low-level radiation cannot be measured directly and because of their fairly low probability of occurrence, radiation risk estimates are determined by studying large population groups who have been exposed to rather large doses of radiation. The primary sources of data on which risk estimates are based include the following groups:

- Japanese atomic bomb survivors
- patients exposed to therapeutic doses of radiation for a variety of medical conditions

- occupationally-exposed populations such as radium dial painters and uranium miners.

After reviewing these data, several scientific committees have estimated the risk involved from exposure to much lower doses. A committee set up by the U.S. National Academy of Sciences on the "Biological Effects of Ionizing Radiations" issued its latest report on "Health Effects of Exposure to Low Levels of Ionizing Radiation" (BEIR V) in 1990 [BEIR90]. The methods applied by these scientific groups involve the use of mathematical models to extrapolate the probability of effects observed at relatively high levels of exposure to levels at which the actual increase in health effects in an exposed population cannot be detected, either through epidemiological or experimental techniques. Figure PR-2 (below) shows a typical representation of radiation dose response relationships.

Considerable evidence supports a linear relationship between dose and risk (Figure PR-2, curve A), in which the number of expected excess effects is proportional to the dose at all dose levels. The linear quadratic dose response model—in which effects are very nearly proportional to dose at very low doses and proportional to the square of the dose at high doses (Figure PR-2, curve B)—is supported by some epidemiological studies and a number of radiobiological laboratory studies.

According to the BEIR V report [BEIR90], the dose-dependent excess of mortality from all cancer other than leukemia, shows no deviation from the linear dose-response model in the range below 400 rem or [4 sievert(Sv)]. However, mortality data for leukemia are compatible with a linear-quadratic dose response relationship. These dose-response relationships for carcinogenesis are influenced by sex, age at exposure, the dose rate and type of radiation and other variables. The U.S. EPA (40 CFR 193) also believes that these two models are compatible with most of the data on human cancer.

Risk Estimates

Estimates of risk are determined from these dose response models. In addition, the latest BEIR committee used standard lifetable techniques to estimate the lifetime risk for each type of cancer based on these dose response models [BEIR90]. Using the available evidence and best models, the BEIR committee estimated the population-weighted average lifetime excess risk of death from cancer following an acute dose equivalent to all body organs of 10 rem (0.1 Sv) to be 0.8%, or 8×10^{-4} per rem (8×10^{-2} per Sv).

This means that if one million persons of all ages received a whole body dose of 10 rem (0.1 Sv) of radiation in a single brief exposure, about 8,000 extra cancer deaths would be expected to occur during their remaining lifetimes. These excess cancers are expected in addition to the nearly 200,000 cancer deaths that would occur in the absence of radiation. According to the BEIR V report, if the same amount of radiation is given over weeks or months, the lifetime risk would be reduced by a factor of two or more.

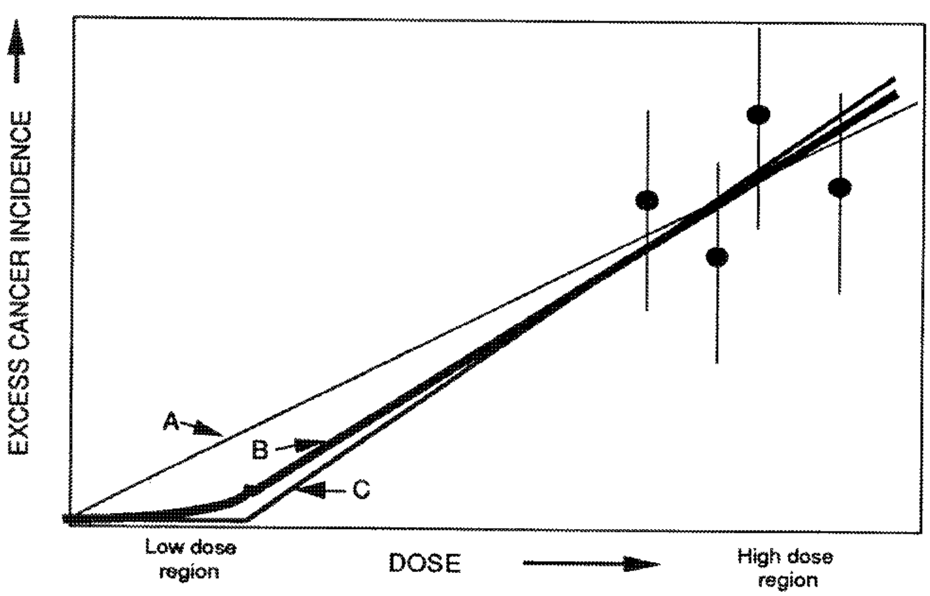


Figure PR-2. Typical radiation dose-response relationships

Because the excess deaths would be indistinguishable from those that occurred naturally, it is a difficult statistical problem even to determine how many extra deaths occurred. The answers are subject to statistical errors which can be exaggerated by the limited sample size.

Other scientific groups have also developed mathematical models to estimate risk. For example, the U.S. Nuclear Regulatory Commis-

Table PR-1
Lifetime Radiation Risk Estimates

Fatal Cancers per Million Persons

BEIR V Model Excess Cancers	NRC "Best Estimate" Excess Cancers	U.S. "Normal Incidence" of Cancers
8,000 (8×10^{-4}/rem)	230 (2.3×10^{-4}/rem)	200,000 (2×10^{-4}/rem)

sion (NRC) combined absolute and relative risk projection models from the BEIR III report to estimate health effects from the Chernobyl accident [Go87]. They used the most recent data on organ sensitivity and dose response and provided three estimates of the risk range—an upper estimate, a best (central) estimate, and a lower estimate. The NRC best estimate was a lifetime risk of 2.3×10^{-4} per rad (2.3×10^{-2} per Sv), or 230 excess cancers for one million people exposed to 1 rad (see Table Pr-2).

Genetic effects of radiation have not been clearly demonstrated in humans but are well characterized in the mouse. According to the BEIR V report, it is estimated by means of extrapolation from mice to humans that at least 100 rad (1 gray) of low dose-rate, low-LET [linear energy transfer radiation, (x-rays and gamma radiation)] is required to double the mutation rate in humans.

Since information on the lifetime cancer experience is not available for any of the human studies, the overall risk of cancer can only be estimated by means of models which extrapolate over time. In the same manner, estimates on the induction of human genetic disorders by radiation are based on limited data from studies of human populations and therefore rely largely on studies with laboratory animals.

Uncertainties in Risk Estimates

The BEIR V committee emphasizes that the risk estimates derived from epidemiological and animal data should not be considered precise. Even with this extensive database, the quantitative estimation of the carcinogenic risk of low-dose, low-LET radiation is subject to numerous uncertainties (BEIR 1990). Thus, the BEIR committee has placed more emphasis on the method of estimation than on the numerical estimates obtained.

Even though the database for radiation risk assessment is quite large, disagreement still exists between the models, based upon the large degree of uncertainty associated with the exact shape of the dose-response curves at low doses of radiation. Since there is some uncertainty, many scientists will use the linear model as an upper limit of the actual dose-effect relationship when actual data are limited. The linear model is thought to be a conservative estimate, or overestimate, of the actual risk.

Comparison of Various Levels of Radiation Dose

Table PR-2 on the following page presents a scale of radiation dose levels, with an example of the type of exposure that may cause such a dose, or the special significance of such a dose. This information is intended to help the reader become familiar with a range of radiation doses that various individuals may receive.

PERSPECTIVES ON CHEMICAL RISK

Just as all humans are exposed to radiation in the normal daily routine, humans are also exposed to hazardous chemicals. Unlike radiation exposures, there is not a natural background to which people are continuously exposed for most chemicals.

Some Sources of Hazardous Chemicals

Some hazardous chemicals do exist in the natural environment. In many areas of the country, soils contain naturally elevated concentrations of metals such as selenium, arsenic, or molybdenum, which may be hazardous to humans and animals. However, exposures to many more hazardous chemicals are due to the direct or indirect actions of humans. Building materials used for the construction of homes may contain chemicals such as formaldehyde (in some insulation materials), asbestos (formerly used in insulations and ceiling tiles), and lead (formerly used in paints). Thus, people are exposed to these chemicals in their normal lives.

Personal uses of automobiles involve the potential exposure to many hazardous chemicals. Gasoline

Table PR-2. Comparison and Descriptions of Various Radiation Dose Levels

Dose Level	Description
1 mrem	One one-thousandth of a rem. Approximate daily exposure from natural background radiation and radon.
2.5 mrem	Cosmic radiation dose to a person on a one-way airplane flight from New York, NY to Los Angeles, CA.
10 mrem	Dose due to one chest x-ray using modern equipment.
25 mrem	Yearly exposure limit set by the U.S. Environmental Protection Agency for people who live near commercial nuclear power plants.
28 mrem	Average yearly dose from cosmic radiation to people in the U.S.
60-80 mrem	Average yearly dose from cosmic radiation to people who live in the Rocky Mountain area.
80 mrem	Average yearly dose to people in the U.S. from man-made sources.
83 mrem	The estimate of the largest dose any offsite person could have received from the Three Mile Island accident on March 28, 1979.
110 mrem	Average occupational dose received by radiation workers in 1980.
160 mrem	Yearly average dose to the airline flight crew member from cosmic radiation.
300 mrem	Average yearly dose to people in the U.S. from all sources of natural radiation.
500 mrem	Annual limit from all sources of man-made radiation (except medical and dental) for a person in the U.S. who is not a radiation worker.
900 mrem	Average dose from a lower intestine diagnostic x-ray series.
1-5 rem	Under the U.S. EPA's "Protective Action Guidelines," public officials should take emergency action when the dose to a member of the public from a nuclear accident is likely to reach this range.
5 rem	Annual limit for nuclear workers set by the U.S. NRC and DOE.
10 rem	An acute dose at this level is estimated by the BEIR V committee to result in a lifetime, excess risk of death from cancer caused by the radiation, of 0.8%.
25 rem	U.S. EPA guideline for voluntary maximum dose to emergency workers for non-lifesaving work during an emergency.
75 rem	U.S. EPA guideline for the maximum dose to emergency workers volunteering for lifesaving work.
50-600 rem	Doses in this range received over a short period of time will produce radiation sickness, in varying degrees. At the lower end of this range people are expected to recover completely, given proper medical attention. At the top of this range, most people exposed to this level will die within 30 days.

fumes, which contain the hydrocarbons heptane and octane, benzene, and tetraethyl lead (being phased out), may be inhaled while refueling. Used motor oils, refrigerants for air conditioners, and combustion exhaust gases may also be frequently encountered. Many hazardous chemicals are used or produced in manufacturing facilities. Examples include solvents used for cleaning materials (such as toluene, xylene, or trichloroethylene), fine particles of many metals (from mechanical processing), and acids and other organic compounds used in chemical reactions.

Chemical Risk Assessment

In concept, risk assessments can be performed for exposures to hazardous chemicals in much the same way as for radiation exposures. However, for a number of reasons, the assessments of chemical risks have not progressed as far as the radiation risk studies. In the discussions below, references will be made to radiation risk assessments regarding the limitations and deficiencies of current chemical risk assessments.

With regard to hazard identification, no simple method or criterion can be used to determine whether a chemical will be a human health hazard (see Figure PR-3, right). On the other hand, the results of radiation risk assessment represent actual harm that could occur to humans under some exposure conditions, despite the uncertainties of dose rate and dosimetry. For most chemicals debate continues on the key question, "Is this compound a carcinogen?" In addition, chemicals produce many different types of effects, which may not be easily measured or categorized. Often the effects of a chemical are assumed, based on effects produced by a substance in a class of chemically related compounds.

In establishing dose-response relationships, the database on human risks from chemical agents is still inadequate for more than rough guidelines. It is generally accepted that the most appropriate data for cancer risk estimation are obtained from epidemiological studies. Many investigators believe that a single, defensible epidemiological study on the potential health effects to residents near hazardous waste disposal sites has not been conducted [Co85]. For genetic effects, no studies of the offspring of humans exposed to a chemical mutagen meet current epidemiological standards. Thus, the main data source—results of animal studies—remains only a gross approximation.

In addition, dose-response relationships cannot be extrapolated from one chemical to another because

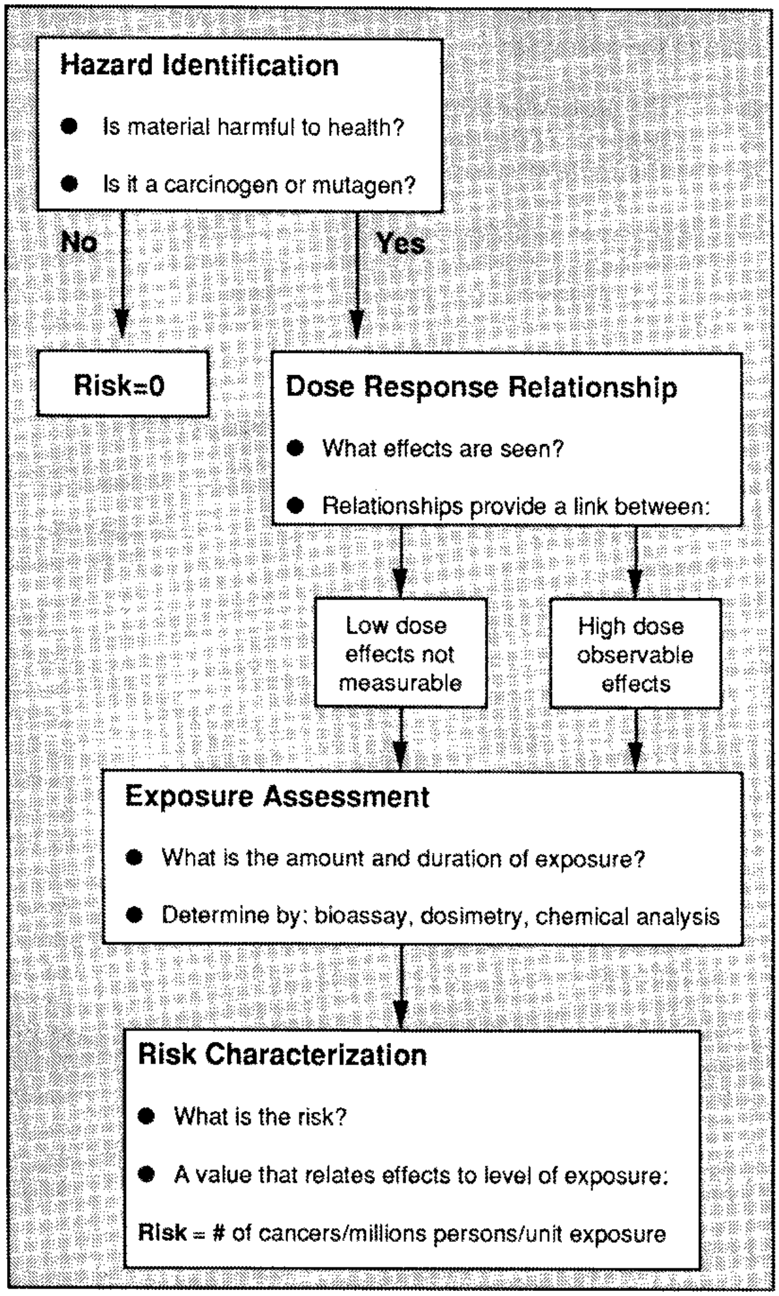


Figure PR-3. Basic identification of hazard and risk

each chemical, or group of chemicals, may produce different, or perhaps interacting effects. This is not the case for radiation exposures. A basic principal of radiation risk extrapolation is that radiation dose, regardless of its source, produces biological effects (cancer and genetic effects) proportional to that dose (with quantifiable modifiers).

Exposure assessment for chemicals is also more complicated than for radiation. All modes of exposure may not necessarily be associated with an equivalent carcinogenic response for several reasons, which include the following:

- the particular properties of the chemical
- behavior of the chemical in the environment
- the route of internal exposure

The persistence and reactivity in the environment and in the human body vary for different chemicals. Given many of the uncertainties already discussed, it is difficult to separate the different contributions to effects of the many chemicals to which an individual is exposed.

Risk characterization of chemicals is not based on a frame of reference for which comparisons can be made. For most chemicals no easily measured baseline or natural background exposure exists, as with radiation exposures. Chemical risks are typically based on strength of the evidence, which produces more of a qualitative comparison with other chemicals, than a quantitative risk assessment. In addition, the mechanisms for carcinogenicity are often different for different chemicals. Many chemical carcinogens require metabolic activation or the presence of co-carcinogens or tumor promoters to produce an oncogenic or genetic change in a cell.

Risk Estimates

With the immense difficulties in developing defensible risk estimates for chemicals, it is easy to understand why chemical risk assessment has not progressed as far as radiation risk assessment. Because of these difficulties, current risk estimates typically represent an upper bound on the actual risks. Table PR-3 (left) lists upper bounds for unit risk estimates for some chemicals that might present the greatest hazards to humans from air pollution [An83].

The U.S. Environmental Protection Agency has emphasized that numerical risk estimates should not be separated from the various assumptions and uncertainties upon which they are based. These values should be treated only as estimates of the upper bound to the risk from the chemicals, and should not be used to calculate an actual risk from a given exposure. It is noted that the exponents of these risk estimates range from 10^{-8} to 10^{-1}, over a millionfold for this set of chemicals. In addition, some chemicals having the strongest evidence for carcinogenicity based on responses in humans have relatively low potencies (for example, vinyl chloride and benzene with unit risks of 10^{-6}).

Table PR-3
Upper-Bound Unit Risks for Some Suspected Carcinogenic Air Pollutants[a]

Chemical	Upper-Bound Unit Risk Estimates[b]
Acrylonitrile	7×10^{-5}
Allyl Chloride	5×10^{-8}
Arsenic	4×10^{-3}
Benzene	7×10^{-6}
Beryllium	6×10^{-4}
Diethylnitrosamine (DEN)	2×10^{-2}
Dimethylnitrosamine (DMN)	5×10^{-3}
Ethylene dibromide	6×10^{-5}
Ethylene dichloride	7×10^{-6}
Ethylene oxide	2×10^{-4}
Formaldehyde	5×10^{-5}
Manganese	4×10^{-4}
Nickel	6×10^{-4}
N-nitroso-N-ethylurea (NEU)	1×10^{-2}
N-nitroso-N-methylurea (NRU)	7×10^{-1}
Perchloroethylene	2×10^{-6}
Trichloroethylene	3×10^{-6}
Vinyl chloride	4×10^{-6}
Vinylidene chloride	4×10^{-5}

[a] From An83.
[b] Unit risk is excess lifetime risk associated with breathing a concentration of 1 $\mu g/m^3$ of the chemical for a 70-year life span for a 70 kg person.

Part II

Environmental Monitoring Methods

1

Sample Collection, Analytical Procedures, and Data Interpretation

SUMMARY—Sampling methods and analytical procedures for the radiological and nonradiological monitoring of environmental media at SRS are described. For the detection and quantification of radionuclides in environmental samples, the chemical separation, purification, and concentration techniques, as well as the instrumentation and counting geometries, are described in detail.

The chapter outlines radiological monitoring procedures for air, the Savannah River and streams, seepage basins, groundwater, milk, food, drinking water, rainwater, soil and sediments, vegetation, and wildlife. Ambient gamma radiation levels on and around SRS are measured with thermoluminescent dosimeters.

The nonradiological monitoring program includes the monitoring of chemicals, metals, and organics in SRS liquid effluents, site streams, the Savannah River, groundwater, drinking water, air, and fish. Ambient air quality is continuously monitored at five stations within the site boundary.

In addition, SRS wastewater effluents or outfalls are regulated by SCDHEC under National Pollutant Discharge Elimination System (NPDES) permits and sampled by EMS. Outfall samples are routinely analyzed for temperature, pH, total nonfilterable residue, oil and grease, and fecal coliform.

Several SCDHEC-certified laboratories provide support in analyzing samples from the 1,039 groundwater monitoring wells in the nonradiological monitoring program.

INTRODUCTION

The environmental monitoring program at the Savannah River Site (SRS) includes radiological and nonradiological monitoring that encompasses a 30,000–square–mile area. This chapter describes how environmental samples are collected and prepared, as well as the analytical techniques used to determine the concentrations of radioactive and nonradioactive contaminants within the samples. Chapters 4 through 11 in Part III—Environmental Monitoring Programs—provide tables and figures that identify sampling stations and locations.

In 1989, approximately 100,000 radiological analyses were performed on about 25,000 air, water, soil, sediment, vegetation, milk, food, and wildlife samples. About 120 additional samples were collected and 300 analyses performed during special radiological surveys. Ambient gamma radiation levels were monitored at 454 locations.

Except for a few cases, the nonradiological monitoring program is confined within the SRS boundaries. In 1989, approximately 17,500 nonradiological analyses were performed on 5,400 samples of surface water, soil, sediment, and fish to determine the concentrations of nonradioactive contaminants. In addition, approximately 214,000 analyses were performed on groundwater samples during 4,626 sampling events, which may consist of filling from one to 10 sample bottles for various analyses. Ambi-

Table 1-1. General Radiological Sampling and Analysis Schedule

Environmental medium	Frequency	Analysis
Air	Continuous sampling Weekly analysis	Alpha, beta, ^{238}Pu, ^{239}Pu, Gamma emitters, and $^{89,90}Sr$
Air silica gel	Biweekly	Tritium
Ambient radiation (TLDs)	Quarterly	Gamma radiation
Streams and Savannah River	Continuous sampling Weekly analysis	Alpha, beta, tritium, gamma emitters, $^{89,90}Sr$, and U/Pu
Seepage basins	Quarterly	Alpha, beta, tritium, Gamma emitters, $^{89,90}Sr$, ^{238}Pu, ^{239}Pu, and U/Pu
Groundwater	Quarterly	Alpha, beta, tritium, ^{90}Sr, and gamma emitters
Milk	Biweekly	^{131}I, ^{137}Cs, and tritium
	Quarterly	^{90}Sr
Food	Annually	Tritium, gamma emitters, U/Pu, and ^{90}Sr
Drinking water		
Onsite	Monthly or quarterly	Alpha, beta, and tritium
Offsite	Semiannually	Alpha, beta, and tritium
Water treatment plants	Daily sampling Monthly analysis	Alpha, beta, and tritium
All locations	Annually	^{90}Sr
Wildlife	Annually	Alpha, beta, ^{137}Cs, and Tritium
Rainwater	Continuous sampling Monthly analysis	Alpha, beta, tritium, Gamma emitters, ^{238}Pu, ^{239}Pu, $^{89,90}Sr$, and ^{90}Sr
Soil and sediments	Annually	^{90}Sr, ^{238}Pu, ^{239}Pu, and gamma emitters
Vegetation		
F, H, S, and Z Areas Outside Burial Ground	Quarterly	Alpha, beta, tritium, Gamma emitters, and $^{89,90}Sr$
Seepage/retention basins Inside Burial Ground fence	Annually	

ent air quality was continuously monitored at five stations within the site boundary.

The Environmental Monitoring Section (EMS) of the Environmental and Health Protection Department (EHP) manages the SRS environmental monitoring program. Sample collection, radiochemical sample preparation, chemical analysis, radioanalytical counting, and data management activities are performed primarily by the EMS Environmental Sampling, Chemistry and Analysis, and Data Evaluation and Publications groups. In addition, commercial subcontractors provide support to EMS for several of these activities in the nonradiological monitoring program.

RADIOLOGICAL MONITORING PROGRAM

Program Goals

The EMS environmental monitoring program has two established goals. The first is to monitor the environment on and around SRS, and the second is to determine the types and quantities of radioactivity in the site's effluents and other environmental samples in order to assess their impact on the public and environment. EMS has established a routine radiological sampling and analysis program which is summarized in Table 1-1 (left) to achieve these goals.

Radioactivity Measuring Techniques

In its monitoring program, EMS measures three types of radiation—alpha particles, beta particles, and gamma rays (right). The type and energy of radiation emitted is used to identify specific radionuclides, although it is not always easy to accomplish this task. In most cases, the radionuclide of interest in a sample can usually be determined only after it has been concentrated and chemically separated from other radionuclides in the sample. However, it is possible to determine some gamma-emitting radionuclides with little or no sample preparation.

Measuring radioactivity in environmental samples presents a special problem. Since the radioactivity being measured in the sample is at very low levels, the sample counting rate is usually not much larger than the background (blank) counting rate. As a result, the difference between the two counting rates is very small (sometimes zero or negative) and causes a statistical error that is large relative to the measurement. The problem is compounded by the presence of naturally occurring radionuclides throughout the environment.

To overcome this problem, very sensitive counting instruments and extensive chemical separation, purification, and concentration techniques are required for accurate detection of radioactivity present in a sample. After the radioactivity in the sample is measured, the quantity or concentration of the radionuclide is usually expressed as the rate of disintegrations per unit mass or volume of sample (e.g., pCi/g, pCi/m^3, pCi/L).

Instrumentation

Measuring radioactivity in environmental samples requires instruments that can detect alpha, beta, or gamma radiation. Since no one detector is applicable

Principal Radiation Types Emitted by Radionuclides

Alpha

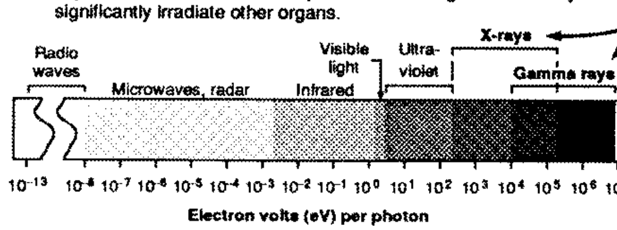
- Emitted from the nucleus as 2 protons and 2 neutrons.
- Low penetration: the mean range of a 5 MeV alpha particle in air is about 3.5 cm.
- For environmental dosimetry, particularly important for internal emitters, especially in the respiratory passages, on bone surfaces, and in red marrow. Their energy is concentrated along short paths and can deliver high localized doses to sensitive surface regions.

Beta

- Electron emitted from the nucleus.
- The range in air of the average-energy beta particle emitted from Sr-90 is 38 cm; in body tissue, the range is about 0.5 mm.
- For environmental dosimetry, of primary concern for internal emitters. Because of their relatively short range in tissue, beta particles principally irradiate the organs in which they originate.

Gamma and X-rays

- Electromagnetic radiation, emitted as energy packets called photons, like light and radio waves, but from a different energy region of the electromagnetic spectrum.
- Penetrating radiation: to absorb 95% of the gamma energy from a Co-60 source, 6 cm of lead, 10 cm of iron, or 33 cm of concrete would be needed.
- For environmental dosimetry, important both for internal and external exposure. Gamma emitters deposited in one organ of the body can significantly irradiate other organs.



in all situations, EMS uses four different types of instruments in the Counting Laboratory. Each instrument requires that the sample be prepared in a particular form, volume, and container. This set of conditions, together with the position of the sample container on the detector, is called the sample counting geometry. A fixed and reproducible sample geometry is very important for accurate analysis of radioactivity.

When radioactivity is being measured in the prepared sample, the instrument detects and counts the number of radioactive disintegrations per unit time. This procedure is referred to as "counting the sample." An instrument's detection efficiency depends on the type of sample, the sample geometry, and the detector specifications. An instrument's detection efficiency, for a given set of measurement conditions, is the fraction of the radioactive emissions from the sample that the instrument records during the counting interval. Because the instrument does not record all radioactive emissions from the sample, its detection efficiency is always less than 100%. Therefore, the instruments must be calibrated to relate the detector's efficiency to each detector and sample type.

A detection instrument is calibrated by using it to count a standard calibration source of radioactivity that is prepared in the same counting geometry as the sample. The calibration source contains known quantities of specific radionuclides and are traceable to the National Institute of Standards and Technology (NIST) or other international standards of measurement. For the given set of measurement conditions, the calibration determines the detection efficiency, which is computed as the measured counts for the calibration source divided by the theoretical number. The count for the unknown sample is then divided by the detection efficiency and by the sample

Table 1-2. Specific Radionuclide Analyses for Radioanalytical Instruments

Instrument Type (Detector)	Radioactivity Detected	Specific Analyses
Low-level alpha or beta counter (gas-flow proportional detector)	Various alpha and beta emitters	Gross alpha Nonvolatile beta $^{89,90}Sr$ ^{90}Sr U/Pu Am/Cm Chemical cesium
Liquid scintillation counter (LSC) (photomultiplier detector)	Low-energy beta emitters	Tritium ^{35}S ^{32}P ^{147}Pm ^{91}Y
Alpha spectroscopy system (silicon surface barrier detector)	Alpha emitters	Total uranium ^{238}Pu ^{239}Pu $^{241,243}Am$ $^{242,244}Cm$
Gamma spectroscopy system (high purity germanium detector HPGe)	Gamma emitters	^{7}Be ^{88}Y ^{141}Ce ^{40}K ^{95}Nb ^{144}Ce ^{51}Cr ^{103}Ru ^{212}Pb ^{57}Co ^{106}Ru ^{214}Pb ^{58}Co ^{124}Sb ^{226}Ra ^{60}Co ^{125}Sb ^{235}U ^{65}Zn ^{134}Cs ^{238}U ^{75}Se ^{137}Cs

volume to give the total rate of radioactive disintegrations per unit mass or volume of sample.

Listed below are the instruments and the associated sample geometry types used by EMS to measure radioactivity. Tables 1-1 through 1-8 in Vol. II provide the lower limits of detection for these instruments under a given set of measurement conditions.

- **Gas-flow Proportional Counters.** Used to detect alpha and nonvolatile beta emitters. The prepared sample is placed in a small stainless steel planchet for counting.
- **Liquid Scintillation Counters (LSC).** Used to detect low-energy beta emitters. The prepared sample is dissolved in a liquid scintillation cocktail and placed in a plastic scintillation counting vial for counting.
- **Silicon Surface Barrier Detectors.** Used for alpha-particle spectroscopy measurements, which help identify with specific alpha-emitting radionuclides. The prepared sample is electrodeposited on a small stainless steel planchet for counting.
- **High-Purity Germanium (HPGe) Detectors.** Used for gamma-ray spectroscopy measurements, which identify specific gamma-emitting radionuclides. The sample geometry is variable for each sample type and is discussed in the following section.

Table 1-2 (left) lists the instruments, detectors, and specific radionuclide determinations made with each instrument.

Two other types of instruments are not used in the Counting Laboratories but are used to measure radioactivity. Thermoluminescent dosimeters measure ambient gamma radiation and portable sodium iodide [NaI(Tl)] detectors are used in the field to scan samples for gamma-emitting radionuclides without bringing the samples into the laboratory.

Counting Geometries for Gamma-Emitting Radionuclide Analysis

The gamma spectroscopy system is the most versatile radioanalytical instrument because a variety of sample types can be measured, sometimes with little or no sample preparation. Geometries of the calibration standards are chosen to match closely the sample type and physical configuration. The goal in selecting counting geometries is to ensure the highest accuracy while providing the best counting efficiency with minimum sample preparation. It is not always practical, however, to have a counting geometry that exactly matches every sample type. After chemical preparation, many of the samples analyzed have densities similar to water; therefore, calibration standards are prepared as though they were water samples.

In 1989, EMS added the ion exchange column geometry and additional charcoal and air filter geometries for the HPGe detectors. Summarized below are standard counting geometries used to determine gamma-emitting radionuclides in environmental samples:

<u>Water Geometries</u>
Three geometries are used to count samples having densities similar to water. All water, wildlife, and vegetation samples are counted using one of the following geometries:

- 1 L of water in a 1-L polyethylene Marinelli beaker
- 500 mL of water in a 500-mL polyethylene bottle
- 200 mL of water in a 500-mL polyethylene bottle

<u>Air Filter Geometries</u>
Air filters used to collect air particulates are counted in one of the following geometries:

- 7.6-cm glass fiber filter in a Caplug® plastic holder
- 4.7-cm glass fiber filter in a Caplug® plastic holder

<u>Charcoal Geometries</u>
Charcoal collects airborne volatile iodines. Charcoal samples are counted in the following geometries:

- 1 L of charcoal in a 1-L polyethylene Marinelli beaker
- 3 × 2 in. triethylenediamine-impregnated charcoal cartridge
- 2.5-in. Mine Safety Appliance metal screw-on charcoal cartridge

<u>Soil Geometry</u>
Soil and sediment samples are counted using the following geometry:

- 500-mL of soil in a 500-mL polyethylene bottle

Ion Exchange Column Geometry

Large volume water and rainwater samples are counted in the following geometry:

- 1.5 x 4 in.-Teflon® column containing an ion exchange resin

In this geometry, the resin collects and concentrates both cations and anions present in the water as it passes through the column.

General Measurement Processes

Although the procedures used for specific analyses are complex, EMS follows general steps for environmental sample collection, preparation, and analysis. These steps are similar for all samples and are depicted in Figure 1-1 (below).

Table 1-1, Vol. II presents sample preparation data for specific media.

RADIOLOGICAL SAMPLE COLLECTION AND ANALYTICAL PROCEDURES

Ambient Gamma Radiation

Panasonic thermoluminescent dosimeters are used on and around SRS to measure and establish ambient gamma radiation levels during facility operations. In 1989, over 8,600 Panasonic thermoluminescent dosimeters (TLDs) were placed at stations in 454 locations within an 8,000-square-mile area of the site. This area includes stations onsite, at the site perimeter, and in nearby South Carolina and Georgia towns.

The Panasonic dosimeters used at SRS consist of two copper-activated calcium sulfate crystals ($CaSO_4$:Cu) and two thallium-activated lithium borate ($Li_2B_4O_7$:Tl) crystals. The dosimeters are annealed, placed in plastic holders, and stored inside heat-sealed plastic bags before they are taken to the field.

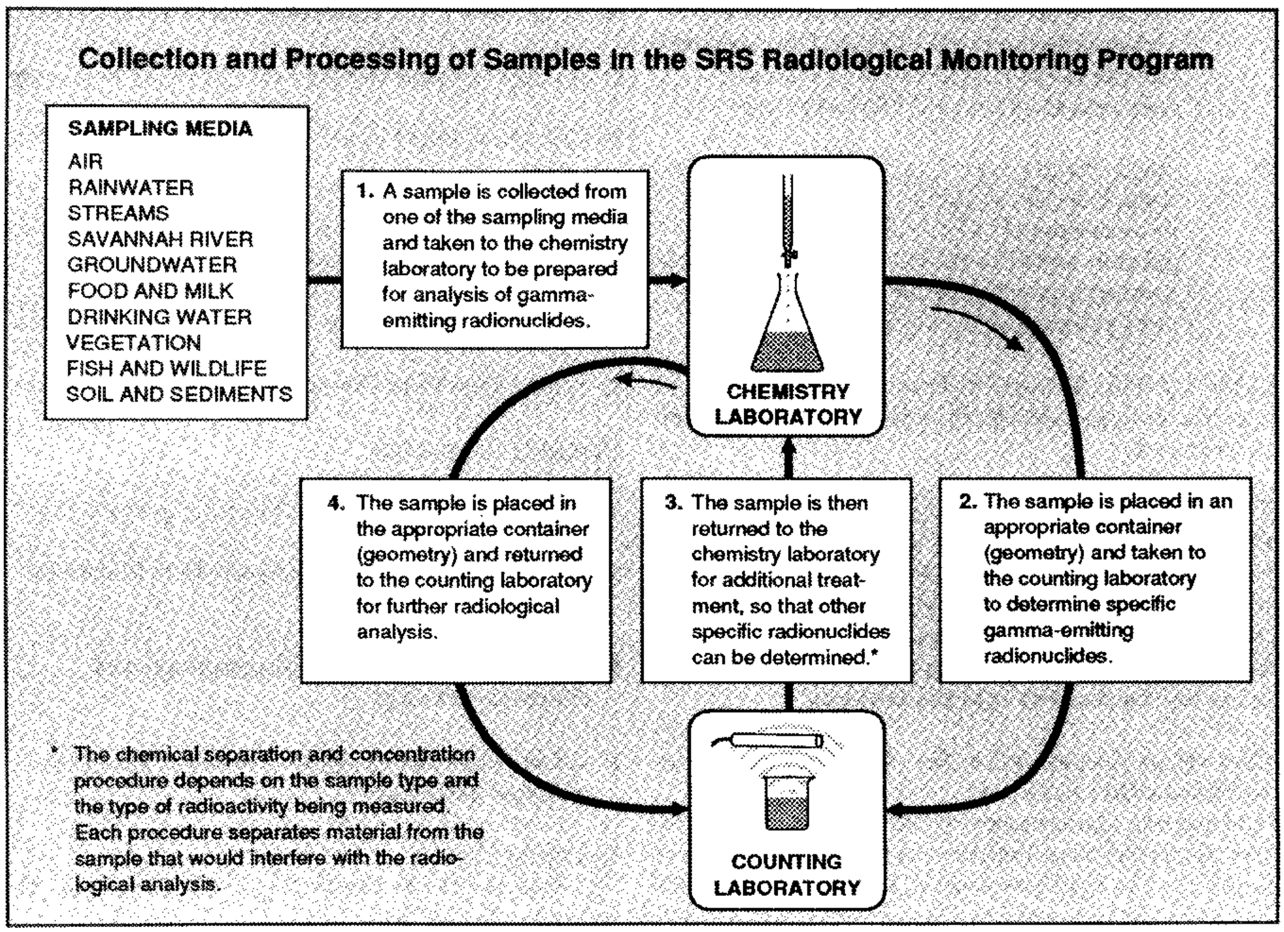


Figure 1-1. General measurement process for environmental samples

A set of control TLDs, some irradiated to a known exposure, accompanies the field badges to correct for systematic errors that occur when exposing and reading the dosimeters. Some nonirradiated control TLDs accompany the field badges and are kept in shielded storage for the complete 90-day field cycle to correct for dose during transportation to and from the field and any natural thermoluminescence exhibited by the crystals.

Five TLDs are normally placed side by side at each monitoring location to provide increased precision in the reported results. The field and control TLDs are collected and analyzed quarterly to determine ambient gamma radiation exposure. The exposure is measured by determining the average response of the two TLD calcium sulfate crystals. The results are reported in milliroentgens (mR) per day.

Air

Sample Collection

Air is sampled continuously at air monitoring stations located onsite, at the site perimeter, and within a 25- and 100-mile radius. At each monitoring station particulate airborne radioactivity is sampled by continuously drawing air through a 2-in.-diameter, high-efficiency glass fiber 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, iodine in air is sampled with charcoal cartridges that are located down-line from particulate filters. Tritium is collected using a desiccant at each sampling station. An air sampling station is presented in Figure 1-2 (following page).

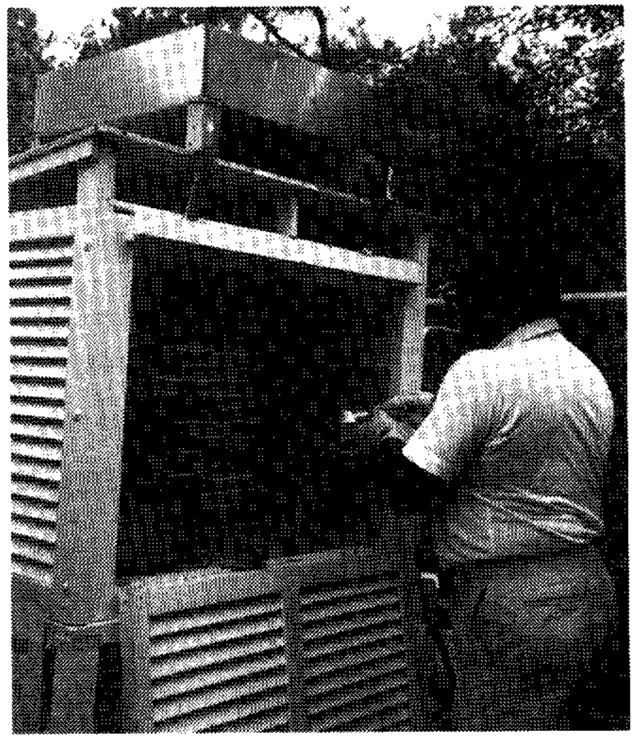
Sample filters and charcoal cartridges are collected weekly from 35 monitoring stations for analyses. Tritium desiccants are collected every two weeks.

Analytical Procedures

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

<u>Gross Alpha and Nonvolatile Beta</u>

Gross alpha- and nonvolatile beta-emitting radionuclides are analyzed simultaneously by a direct count of individual particulate filters using a gas-flow proportional counter. These results determine to what extent alpha-particle and beta-particle emitters are present in the sample, but do not identify specific radionuclides.



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

<u>Gamma-Emitting Radionuclides</u>

After the gross alpha and nonvolatile beta analysis, certain weekly filters are composited monthly by location. The composites are analyzed for gamma-emitting radionuclides using an HPGe detector. Air filters do not require chemical processing for this analysis.

After gamma analysis, each filter composite is cut into sections; one-half is used for plutonium analysis, 40% is used for strontium analysis, and 10% is composited quarterly and analyzed by Savannah River Laboratory (SRL) for specific radionuclides.

<u>Tritium</u>

Tritium oxide concentrations in air are determined from moisture that 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, followed 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 and are not analyzed.

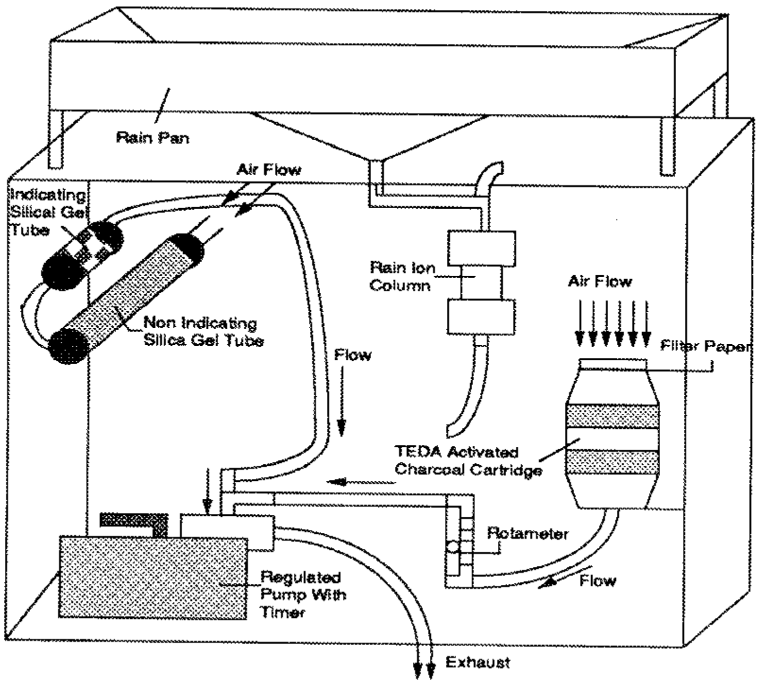


Figure 1-2. Air flow through an air monitoring station

In the analysis, free water is removed by distilling the non-indicating silica gel over low heat. The distillate consists of the total moisture content in the air sampled. The distillate is then suspended in a liquid scintillation cocktail, which contains a fluorescent solute in an organic solvent.

The concentration of tritium oxide in the moisture is determined with a liquid scintillation counter which detects the light 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 by multiplying the tritium oxide in the atmospheric moisture (pCi/g) with the absolute humidity [moisture in the air (g/m^3)] for the volume of air sampled.

Strontium

A single chemical separation method is used to measure total radioactive $^{89,90}Sr$. For $^{89,90}Sr$ analysis 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.

Barium is then removed from the strontium isotopes by precipitating barium chromate in an acetate buffer solution. It is necessary to remove the barium because it interferes as a fission product, and also with weight recovery.

The strontium carrier and the radionuclides of strontium are 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. The total radioactive strontium is calculated from a single count.

Plutonium

Air filters are dry ashed and leached with acid during preparation for ^{238}Pu and ^{239}Pu analysis. The solution is evaporated to dryness, dissolved in 7.2*N* nitric acid, and passed through an anion exchange resin, which extracts and holds the plutonium. The extracted plutonium is then removed from the resin column with an ammonium iodide–hydrochloric acid solution, evaporated to dryness and then redissolved in a sulfate medium. The plutonium and sulfate medium is then electrodeposited on a stainless steel disk and counted on a silicon surface barrier detector. This detector system detects the separate alpha emitters. The result is then used to verify the purity of the chemical separation and to quantify the amount of ^{238}Pu and ^{239}Pu present in the sample.

Iodine-131

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

Streams

Sample Collection

Site streams are sampled continuously using primarily two systems, paddlewheel samplers and Brailsford motor pumps. The paddlewheel sampler is a paddlewheel constructed of Lexan® suspended on two pontoons. The sampler is anchored in the stream. Samples are collected in small cups that are attached to the paddlewheel. Each cup samples approximately 0.5 mL of water. As the stream velocity rotates the paddlewheel, water is collected in the cups and emptied into a collection trough attached to the sampler. The water sample flows by gravity from the trough, through a connecting tube, and into a polyethylene jug attached to the sampler. A paddlewheel sampler diagram is presented in Figure 1-3 (below).

The Brailsford pump system consists of an all-plastic, variable speed, valveless piston that is driven by a Brailsford AG fractional watt motor. The pump samples stream water at a rate of 0.75 gal/day. Sampling jugs are emptied weekly.

Analytical Procedures

EMS monitors site streams for gross alpha, nonvolatile beta, gamma-emitting radionuclides, tritium, radioactive isotopes of strontium, and uranium/plutonium.

Gamma-Emitting Radionuclides

Gamma-emitting radionuclides are directly analyzed on an HPGe detector by counting a 500- or 1,000-mL sample aliquot.

Gross Alpha and Nonvolatile Beta

Gross alpha- and nonvolatile beta-emitting radionuclides are measured by a direct count of the residue remaining after evaporating a 1-L aliquot of the 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 radiation. The sample is then counted on a gas-flow proportional counter.

Tritium

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

Uranium/Plutonium

Alpha-emitting radionuclides are extracted from 1-L samples with triisooctylamine (TIOA) in xylene. Both uranium and plutonium are stripped from the TIOA organic layer with 0.1*N* hydrochloric acid (HCl). The acid solution is then evaporated to dryness to remove HCl, which damages the stainless steel planchet. The residue is dissolved in 8.0*N* nitric acid, transferred to a stainless steel planchet, and counted on a gas-flow proportional counter.

Strontium

Strontium-89,90 concentrations are measured by the same procedure used for air filter samples.

To determine ^{90}Sr concentrations, the beta emissions of $^{89,90}Sr$ are resolved by observing the decay of ^{89}Sr and ingrowth of ^{90}Y, a daughter product, with at least two counting intervals in the gas-flow proportional counter, over a 7- to 14-day period. It is then possible to use these results to derive two simultaneous equations that can be solved for the individual count rates of ^{89}Sr and ^{90}Sr.

Chemical Cesium

Chemical cesium analyses measure total concentration of cesium present in the sample with no radionuclide distinction. EMS discontinued chemical cesium analyses in 1989 because total cesium concentration could be calculated after measuring ^{134}Cs and ^{137}Cs in the gamma-emitting radionuclides analysis.

Savannah River

Sample Collection

The Savannah River is sampled continuously by paddlewheel samplers equipped with 26-L polyethylene jugs. River sampling jugs are emptied weekly.

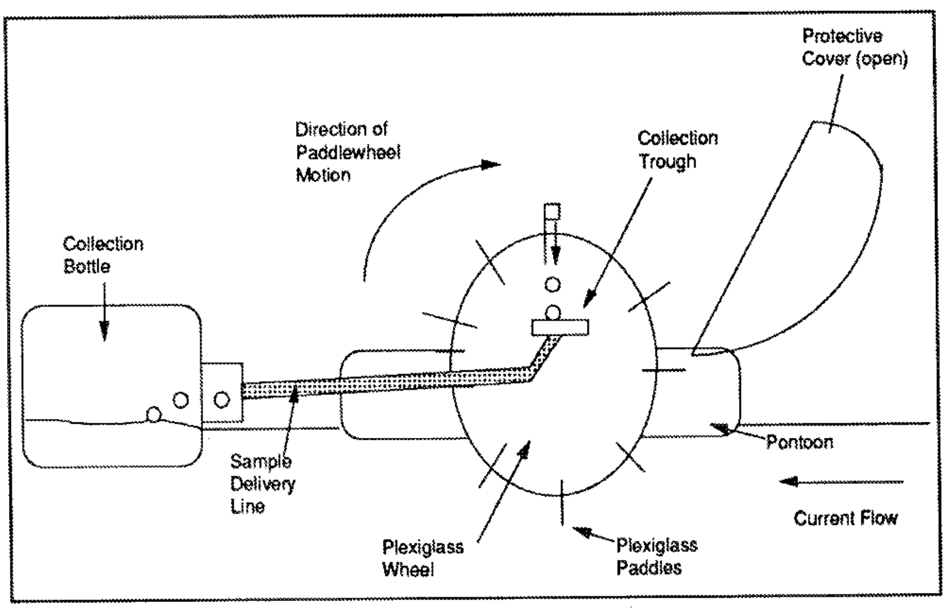
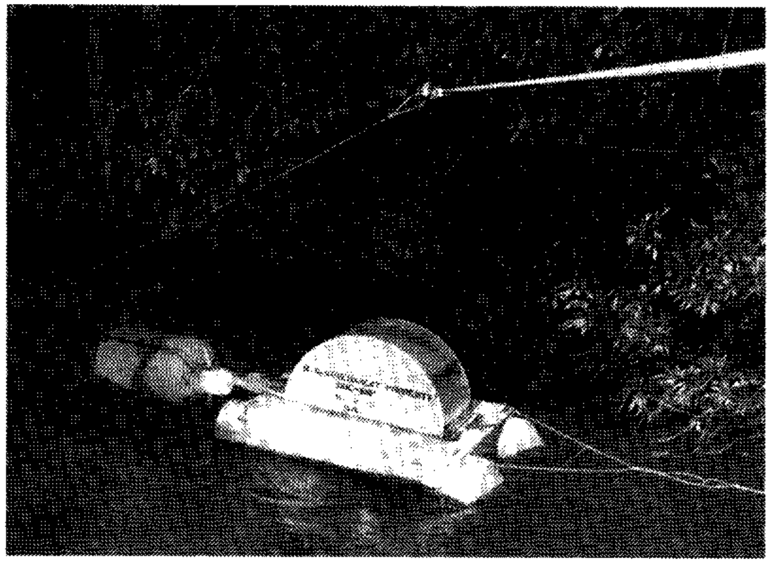


Figure 1-3. Paddlewheel sampler amd component diagram

In addition, the Savannah River Laboratory (SRL) samples two locations (upriver at River-2 and downriver at River 10) using a continuous sampler that typically processes 300 to 500 L of water per week. Samples are collected biweekly for low-level analysis of gamma-emitting radionuclides



EMS monitors SRS streams and the Savannah River with paddlewheel samplers

Analytical Procedures

Savannah River samples are analyzed to determine concentrations of gross alpha, nonvolatile beta, gamma-emitting radionuclides, tritium, and radioactive isotopes of strontium and plutonium.

Gamma-Emitting Radionuclides

Gamma-emitting radionuclides are measured by passing from 8 to 24 L of the sample through a cation-anion exchange column. This process increases analytical sensitivity by concentrating the radionuclides that are present. The column is then 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.

For the low-level analysis of gamma-emitting radionuclides performed by SRL, the river water sample is concentrated on an ion exchange material and counted for approximately 16 hours on an HPGe detector in a low-background counting facility. This sensitive procedure provides the capability to measure lower-levels of gamma-emitting radionuclides than the EMS procedure allows. The concentrations of ^{137}Cs presented in this report for Savannah River water at River-2 (Shell Bluff) and at River-10 (Highway 301) were measured by SRL.

Gross Alpha and Nonvolatile Beta

Gross alpha and nonvolatile beta-emitting radionuclides are determined using the same analytical procedure described for streams.

Tritium

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

Plutonium

Plutonium-238 and ^{239}Pu concentrations are determined from an aliquot of the eluate taken from the ion exchange column used for the gamma-emitting radionuclides analysis. The analytical procedure is the same as that used for air filters.

Strontium

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

Seepage Basins

A 2-L grab sample is collected quarterly from each seepage basin sampling location in F, H, P, C, and L Areas. Although F and H Area seepages basins are no longer used, samples from these locations will be collected until the basins are dry. These samples are analyzed for gross alpha, nonvolatile beta, tritium, strontium, uranium/plutonium, and gamma-emitting radionuclides following the same procedures as those used for stream and river samples.

Groundwater

Sample Collection

The 201 onsite groundwater monitoring wells in the radiological monitoring program are sampled quarterly, semiannually, or annually. Field measurements of alkalinity, specific conductance, depth to water, pH, and temperature are taken each quarter.

Water samples are collected from monitoring wells either by pumping or bailing. When pumping, the groundwater sample is collected after the pH and conductivity have stabilized and stagnant water has been purged from the well. Bailed samples are collected using one-L stainless steel bails. Each well has an assigned bailer to prevent cross-contamination. The normal sample volume collected for analysis is 2 L.

Monitoring wells are constructed according to SRS standard [DPSOP 254] methods and regulations. Bentonite and grout seals prevent mixing of groundwater within the screened zone with other groundwater. Caps or seals prevent introduction of atmospheric water into the well. Figure 1-4 (right) details a cross-section of a typical monitoring well.

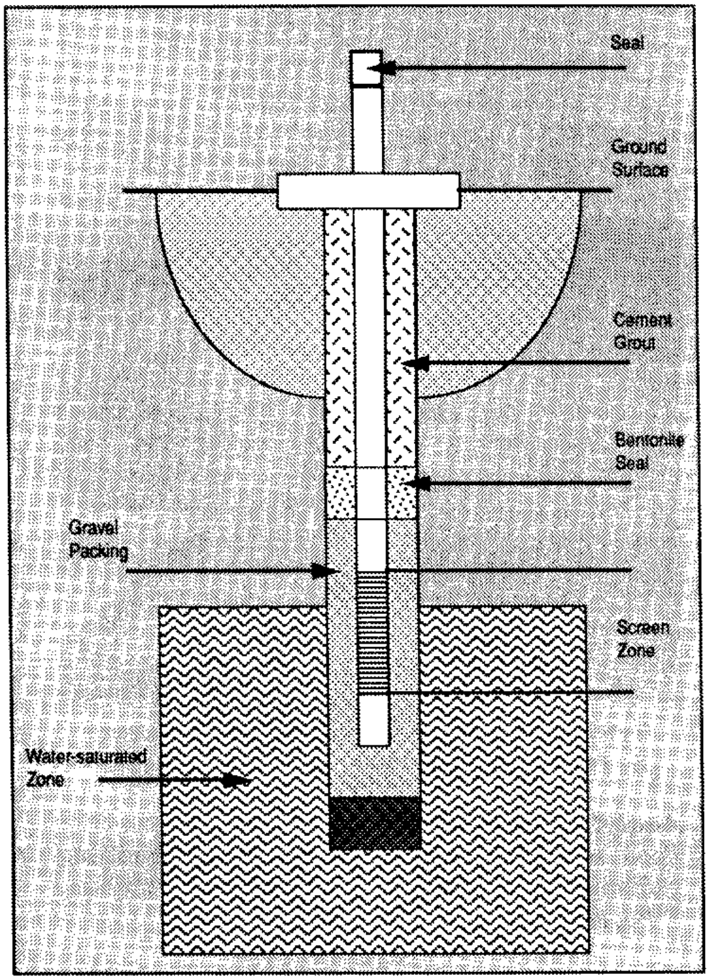


Figure 1-4. Components of a monitoring well

Analytical Procedures
The EMS Chemistry and Counting Laboratories prepare and analyze groundwater samples that are included in the radiological monitoring program. Analytical procedures for gross alpha, nonvolatile beta, tritium, gamma-emitting radionuclides, and ^{90}Sr analyses are the same as those described for stream and river samples.

Milk

Sample Collection
One-half gallon of fresh raw milk is collected from each of five local dairies and from a major distributor every two weeks and analyzed for ^{131}I, ^{137}Cs, and tritium. An additional one-half gallon is collected from each location quarterly and analyzed for ^{90}Sr.

Analytical Procedures

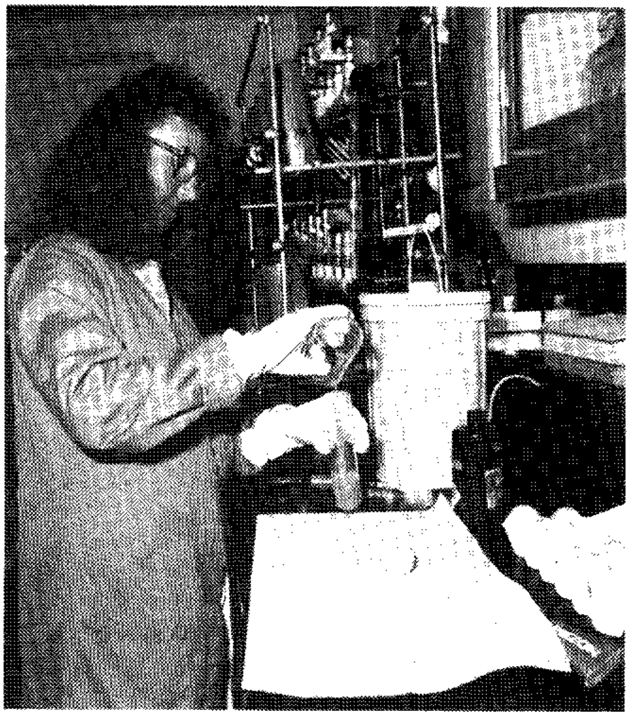
Iodine-131 and Cesium-137
Concentrations of ^{131}I and ^{137}Cs are determined by direct count of a 1-L sample aliquot on an HPGe detector.

Strontium
A cation exchange resin is used to separate strontium and yttrium from the milk as chlorides. Strontium-90 is determined by evaporating the sample to dryness and dissolving the residue in 0.08*N* hydrochloric acid. To begin the ^{90}Y ingrowth, ^{90}Y is removed from the strontium using 2-di-ethylhexyl phosphoric acid (HDEHP) in toluene. Equilibrium of ^{90}Y is approached over a 15-day period and the short-lived ^{90}Y daughter is removed 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
Two 5-mL aliquots of milk, distilled to reduce quenching interferences, are analyzed with a liquid scintillation counter to determine the concentration of tritium oxide.

Food

Sample Collection
Local foods, including fruits, grains, corn, collards, eggs, chicken, beef, and pork, are obtained from farms located within a 25-mile radius of SRS. Food samples are collected annually except for eggs, which are collected quarterly.



Tritium in eggs is measured in free water by freeze-drying a portion of the sample

Analytical Procedures
Food samples are analyzed for gamma-emitting radionuclides, tritium, ^{90}Sr, uranium/plutonium, ^{238}Pu, and ^{239}Pu.

With the exception of grains, all foods are prepared as though for human consumption; 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
Gamma-emitting radionuclides are determined by a direct count of the acid solution on an HPGe detector.

Tritium
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.

Strontium
The procedure for ^{90}Sr analysis is the same one described for stream samples.

Uranium/Plutonium
Uranium/plutonium is measured in foods following the same procedure described for stream samples.

Plutonium
Concentrations of ^{238}Pu and ^{239}Pu are determined by the same procedure described for river samples.

Drinking Water

Drinking water samples are collected at onsite sampling locations and in communities surrounding SRS. Samples are collected from faucets and drinking fountains. Some onsite samples are collected monthly, while others are collected quarterly. Offsite samples are collected semiannually except from water treatment plants, where raw and finished drinking water samples are collected daily, composited, and analyzed monthly. All drinking water samples are analyzed for gross alpha, nonvolatile beta, tritium. Once a year, additional samples are collected for ^{90}Sr analysis. Analytical procedures for drinking water are the same as those used for stream and river samples.

Wildlife

Sample Collection
The collection of fish, furbearers, and waterfowl for analysis 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-013-89, EMS was authorized to collect wildlife specimens during 1989.

Fish
Fish are caught in traps or by hook and line. Whole fish are analyzed for gamma-emitting radionuclides on an HPGe detector. 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.-stainless steel planchet and counted in a gas-flow proportional counter.

Deer and Hogs
Deer and hogs are monitored annually through onsite controlled hunts during the November and December hunting season. EMS performs field analyses of ^{137}Cs on deer and hogs at the hunt site with portable 2 × 2-in. sodium iodide [NaI(Tl)] detectors. The portable detectors are calibrated so that ^{137}Cs concentrations in flesh may be calculated from the field measurements.

The accuracy of the calibrations is verified by laboratory analysis of approximately 5–10% of the deer and hog samples. Muscle tissue and thyroids are collected randomly during each hunt and analyzed for ^{137}Cs and ^{131}I on an HPGe detector.

The samples are also analyzed for ^{90}Sr and tritium using the same analytical procedures described for stream samples and for food samples, respectively.

Furbearers

Furbearing animals, including raccoons, opossums, foxes, and beavers are trapped. All animals except beavers are analyzed for gamma-emitting radionuclides by counting a portion of the animal tissue on an HPGe detector. Since beavers are not expected to leave the site, they are monitored in the field using a portable NaI(Tl) detector.

Ducks

Ducks such as coots, buffleheads, ruddys, scaups, and mallards are trapped and a portion of the tissue is counted for gamma-emitting radionuclides using an HPGe detector.

Turkeys

Turkeys on SRS are trapped live and ^{137}Cs concentrations are monitored using a portable 2 × 2-in. NaI(Tl) detector.

Rainwater

Sample Collection

Radioactivity in rainwater is determined from monthly rainfall samples. Rainwater is collected in 2-ft-square metal pans located on top of air monitoring 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.

Analytical Procedures

Rainwater samples are analyzed for gross alpha, nonvolatile beta, gamma-emitting radionuclides, tritium, ^{89,90}Sr, ^{90}Sr, ^{238}Pu, and ^{239}Pu.

Gross alpha, nonvolatile beta, plutonium, and strontium analyses are performed on the eluate from the ion exchange column after determining the gamma-emitting radionuclides. The analytical procedures for these analyses are the same as those described for stream and river samples.

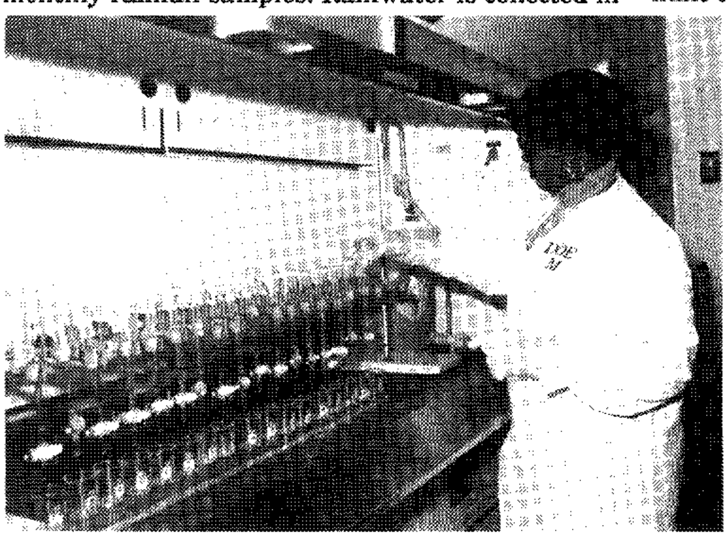
Gamma-Emitting Radionuclides

The ion exchange columns are counted directly for gamma-emitting radionuclides on an HPGe detector. The column is then eluted and the eluate is used for subsequent analyses.

Tritium

Since tritium does not collect on the rain ion exchange column, tritium concentrations are determined by analyzing the rainwater collected in the jugs by liquid scintillation counting.

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).



Sample preparation before performing analysis for beta-emitting radionuclides

Soil and Sediment

Sample Collection

Soil samples are collected annually from each of the four quadrants around F and H Area (Separations Areas), around the Defense Waste Processing Facility (DWPF) in S Area and the Saltstone Facility in Z Area, at the site perimeter, and at the 100-mile-radius locations. Soil samples are also collected during special monitoring surveys. Ten soil plugs, each 8 cm deep, are taken 30 cm apart in a straight line at each sampling location.

EMS collects sediment samples 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.

Analytical Procedures
After collection, the 10 soil cores are combined into composites by location. The composited soil samples and sediment samples are dried, sieved, and pulverized before being analyzed for gamma-emitting radionuclides, ^{90}Sr, ^{238}Pu, and ^{239}Pu.

Gamma-Emitting Radionuclides
For analysis of gamma-emitting radionuclides, an aliquot of the prepared soil is placed in a 500-mL plastic bottle and counted on an HPGe detector.

Strontium
For ^{90}Sr analysis, 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). The sample is then analyzed using the same method described for stream samples.

Plutonium
Soil and sediment samples analyzed for ^{238}Pu and ^{239}Pu follow the procedure as described for air filters.

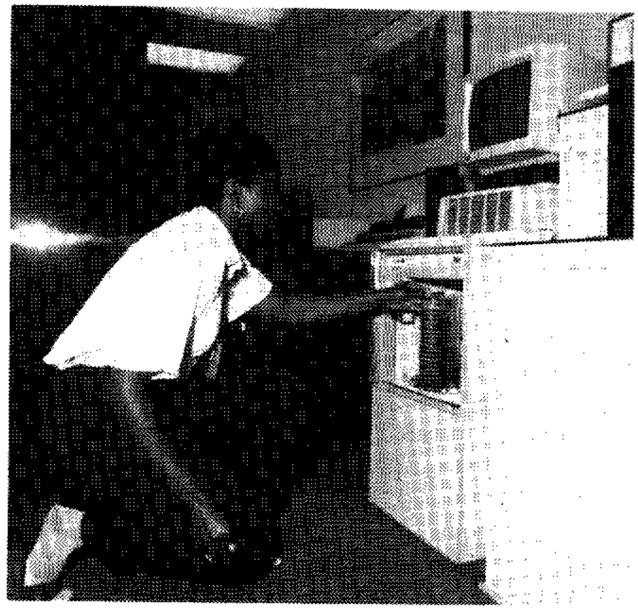
Vegetation

Sample Collection
EMS collects vegetation samples onsite, at the site perimeter, and within a 25- and 100-mile radius of SRS. Vegetation samples are collected annually inside the Burial Ground fence and at retention/seepage basins, while samples are collected quarterly at all other locations.

Analytical Procedures
Vegetation samples are analyzed for gross alpha, nonvolatile beta, gamma-emitting radionuclides, tritium, ^{89,90}Sr.

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

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



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

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

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

INTERPRETATION OF RADIOLOGICAL MONITORING DATA

The final product of an efficient and thorough monitoring program is a report containing reliable data. This section describes how EMS reports data, the significance of the data, and how to interpret the reported values.

Overview

Reporting radiological measurement data is subject to the following criteria:

- Measurement results must be reported with the proper dimensions (i.e., units) and the appropriate number of significant figures. Additional specifications, such as how the sample was collected or how it was composited, may sometimes be necessary to understand and interpret the results.

- A reported value must include an assessment of its uncertainty. The uncertainty value must be based on as complete an assessment as possible, taking into account errors such as random errors, systematic errors, rounding errors, or calibration errors, so that sufficient information is conveyed and its meaning is unambiguous. Both precision and accuracy of the results should be addressed.

- The minimum achievable detection limit under a given set of practical conditions should be estimated and reported for low-level environmental measurements. The recommended expression for this concept is the estimated minimum detectable concentration or "MDC."

A complete discussion of the theoretical basis and procedures for data reduction and interpretation of environmental monitoring measurements is beyond the scope of this report. Detailed discussion of these topics can be found in the following references:

Bevington, P. R., *Data Reduction and Error Analysis for the Physical Sciences*, McGraw Hill Book Co., N.Y. (1969).

National Council on Radiation Protection and Measurements, Environmental Radiation Measurements, NCRP Report No. 50 (1988).

Natrella, M. G., *Experimental Statistics, National Institute of Standards and Technology*, Handbook 91, Wiley & Sons, N.Y. (1966).

Watson, J. E., Chairman, *Upgrading Environmental Radiation Data*, Health Physics Society Committee Report HPSR-1 (1980), EPA 520/1-80-012 (August 1980).

Interpretation of Measured Values

Nomenclature

Text in Volume I and data tables in Volume II refer to radionuclides, using radiochemical nomenclature. Appendix D interprets the radiochemical nomenclature used in this report.

Presentation of Units

The data in this report are presented in terms of the most practical units of measurement for each quantity being measured. Most radiological data are presented as unit activity per unit volume or mass [e.g., pCi/L (picocuries per liter) or pCi/g (picocuries per gram)]. Although picocurie (pCi) is the most common activity unit used in this report; in some cases, data are presented in fCi (femtocuries) or aCi (attocuries). Fractions and multiples of units, as well as conversion tables, are shown on the inside cover of Volume I of this report.

Table 1-1 in Volume II shows typical sample sizes and aliquots. The dimensional units and other necessary information for the reported values are provided in the data tables or within the Volume I text. Statistical uncertainties are not presented with data reported in Volume I except in cases where certain measurements are characteristically subject to large uncertainties (e.g., wildlife monitoring).

Significant Figures

Most data tables in Volume II of this report are transferred from a computer database. These data are either entered manually or directly entered into the database from the radioanalytical instruments. The database software was not designed to detect and report the correct number of significant figures for the data. Therefore, in some cases, rounding errors result, and the significant figures reported for the result and the uncertainty are inconsistent. EMS is currently acquiring a new computer and developing software to avoid this discrepancy.

Radionuclides Reported

This report follows practice, common in environmental monitoring literature, of reporting gross alpha and nonvolatile beta measurements. Samples prepared for gross alpha and nonvolatile beta measurements usually contain an unknown radionuclide mixture, and these measurements provide no information on the identity of the radionuclides present in the sample. An arbitrary choice must be made in selecting a standard for calibrating the counting system and determining the conversion of sample counting rates to disintegration rates. The calculated disintegration rate refers only to the concentration of the radionuclide used to calibrate the instrument that would result in the observed counting rate. The data in this report were calculated using ^{210}Po for the gross alpha calibration and ^{90}Sr for the nonvolatile beta calibration.

Gross activity measurements are useful in indicating whether additional radionuclide-specific measurements should be made and in showing data trends. Care must be taken in interpreting gross alpha and nonvolatile beta measurements. Conclusions should not be made from gross measurements on dosimetric significance or on environmental behavior and movement of the unknown radionuclides in these samples.

Many data tables quote activities of some naturally occurring radionuclides and radionuclides that may arise from cosmic processes or fallout from previous nuclear weapons testing (e.g., ^{40}K and ^{7}Be). The fact that these activities are listed in this report does not necessarily imply that these radionuclides are released into the environment by SRS operations.

EMS measures concentrations of other specific radionuclides in the environment that are possibly contributed from SRS operations. Some of these analyses include tritium, ^{137}Cs, strontium, plutonium, and other gamma-emitting radionuclides.

Measurement Difficulties

Environmental samples often contain very low levels of radioactivity, and the ratio of the sample count to the background count (i.e., radioactivity count taken with no sample present) is consequently small. Since all measurements involve statistical variations, the net sample activity is sometimes negative (i.e., less than zero) after the blank has been subtracted. All of the counting instruments, except the gamma analysis system, produce a net sample count, even if the result is small or less than zero. Although negative results have no physical meaning, the data are still statistically valid, and reported and figured into yearly and composite averages.

The gamma analysis system will produce a net sample count only if the value is above the instrument's theoretical detection limit and is not negative or accompanied by a large uncertainty. However, if these conditions are not met, the gamma analysis system calculates an estimated LLD. This difference is reflected in data tables that report the concentrations of gamma-emitting radionuclides. When the sample activity is not available for the gamma-emitting radionuclide, the concentration is reported as zero; and the LLD is reported in the uncertainty column. In this case, the LLD should not be interpreted as a plus or minus uncertainty. If activity is present, it is probably less than the reported LLD.

Interpretation of Uncertainties

The absolute error or uncertainty of a reported value (the deviation from the true value) cannot be known because the true value is not known exactly. However, the limits to this uncertainty can be inferred and estimated from the measurement process itself. This uncertainty assessment includes an incumbent risk of being incorrect, which is called the confidence limit. The absolute uncertainty of a measurement is composed of illegitimate (gross), random, and systematic errors.

Illegitimate Errors

Illegitimate or gross errors are described as those errors that are so serious that to obtain an adequate measurement, a new sample must be collected or new measurement must be performed. Such errors are normally easily recognized and corrected.

Random Errors

Random errors affect the precision of a measured value (i.e., the reproducibility of a set of successive, independent measurements). These errors arise from random variations at all stages of the sample collection, sample preparation, and measurement process. The overall random uncertainty of a measurement is assessed by calculating the standard deviation of the mean (average) of numerous replicate determinations. However, replicate measurements of environmental samples are uncommon and usually not feasible due to time and cost constraints.

Counting data follow the Poisson distribution; thus, the standard deviation can be estimated from the number of counts obtained for a single measurement. This counting error takes into consideration only uncertainties arising from the random nature of the radiodecay process itself. Ideally, random uncertainties arising from every major step or component of the measurement process should be independently assessed. This approach, however, is usually not feasible and it is uncommon for reporting environmental data. EMS sampling and analytical procedures are designed to minimize the random errors that are not included in the counting error assessment.

Systematic Errors

Systematic errors affect the accuracy of a measured value (i.e., the proximity to the true value). These errors arise from bias introduced by improperly calibrated instruments, errors in reagents and calibration standards, and imperfect analytical technique and experimental design. This bias affects each measurement in the same way. The deviation from the true value is always of the same magnitude and direction. Thus, systematic errors cannot be estimated from the data themselves by calculating averages and standard deviations of replicate measurements. Systematic errors may also arise from random or stochastic processes that cannot be (or are not) assessed by statistical methods. Assessing systematic uncertainties is complex and rather subjective. Therefore, systematic errors are usually not reported in the scientific literature; nor are they included in the uncertainties for measured values in this report.

Systematic errors, and thus the accuracy of the measurement process, may be estimated by measuring standards that have reasonable well known concentrations. EMS participates in EPA and DOE laboratory intercomparison programs to ensure the accuracy of the reported data. These efforts are discussed in Chapter 2 of this report. To further minimize systematic errors, EMS uses defined quality assurance/quality control procedures, conducts periodic training sessions for all analysts, performs frequent reviews of experimental designs and measurement procedures, and uses standard reference materials traceable to NIST or other international standards of measurements for all calibrations.

Uncertainties quoted in this report for individual measurements such as the maximum or minimum in a range of measurements are calculated using the Poisson assumptions and are expressed at the 95% confidence limit. The counting errors shown in the data tables in Volume II are labeled "CT ERR 2σ". The uncertainties quoted for mean values are the standard deviations of the mean expressed at the 95% confidence limit. These are labeled "2 Std Dev" in the data tables. The standard deviation of the mean is not reported when the mean is calculated from an insufficient number of determinations (<5 measurements) to give a valid standard deviation. The total absolute uncertainties, which includes random and systematic errors, are higher than the counting uncertainties reported.

Interpretation of Lower Limits of Detection

Numerous expressions and definitions of "detection limits" are frequently encountered. Their meanings are often ambiguous and incorrectly interpreted. The terms "lower limit of detection" (LLD), and "minimum detectable concentration" (MDC) are used interchangeably in this report.

Detection limits are useful criteria for selecting alternative measurement procedures. Detection limits may also serve as guides set by regulatory bodies for establishing minimum acceptable detection capabilities for a given analysis. Any calculation of detection limits is, at best, only an estimate. Detection limits serve only as guideposts, and not as absolute levels of activity that can, or cannot, be detected by a counting system or analytical method. It is common to report measurements which are less than the theoretical LLD.

The LLD corresponds to an *a priori* limit above which the level of activity is reliably estimated using a given instrument, method, and sample type. It depends not only on the instrument and sample characteristics, but also on many other specific factors involved in the measurement process such as those listed below:

- length of the counting interval
- chemical yield
- sample geometry and density
- decay time
- other radionuclides present in the sample

Since all of these factors can influence the value of the LLD, it must be emphasized that the MDC or LLD is not a limit below which radioactivity is undetectable. Rather, under a given set of practical conditions, it is a limit above which there is a high probability of detecting radioactivity that is present in a sample and a low probability of reporting a false positive.

The LLD values in this report were calculated with the formula listed below [WA80]:

$$LLD = K(k^2 + 2k\sqrt{2s}) = K(2.71 + 4.65s)$$

where:

k = 1.645 (95% confidence level)
s = standard deviation of the background count
K = proportionality constant which relates counts to the activity concentration for a given set of measurement conditions

Tables 1-2 through 1-8, of Volume II, list estimated lower limits of detection for each instrument and various sample types under typical measurement conditions.

NONRADIOLOGICAL MONITORING PROGRAM

Nonradiological surveillance at SRS began in 1951 with monitoring water quality on the Savannah River. Since that time, the nonradiological monitoring program has expanded to include monitoring chemicals, metals, and organics in SRS liquid effluents, site streams, the Savannah River, groundwater, drinking water, air, and fish.

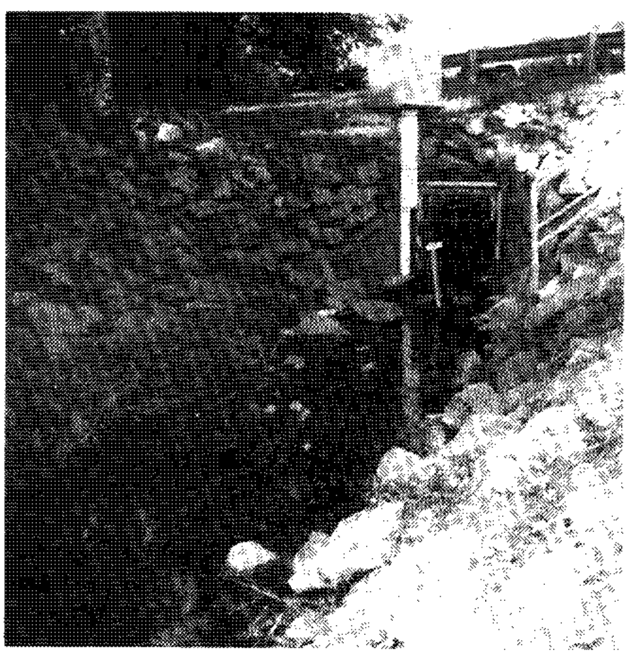
In recent years, the nonradiological monitoring program has grown significantly. In 1980, just over 5,000 analyses were performed on 1,000 samples. In 1989, over 231,000 laboratory analyses were performed on over 10,000 samples.

Table 1-3 on the facing page lists the general nonradiological sampling and analysis schedule for specific environmental media.

NONRADIOLOGICAL SAMPLE COLLECTION AND ANALYTICAL PROCEDURES

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). Particulate matter less than 10 microns (PM_{10}) is monitored every six days over a 24-hour period.



Typical NPDES outfall on SRS

Measurements are made using five NO_x analyzers, three SO_2 analyzers, two O_3 analyzers, and six PM_{10} samplers. One monitoring station contains two adjacent PM_{10} samplers for quality assurance purposes. Sampling and analyses are performed in accordance with EPA requirements and South Carolina Department of Health and Environmental Control (SCDHEC) guidelines (40 CFR 58, Appendix B).

NPDES Outfall Locations

Sample Collection
SRS wastewater effluents (outfalls), regulated by SCDHEC under National Pollutant Discharge Elimination System (NPDES) permits, are sampled according to procedures consistent with EPA and SCDHEC methods (40 CFR Chapter 1, Part 136). The sampling frequency varies with the outfall location and the chemicals or properties being measured.

Analytical Procedures
The types of analyses performed also vary with each permitted outfall. However, most outfall samples are routinely analyzed for temperature, pH, total nonfilterable residue, and oil and grease. Certain outfall samples are also analyzed for metals, fecal coliform, nutrients, pesticides, herbicides, and organic chemicals. All analyses are performed using accepted procedures in 40 CFR Chapter 1, Part 136.

Offsite laboratories perform all NPDES analyses, except fecal coliform and field measurements (flow, temperature, and pH). The fecal coliform analyses are performed onsite by the D-Area laboratory to ensure that analyses begin within six hours of sample collection as required by EPA-approved methods [EPA79]. The D-Area laboratory and offsite laboratories analyzing NPDES samples are certified by SCDHEC.

Streams and River

Sample Collection
Six site streams are sampled continuously by paddlewheel samplers for metal analyses. EMS collects the water samples weekly and preserves them according to EPA procedure [EPA79]. The samples are composited quarterly for metals analyses only.

EMS collects grab samples from seven stream locations and two Savannah River locations monthly for nonmetals analyses. These samples are preserved according the EPA procedures. Composited samples are not used for nonmetals analyses because of short

Table 1-3. General Nonradiological Sampling and Analysis Schedule

Environmental medium	Frequency	Analysis
Air	Continuously	SO_2, NO_x, and O_3
	Six-day intervals	PM-10[a]
Liquid effluents (NPDES)	Varies with permit requirements	Varies with permit requirements
Savannah River	Monthly sampling Quarterly analysis	Metals
	Monthly	Chlorides, Total dissolved solids
	Weekly	Temperature, pH, dissolved oxygen, conductivity, and fecal coliform
	Annually	Pesticides and herbicides
Streams	Weekly sampling Quarterly analysis	Metals
	Monthly	Chlorides, TDS, organics, pesticides, herbicides, temperature, pH, dissolved oxygen, and conductivity
Groundwater	Quarterly	Temperature, pH, depth to water, and conductivity
	Quarterly, Semiannually, or Annually	Site-specific contaminants
	Biannually	Comprehensive chemical analysis
Drinking water		
Primary systems	Annually	Chemicals, metals, and organics
Smaller systems	Varies with use	
All systems	Varies with use	Total coliform and residual chlorine
Soil and sediments	Annually	Pesticides and herbicides

[a]Particulate matter less than 10 microns.

EPA-recommended holding times and restrictive preservation requirements.

Analytical Procedures
Site streams and the Savannah River are monitored for chemicals, metals, and physical and biological properties. All analyses are performed in accordance with EPA-approved methods [EPA79]. Table 1-4 lists some analytical methods used for analyses.

Field measurements of pH, dissolved oxygen, conductivity, and temperature are taken weekly at all river sampling locations and monthly at all stream sampling locations.

Table 1-4
Chemical Analyses and Methods for Stream and River Samples

Analysis	Method[a]
Non-Metals	
Alkalinity	EPA 310.1
Ammonia - Nitrogen	EPA 350.1
Chemical Oxygen Demand	EPA 410.2
Chloride	EPA 325.3
Specific Conductance	EPA 120.1
Nitrate-Nitrite-Nitrogen	EPA 353.2
pH	EPA 150.1
Phosphate - Phosphorus	EPA 365.1
Sulfate	EPA 375.4
Temperature -Thermometric	EPA 170.1
Total Solids, Volatile Solids, Fixed Residue, Suspended Solids, Total Dissolved Solids	EPA 160
Turbidity - Nephelometric	EPA 180.1
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 (by calculation)	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.

Groundwater

Sample Collection
Groundwater is sampled quarterly, semiannually, or annually using sampling procedures consistent with both EPA and SCDHEC methods [EPA79]. A company under contract to SRS samples the 1,039 groundwater monitoring wells in the nonradiological monitoring program.

The structure of the monitoring wells and the procedures for extracting samples from the wells are described in the "Radiological Sample Collection and Analytical Procedures" section for groundwater on pages 34 and 35.

EPA-recommended preservatives and sample-handling techniques are used during sample storage and transportation to both onsite and offsite certified analytical laboratories that analyze the samples. Bottles and coolers are tested according the U.S. Department of Transportation standards (49 CFR Part 172) and approved for shipping. EMS screens potentially radioactive samples for radioactivity before shipment to offsite laboratories.

Analytical Procedures
Groundwater samples collected in the nonradiological monitoring program are analyzed for nonradioactive constituents and certain radioactive constituents using procedures consistent with EPA-recommended methods [EPA79, SW86]. A representative list of analyses performed and the corresponding EPA methods is given in Table 1-5 (facing page).

Envirodyne Engineers, Inc. (EE) of St. Louis, Missouri, performed analyses on samples collected during the first quarter 1989. MetaTRACE, Inc. (MT) of St. Louis, Missouri, and General Engineering Laboratories (GE) of Charleston, South Carolina, performed these analyses for the remaining quarters in 1989. Teledyne Isotopes (TI) of Westwood, New Jersey, performed specific radionuclide analyses in 1989 using industry accepted or EPA-approved procedures. All laboratories are certified by SCDHEC.

Field measurements of alkalinity, specific conductance, depth to water, pH, and temperature are taken quarterly.

Table 1-5. Chemical Analyses and Methods for Groundwater Samples

Analyte	Method[a]		
	General Engineering	metaTRACE	Environdyne Engineers
Alkalinity	-	310.1	310.1
Antimony	7041	204.2	200 (ICP)[b]
Arsenic	7060	7060	200 (AA-flameless)[c]
Chloride	300.1	300	300
Chromium	6010	200.7 (ICP)	200 (ICP)
Cyanide	9012	335.2	335.2
2,4-Dichlorophenoxyacetic acid	8150	509B	615
Endrin	8080	608	608
Fluoride	340.1	300	340.1
Gross alpha	900	900	900[d]
Iron	6010	200.7 (ICP)	200 (ICP)
Lead	7421	7421	200 (ICP)
Lindane	8080	608	608
Mercury	7470	245.1	245.1
Metals[e]	6010	200.7 (ICP)	200 (ICP)
Methoxychlor	8080	608	608
Nitrate (as Nitrogen)	353.3	352.1	353.3
Nitrite (as Nitrogen)	300.1	300	353.3
Nonvolatile beta	900	900	900[d]
pH	150.1	150.1	150.1
Phenols	420.1	420.1	420.2
Potassium	6010	200.7 (ICP)	200 (ICP)
Selenium	7740	7740	200 (AA-flameless)
Silica	6010	200.7 (ICP)	370.1
Silver	6010	200.7 (ICP)	200 (AA-flameless)
Silvex	8150	509B	615
Specific conductance	120.1	120.1	120.1
Sulfate	300.1	300	300
Total dissolved solids	160.1	160.2	160.1
Total organic carbon	9060	415.1	415.1
Total organic halogens	9020	450.1	450.1
Total phosphates	365.2	365.4	365.1
Total radium	900.1	903	900[d]
Toxaphene	8080	608	608
Tritium	906	9763M[f]	-
Volatile organics	8240	624	601

[a] The methods listed are summary methods. Laboratories may use more than one method for a parameter. Methods are based on the following references, which are listed in the back matter of Volume I: [EPA79], [EPA82], [LA83], and [SW86].

[b] ICP = Inductively coupled plasma.

[c] AA-flameless = Atomic absorption spectroscopy-flameless.

[d] These analyses were conducted by Radiation Measurements, Inc., under subcontract to Envirodyne Engineers, Inc.

[e] Metals are determined by separate analyses but the same method may be used. Metals determined using these methods include aluminum, barium, beryllium, cadmium, calcium, magnesium, lithium, manganese, nickel, sodium, uranium, vanadium, and zinc.

[f] In-house method based on the Los Alamos *Manual of Methods for Radiobioassay.*

Table 1-6
Groundwater Monitoring
Comprehensive Analyses

Arsenic	Nonvolatile beta
Barium	pH
Calcium	Phenols
Cadmium	Potassium
Chloride	Selenium
Chromium	Silica
Copper	Silver
Fluoride	Sodium
Gross alpha	Specific conductance
Iron	Sulfate
Lead	Total Dissolve Solids
Mercury	Total Organic Carbon
Magnesium	Total Radium
Manganese	Total Organic Halogens
Nickel	Total Phosphates
Nitrate	Tritium

New wells that have not been sampled and are added to the nonradiological monitoring program receive four consecutive quarters of comprehensive analyses, which are listed in Table 1-6 (above). In addition, all wells in the nonradiological program receive the comprehensive analyses every two years.

The frequency of additional sampling and analysis is determined by the results of the comprehensive analyses, EPA and SCDHEC regulations, and by special requests. Samples having constituent concentrations above specific limits are flagged by a computer program and will subsequently be analyzed either annually or semiannually depending on the concentration of that constituent.

Drinking Water

The Power Operations Department operates 27 separate drinking water systems at SRS, and the Defense Waste Processing Facility operates one system in S Area. 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 use shallow wells which draw water from the Congaree or McBean formations. The domestic water system in D Area is supplied with treated surface water from the Savannah River.

Chlorine is added at each facility for bacteriological control. The larger systems are pH-adjusted by the addition of sodium hydroxide or soda ash. Polyphosphates are added to three systems for iron and corrosion control. All 27 systems are monitored daily to determine the concentration of chemicals added to the water. Bacteriological samples are collected at frequencies ranging from daily to monthly, depending upon the size and type of the system.

A certified offsite laboratory collects samples from the 16 largest domestic drinking water systems every 12 to 16 months. These samples are analyzed for an extensive list of chemical and physical attributes and contaminants to ensure that all systems meet SCDHEC and EPA drinking water standards. Samples were collected in November 1988; however, no samples were collected in 1989. When sampling resumes in 1990, this program will be expanded to include all 27 systems.

In addition, SCDHEC collects samples for bacteriological and chemical analyses from the 14 larger systems onsite to ensure the safety of the drinking water supplies.

The Safe Drinking Water Act Amendments of 1986 require that each drinking water supplier determine the concentrations of 51 unregulated volatile organic compounds once per quarter for four consecutive quarters. This program was initiated in late 1988 and is still in progress. SCDHEC is currently collecting and analyzing these samples. The analytical results will be used to determine how prevalent these organic compounds are and to provide guidance for establishing future drinking water regulations. SCDHEC is also analyzing the drinking water samples for eight volatile organics that are currently regulated.

Soil and Sediments

Sediment samples are collected annually at seven stream locations and two Savannah River locations. In 1989, a 1-L grab sample was taken at each location, shipped to Environmental Testing, Inc. (ETI), and analyzed for pesticides and herbicides using EPA methods 608 and 615 [EPA79]. SRS has conducted this program, in conjunction with stream and river water sampling since 1976 to determine concentrations of these materials in SRS streams and in the Savannah River.

1989 HIGHLIGHTS

- In 1989, approximately 25,000 air, water, soil, sediment, vegetation, milk, food, and wildlife samples were routinely collected and analyzed for radioactivity. About 120 samples were collected during special radiological surveys.
- In 1989, 2,084 Panasonic thermoluminescent dosimeters (TLDs) were placed at stations in 454 locations within a 2,000-square-mile area of the site. Five TLDs are normally placed side by side at each monitoring location to provide increased precision.
- EMS discontinued chemical cesium analyses in 1989 because concentrations of ^{134}Cs and ^{137}Cs were determined during the analysis for gamma-emitting radionuclides.
- There are over 1,200 onsite groundwater monitoring wells that are sampled either quarterly, semiannually, or annually in the environmental monitoring program.
- In 1989, over 10,000 samples of water, soil, sediment, and fish were analyzed to determine the concentration of nonradioactive constituents.

5
Surface Water Monitoring Program

SUMMARY—The surface water monitoring program at SRS includes the sampling and analysis of water from the Savannah River, SRS streams, and seepage basins for both radioactive and nonradioactive constituents. In addition, a summary of tritium releases, and offsite radiation doses calculated for liquid releases are given.

Savannah River water and SRS stream samples are collected for analyses of gross alpha, nonvolatile beta, tritium, and several specific radionuclides at 42 sampling locations. In 1989, no measurable differences were detected between upriver and downriver concentrations of gross alpha and nonvolatile beta in the Savannah River. The only gamma-emitting radionuclide measured in the river was ^{137}Cs. Tritium accounted for more than 99% of the total radioactivity introduced into the Savannah River from SRS activities during 1989.

Of the five major streams on SRS that feed into the Savannah River, Four Mile Creek which receives effluents from F, H, and C Areas, had the highest levels of nonvolatile beta and tritium entering the river at Road A sampling location. Seepage basins in F, H, P, C, L and K Areas were sampled quarterly at six locations and monthly at two locations. The quantity of tritium migrating from all seepage basins represented 79% of the total amount of tritium released to site streams.

The highest potential committed dose to the maximum individual, a person who consumes an average amount of water and a large amount of fish from the river, was 0.30 mrem (0.0030 mSv). This dose is 0.1% of the annual committed dose of 295 mrem (2.95 mSv) received from natural sources of radiation.

As part of the nonradiological program, 76 active outfalls, which discharge operational effluents from SRS facilities, are monitored to ensure that applicable permit limits are met. Concentrations of chemicals, metals, pesticides, and herbicides are reported, along with temperature, dissolved oxygen, and pH measurements for SRS stream and river samples.

INTRODUCTION

The Savannah River flows along a 35-mile stretch of the western boundary of the Savannah River Site (SRS). Five major streams—Upper Three Runs Creek, Four Mile Creek, Pen Branch, Steel Creek, and Lower Three Runs Creek—on SRS feed into the river.

The Savannah River and contributing SRS streams are sampled continuously at locations both downstream of production areas and downriver of stream inlets to the Savannah River. These samples are analyzed for various radioactive and nonradioactive contaminants. Sampling and analyses are performed by the Environmental Monitoring Section (EMS) and the Savannah River Laboratory (SRL). The Savannah River is also monitored by other groups including the South Carolina Department of Health and Environmental Control (SCDHEC) and the Georgia Department of Natural Resources (GDNR).

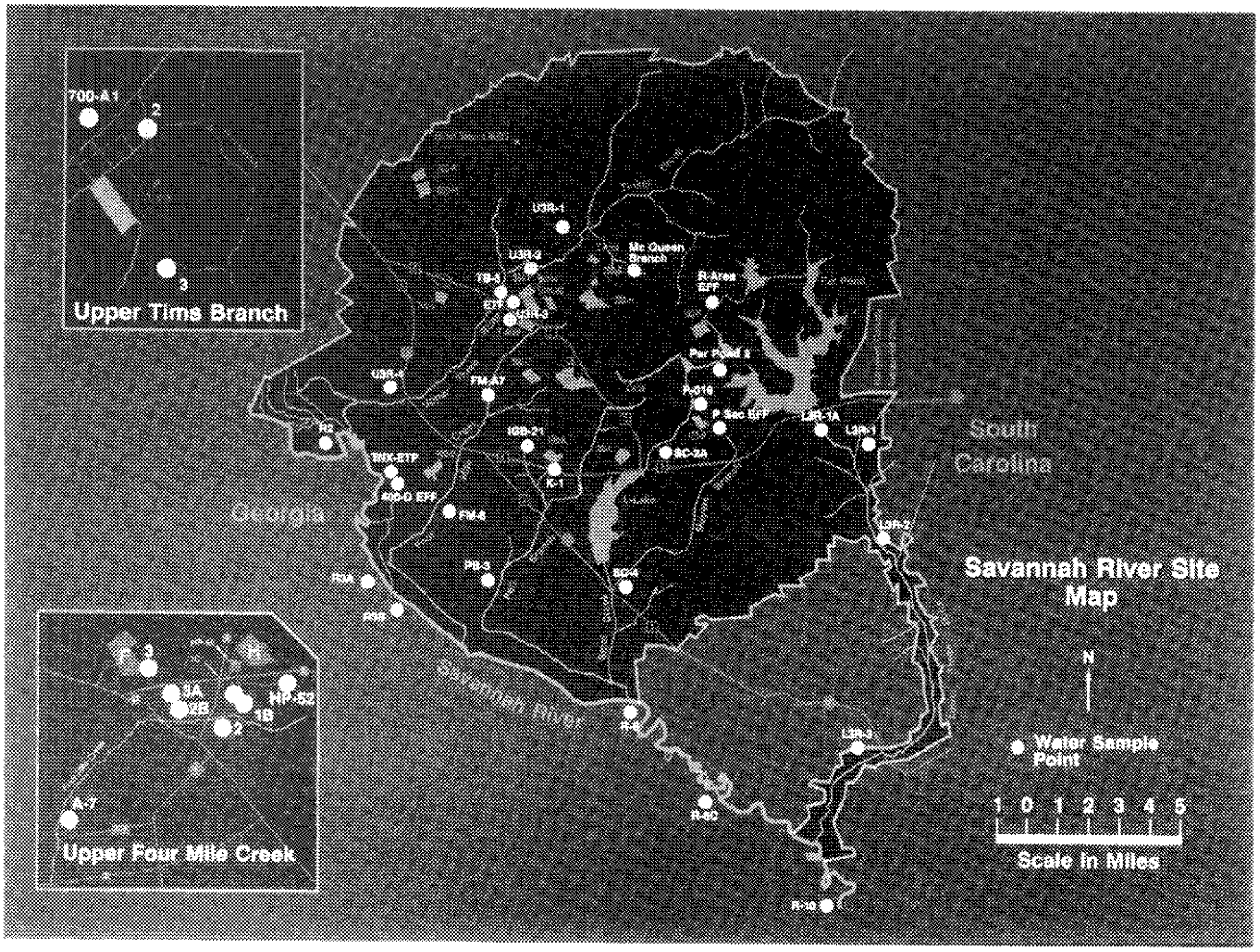


Figure 5-1. SRS streams and Savannah River sample locations

RADIOLOGICAL MONITORING PROGRAM

Savannah River

Description of Monitoring Program

The Savannah River is continuously sampled by paddlewheel samplers at locations upriver of, adjacent to, and downriver from SRS. A monitoring location upriver from SRS provides background analysis data (i.e., data from comparable waterways that are unlikely to have been influenced by SRS operations).

Sampling locations adjacent to and downriver from SRS provide measurements to determine the concentrations of radioactivity released to the Savannah River from SRS streams and from the Plant Vogtle nuclear power plant operated by Georgia Power Company. In 1989, the river radiological monitoring program consisted of the six sampling locations shown in Figure 5-1 (above).

Paddlewheel samplers continuously sample river water based on water-flow velocity. River flow is measured using United States Geological Survey flow recorders at two sampling stations: River-2 upriver from SRS and River-10 downriver from SRS.

In most cases, river water samples are collected weekly for analyses of gross alpha, nonvolatile beta, tritium, and a variety of specific radionuclides. The frequency and type of analyses, which vary from location to location, are based upon the potential quantity and radionuclides likely to be present at a sampling location. Changes in SRS operations and variations in radiological conditions may create sampling changes as well.

In addition, the Savannah River Laboratory (SRL) monitors the Savannah River for ^{137}Cs with ultra-low-level analysis techniques (see Chapter 1). Samples are collected both upriver at the River-2 station and at downriver at the River-10 station every two weeks.

Program Changes in 1989

A problem of separating alpha-emitting radionuclides during sample preparation in the analysis of plutonium was identified with third quarter samples. Plutonium analyses were changed from quarterly to monthly. The monthly analyses will provide a means to determine more quickly when such problems of sample preparation or analysis occur.

Applicable Standards

Derived Concentration Guides (DCGs) for drinking water, listed below in Table 5-1, apply to SRS releases to the Savannah River.

Drinking water standards established by the EPA apply at the water treatment plants in Beaufort and Jasper counties in SC and in Port Wentworth, GA. The water treatment plants are downriver from SRS. The EPA standards are based on an annual whole body dose of 4 mrem/yr (0.04 mSv) for the consumption of 2 L of water per day [EPA75, CFR87]. Drinking water standards for specific radionuclides are listed in Appendix E.

Monitoring Results

Gross Alpha and Nonvolatile Beta

In 1989, no measurable differences were detected between upriver and downriver concentrations of gross alpha and nonvolatile beta in the Savannah River. Concentrations of gross alpha activity in the dissolved sample averaged 0.07 pCi/L upriver and 0.09 pCi/L downriver from SRS. Average concentrations of nonvolatile beta for 1989 were 2.2 pCi/L upriver and 2.0 pCi/L downriver from SRS. River monitoring data are presented in Table 5-1, Vol. II.

Table 5-1
DOE Derived Concentration Guides For Drinking Water (pCi/L)[a]

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

[a]Values of DCGs are from the DOE draft Order 5400.xx. These DCGs are defined as the ingested water concentration of that radionuclide that will give a 50-year committed dose of 100 mrem under conditions of continuous exposure for one year.

Gamma-Emitting Radionuclides

The only gamma-emitting radionuclide detected in the river was ^{137}Cs. SRL detected ^{137}Cs both upriver and downriver from SRS with low-level analysis techniques. In 1989, concentrations of ^{137}Cs upriver from SRS at the River-2 sampling location averaged 0.012 pCi/L, with a maximum of 0.028 pCi/L.

The downriver concentrations at the River-10 (Highway 301) sampling location averaged 0.058 pCi/L, with a maximum of 0.101 pCi/L. The difference between the upriver and downriver concentrations is attributed to site operations. Table 5-1, Vol. II includes ^{137}Cs concentrations measured by SRL from Savannah River samples at River-2 and at River-10.

The 1989 average concentration of ^{137}Cs in drinking water from the downriver water treatment plants, Beaufort-Jasper and Port Wentworth, results in a dose of 0.001 mrem/year, which is 0.03% of the 4 mrem/year EPA dose limit from the liquid pathway.

Tritium

The release of tritium accounted for more than 99% of the total radioactivity introduced into the Savannah River from SRS activities during 1989. On the following page, Figure 5-2 shows direct tritium releases from 1985 through 1989 from each source onsite. The activity of tritium released from SRS, as calculated from measurements downriver from SRS and from river flow rates, was 15,600 Ci in 1989.

The average river flow in 1989 was 7,832 ft^3/sec, which is 52% higher than the 1988 flow rate of 5,151 ft^3/sec. Average Savannah River flow rates over the past 10 years are shown in Figure 5-1, Volume II. After dilution by SRS streams and the Savannah River, tritium concentrations in 1989 averaged 2.9 pCi/mL in the river below SRS at sampling location River-10 (Highway 301).

Strontium

Strontium-90 in river water is also measured by routine analytical techniques. The average ^{90}Sr concentration at the River-2 sampling location upriver from SRS was 0.14 pCi/L. The average concentration

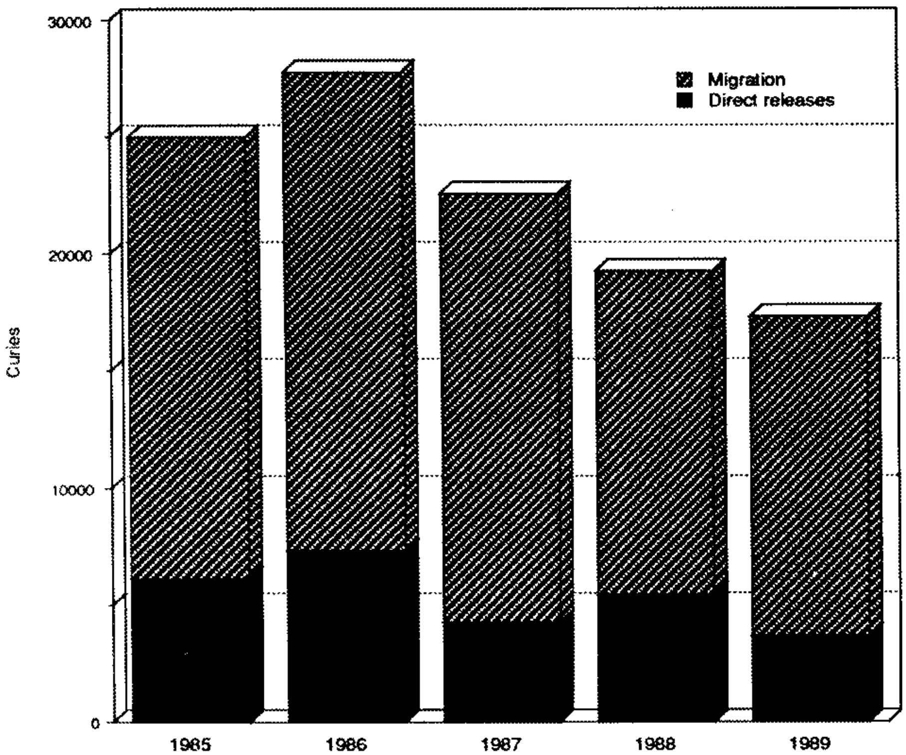


Figure 5-2. Tritium releases to the Savannah River, 1985–1989

Continuous water samples from streams are generally collected weekly and analyzed for gross alpha, nonvolatile beta, tritium, and other specific radionuclides. As is done for river monitoring, the frequency and types of analyses are based on the potential quantity and radionuclide likely to be present at the sampling location.

Offsite surface water is also sampled to provide background data. A good indication of background levels of radioactivity in an offsite surface water system that is similar to SRS streams is provided by analysis of samples from the Edisto River, a small river in South Carolina.

of ^{90}Sr downriver from SRS at the River-10 station was 0.23 pCi/L. Both results are below the DOE DCG of 1,000 pCi/L for ^{90}Sr in drinking water.

Plutonium

Low levels of ^{239}Pu were detected at river sampling locations upriver, adjacent to, and downriver from SRS. The maximum ^{239}Pu concentration was 3.1 fCi/L (0.003 pCi/L), detected at River-2 above SRS. The maximum concentration downriver from SRS was 2.1 fCi/L (0.002 pCi/L). The 1989 concentrations of ^{239}Pu in samples from the Savannah River averaged 0.5 fCi/L (0.0005 pCi/L).

SRS Surface Waters

Description of Monitoring Program

Streams located on SRS are sampled continuously at 37 locations to monitor radioactivity released from SRS facilities. These locations include effluent monitoring points and locations on all major streams near Road A (Highway 125) near the SRS boundary. The locations near Road A are the final stream sampling point before the stream enters the Savannah River. Figure 5-1 gives all stream sampling locations. Stream flows are determined by USGS flow recorders at most sampling locations.

Program Changes in 1989

- A continuous sampler at location HP 15 was added on Upper Three Runs Creek to monitor Tritium facilities in H Area in June 1989. Samples are collected weekly.
- The collection of dip samples from stream locations Burial Ground Ditch, 700-A1, 100-P, and Indian Grave-7 was discontinued in June 1989 because the samples obtained using this method were not representative of the effluents.
- A continuous sampler was installed at Indian Grave-21 in June 1989 to improve the quality of samples collected.

Applicable Standards

DOE DCGs (Table 5-1) apply only at the site boundary, which, for SRS stream waters, is the Savannah River. Although the DCGs do not apply to SRS streams, they are used as guides to gauge the impact of radioactivity in SRS stream water.

Monitoring Results

Background values and DCGs are used to evaluate stream data. Table 5-2 (above right) shows the 1989

Table 5-2
Radioactivity in Site 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 (TB-5)	2.11	0.29	1.4	6.9	1.65	2.9	1.92	0.65	1.12
Upper Three Runs (U3R-4)	3.2	0.50	1.4	3.4	0.55	1.7	26.2	3.29	12
Beaver Dam Creek (400-D)	1.3	-0.39	0.15	5.6	0.8	2.7	364	0.77	20
Four Mile Creek (FM-6)	0.86	-0.34	0.20	50.6	18.9	31	690	370	480
Indian Grave Branch (IGB-21)	0.59	0.19	0.38	1.74	1.01	1.3	10,900	2,030	5,200
Pen Branch (PB-3)	0.61	-0.22	0.16	5.35	1.10	2.4	222	24.5	56
Steel Creek (SC-4)	0.8	-0.19	0.09	4.29	1.21	2.3	5.7	2.96	4.5
Lower Three Runs (L3R-2)	0.8	-0.20	0.16	6.89	3.2	4.8	4.98	1.99	3.5
Control									
Edisto River	3.7	-0.02	1.2	5.68	0.65	1.9	0.85	-0.34	0.28

[a] Does not include effluent sampling points.
Number of significant figures is dependent on uncertainty terms given in Table 5-2, Vol. II

maximum concentrations detected in the Edisto River, which is not impacted by SRS operations. Table 5-2 also compares maximum, minimum, and average concentrations of radioactivity for site streams and the Edisto River. The stream locations compared in this table are below all discharge liquid effluents, where adequate mixing has taken place.

Detailed stream monitoring data are presented in Table 5-2, Vol. II. Quantities of direct liquid releases of tritium to site streams from 1985 through 1989, calculated from measured concentrations and known flow rates, are presented in Figure 5-3 (next page).

Tims Branch

Tims Branch (TB), a tributary of Upper Three Runs Creek (U3R), receives effluents from M Area and SRL. In 1989, M-Area effluents contained small quantities of uranium, while SRL releases were negligible. Releases to TB eventually flow downstream and enter U3R. Weekly samples are collected from TB to monitor the concentrations of M-Area effluent, the SRL effluent concentrations, and TB's entrance to U3R. Samples are analyzed for gross alpha, nonvolatile beta, and tritium. Samples monitoring the M-Area effluent are also analyzed for uranium and plutonium.

The average gross alpha and nonvolatile beta concentrations in the M-Area effluent were 3.8 and 4.9 pCi/L, respectively. Gross alpha averaged 0.8 pCi/L and nonvolatile beta averaged 1.8 pCi/L in the SRL effluent. Concentrations of gross alpha and nonvolatile beta entering U3R from TB averaged 1.4 and 2.9 pCi/L, respectively. These levels are comparable to those measured in the Edisto River (Table 5-2).

Upper Three Runs Creek

Upper Three Runs Creek (U3R) receives liquid discharges from the Effluent Treatment Facility (ETF), flow from Tims Branch, and stormwater runoff from parts of F and H Areas. The ETF, located in H Area, is the largest contributor to radioactivity in U3R.

The maximum concentrations of gross alpha (29 pCi/L) and nonvolatile beta (1,720 pCi/L) were measured

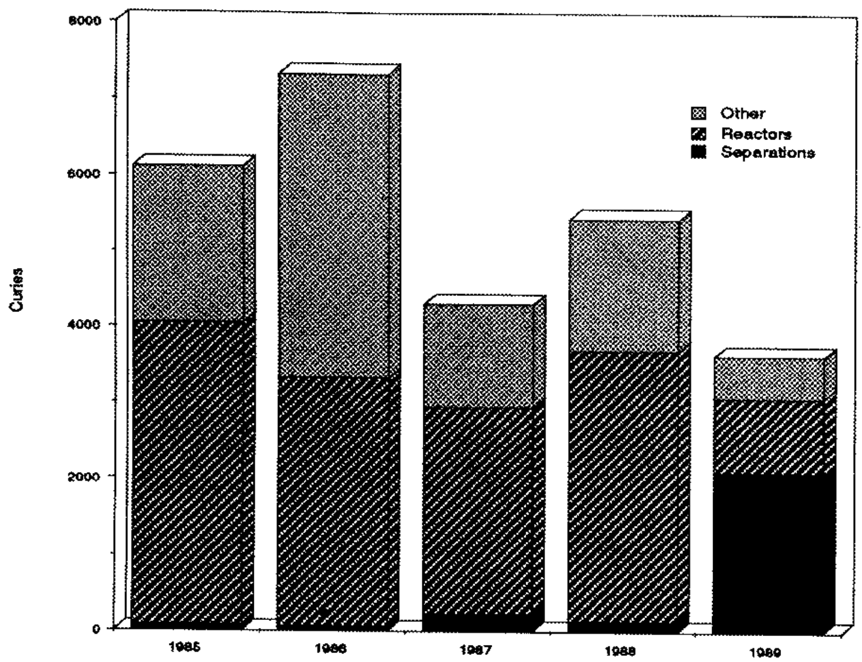


Figure 5-3. Direct tritium releases to site streams, 1985–1989

at the sampling location that monitors ETF effluents (U3R-2A). Measurements of gross alpha were similar to the 1988 maximum gross alpha concentration of 23 pCi/L. The maximum concentration of nonvolatile beta was higher than the 1988 maximum concentration of 62 pCi/L and was attributed primarily to releases of ^{137}Cs in the ETF effluent.

Concentrations of tritium were significantly higher in U3R during 1989 as a result of ETF operations. As discussed in the "Introduction and Program Overview" section, the ETF process does not remove tritium from effluent released to U3R. In 1989, the concentration of tritium in U3R at the ETF sampling location averaged 17,000 pCi/mL. As this water flowed downstream, it was diluted by other waterways. The maximum concentration of tritium entering U3R at Road A was 26.2 pCi/mL, which is 1.3% of the DOE DCG for tritium.

Beaver Dam Creek

Beaver Dam Creek (BDC) receives effluents from the heavy water rework and laboratory facilities in D Area. In 1989, tritium oxide was the principal radionuclide released in the effluents. One sample is collected and analyzed weekly for gross alpha, nonvolatile beta, and tritium to monitor the D-Area effluent.

Average gross alpha and nonvolatile beta concentrations in BDC for 1989 were 0.15 and 2.7 pCi/L, respectively. As Table 5-2 indicates, these concentrations were within the ranges observed in the Edisto River.

The 1989 maximum concentration of tritium in BDC was 364 pCi/mL, with an average of 20 pCi/mL.

Four Mile Creek

Four Mile Creek (FMC) receives effluents from F, H, and C Areas. FMC also receives tritium and ^{90}Sr migrating from the F- and H-Area seepage basins and the Radioactive Waste Burial Ground (RWBG).

C Reactor, which has not operated since 1985, released 16 Ci of tritium to FMC through the C-Area process sewer in 1989. F and H Areas released a total of 28 Ci of tritium to FMC in 1989. The maximum concentration of tritium measured in FMC during 1989 was 2,200 pCi/mL at location FM-3A, which monitors releases from F Area and migration from F-Area seepage basins. The maximum concentration, similar to the maximum concentration in 1988 of 2,900 pCi/mL, was collected from the same location. The average tritium concentration at location FM-3A was 1,770 pCi/mL. The maximum concentration of tritium entering the river from FMC was 690 pCi/mL, which is 24% of the DOE DCG for tritium. Concentrations of tritium in FMC entering the river at Road A averaged 480 pCi/mL.

Elevated nonvolatile beta and ^{137}Cs activities were detected at sampling location FM-1C in 1989. The elevated activity resulted from controlled releases from an H-Area retention basin to Four Mile Creek following a cesium release to the basin (see Chapter 10). Releases totaling 19 mCi of ^{137}Cs occurred during September 1989. The maximum concentration of nonvolatile beta was 301 pCi/L at location FM-1C. The maximum concentration of ^{137}Cs detected at location FM-1C was 393 pCi/L. Concentrations of ^{137}Cs before entering the river (location FM-6 Road A) averaged 0.7 pCi/L.

Pen Branch

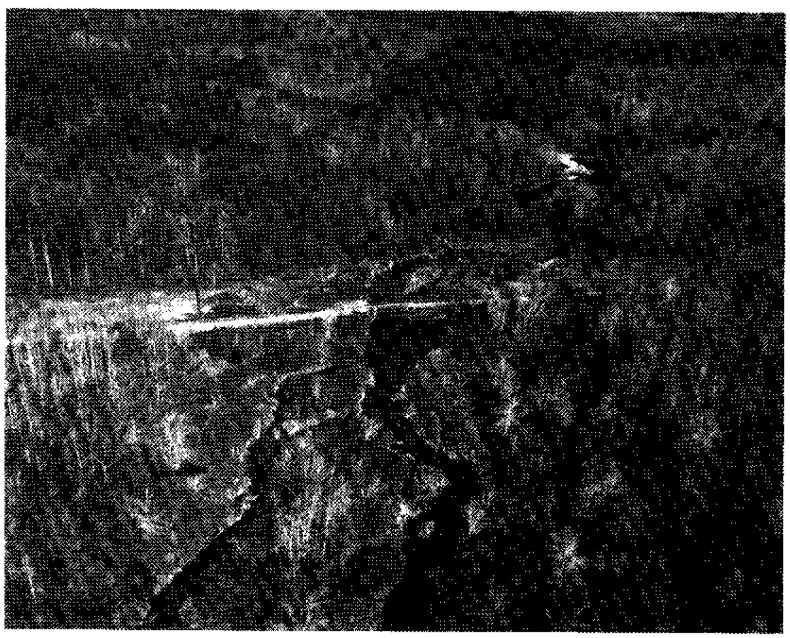
Pen Branch (PB) receives heat exchanger cooling water from K Area and flow from Indian Grave Branch (IGB). Tritium migration from the K-Reactor containment basin outcrops into IGB.

The maximum concentration of tritium in IGB was 10,900 pCi/mL at sampling location IGB-21, which is downgradient from the K-Area containment basin. After dilution, the maximum tritium concentration measured in PB before entering the river at Road A was 222 pCi/mL, which is 11% of the DOE DCG for tritium. This maximum concentration resulted from a tritium release to Pen Branch during the first week in January. Chapter 10, "Nonroutine Occurrences", provides more details on this release. The tritium concentration in PB at Road A averaged 56 pCi/mL during 1989.

As shown in Table 5-2, Vol. II, gross alpha and nonvolatile beta concentrations in PB at Road A were at or near background levels. Concentrations of gamma-emitting radionuclides were below minimum detectable levels (see Table 1-6, Vol. II).

Steel Creek

Steel Creek receives releases from L-Area effluents and tritium migration from the P-Area seepage basins. These releases enter L Lake, which overflow into Steel Creek near Road A. Most concentrations of radionuclides in Steel Creek below L Lake represent notable decreases from their 1985 levels when construction of L Lake was completed. The decreases likely resulted from the increased flow of river water used in L Reactor and from dilution by L Lake. In 1989, concentrations were similar to those measured in the Edisto River.



Pen Branch receives cooling water from K Reactor

Lower Three Runs Creek

Lower Three Runs Creek (L3R) receives overflow from Par Pond, which receives P-Reactor heat exchanger cooling water and other effluents from P Area. Par Pond also receives discharges from all storm sewer outfalls from the deactivated R Area and from a few storm sewers in P Area.

The average concentrations detected in Par Pond water during 1989 were 0.02 pCi/L of gross alpha, 6.1 pCi/L of nonvolatile beta, and 4.6 pCi/mL of tritium. In 1989, concentrations in L3R at Road A averaged 0.21 pCi/L of gross alpha, 4.5 pCi/L of nonvolatile beta, and 2.1 pCi/mL of tritium.

TNX Area

There were no radioactive releases from TNX Area in 1989. Average concentrations measured in the TNX samples were at or near background levels.

Seepage Basins

Seepage basins are shallow, earthen excavations that receive wastewater containing 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].

Description of Monitoring Program

EMS collects water samples quarterly at six seepage basin locations and monthly at two locations. Seepage basins located in the reactor areas were the only active basins in 1989. Use of the basins in F and H Areas was discontinued in 1988 in order to comply with state and federal regulations. However, EMS will continue to monitor the water the F- and H-Area seepage basins until the basins are dry and have been closed.

In addition to monitoring the water in the seepage basins, streams are also sampled downgradient of the basins to calculate the amount of radioactivity migrating from the seepage basins. These results are important in calculating the total levels of radioactivity released to the Savannah River as a result of SRS operations.

Program Changes in 1989

- Sampling of H-Area seepage basins 1, 2, and 4 was discontinued during the second quarter 1989.
- Sampling of F-Area seepage basins 1 and 2 was discontinued during the second quarter 1989.
- The Burial Ground Settling Basin was added to the sampling program to monitor storm water runoff from the Mixed Waste Management Facility. Samples are collected monthly.

Monitoring Results

Water samples collected from seepage basins located in F, H, P, K, L, and C Areas generally reflect concentrations observed in the wastewater released to the basins. Monitoring results of seepage basin water are presented in Table 5-3, Vol. II. Locations are shown in various figures in Chapter 6.

The calculated migration of radioactivity from the seepage basins is presented in Table 5-4, Vol. II. The quantity of tritium migrating from all seepage basins to SRS streams decreased by 1% from 1988. The amount of tritium measured in migration was 13,700 Ci in 1989, compared with 13,900 Ci in 1988. Figure 5-4 (right) shows tritium migration from seepage basins from 1985 through 1989. The tritium migrating from seepage basins represents 79% of the total amount of tritium released to site streams.

Migration of Radioactivity from K-Area Containment Basin

Tritium was the only radionuclide detected migrating from the K-Area containment basin to Pen Branch. Migration of 2,200 Ci was determined from weekly flow measurements combined with tritium concentrations measured in Indian Grave Branch (a tributary of Pen Branch) in 1989. The migration represents a 20% decrease from 1988. The migration is subsequently diluted by K-Area effluents before entering the Savannah River.

Migration of Radioactivity from F- and H-Area Seepage Basins

Migration of radioactivity from F- and H-Area seepage basins was measured with continuous samplers and flow recorders in Four Mile Creek (FMC). Groundwater from the F-Area seepage basins enters FMC between sampling locations FM-3A, FM-2B, and FM-A7.

Most of the H-Area seepage basin outcropping from basins 1, 2, and 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.

Radioactivity from the H-Area seepage basins and the Solid Waste Storage Facility mixes during groundwater migration to Four Mile Creek. Therefore, radioactivity from the two sources cannot be distinguished at the outcrop point. FMC sampling locations are shown in Figure 5-1, page 94.

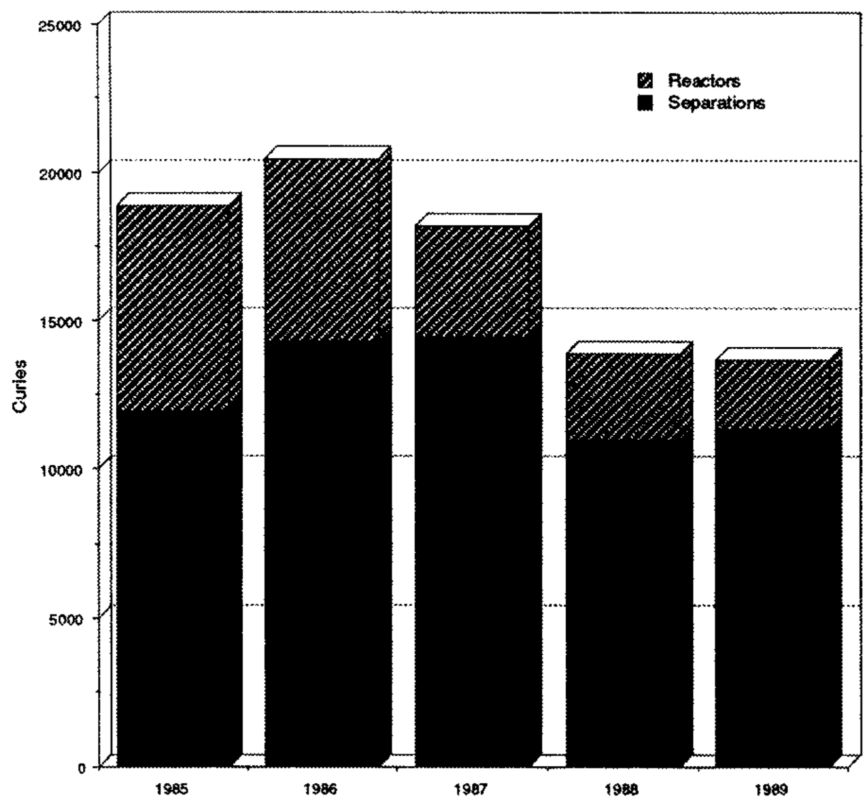


Figure 5-4. Tritium migration from seepage basins, 1985–1989

Table 5-3. 1989 Radioactive Liquid Releases and Concentrations

Nuclide	Curies Released At Emission Source	Below SRS[a] (µCi/mL)	Beaufort-Jasper[b] (µCi/mL)	Port Wentworth[c] (µCi/mL)
H-3	1.74E+04[d]	2.9E-06[e]	2.3E-06[e]	2.3E-06[e]
Zr,Nb-95	1.40E-05	2.3E-15	1.9E-15	1.8E-15
Sr-90	2.89E-01	2.4E-11[e]	3.8E-11	3.7E-11
I-129	2.20E-02	3.6E-12	2.9E-12	2.8E-12
Cs-137	2.06E-01	5.8E-11	2.7E-11	2.7E-11
Pm-147	3.29E-04	5.4E-14	4.4E-14	4.3E-14
U-235,238	4.25E-04	7.0E-14[e]	5.6E-14	5.5E-14
Pu-239	1.42E-02	2.3E-12	1.9E-12	1.8E-12
Ru-103,106	4.61E-03	7.6E-13	6.1E-13	6.0E-13
Ce-142,144	4.50E-05	7.4E-15	6.0E-15	5.8E-15

[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 verified with

Measured migration of tritium in 1989 was 4,440 Ci from F-Area seepage basins (33% increase from 1988), 3,600 Ci from H-Area seepage basin 4 and the Solid Waste Storage Facility (2% decrease from 1988), and 3,310 Ci from the other H-Area seepage basins (17% decrease from 1988).

The amount of ^{90}Sr entering FMC in 1989 was about 100 mCi from F-Area seepage basins and 94 mCi from H-Area seepage basins. Because of the complex analytical and preparation procedures for strontium determination, the strontium measurements are accompanied by large counting uncertainties (Table 5-5, Vol. II).

In 1989, there was no ^{137}Cs migration detected from the F- or H-Area seepage basins. Desorption of ^{137}Cs from sediments in the Four Mile Creek bed could not be distinguished from the direct ^{137}Cs releases into the stream. Radioactivity measured in transport at sample points on Four Mile Creek is shown in Table 5-5, Vol. II.

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 into the Savannah River. The delaying action of the basins reduces the dose that users of water at downriver water treatment plants receive from SRS tritium releases.

Although the seepage basins were used for purging the disassembly basins from the 1950s until 1970, disassembly basin purge water was released directly to SRS streams between 1970 and 1978. The earlier experience with seepage basins indicated that the extent of radioactive decay during the holdup was sufficient to recommend that the basins be used again in P and C Areas.

Equipment was installed at surface water locations downgradient from each basin to measure tritium migration. Results from samplers installed on Twin Lakes and Castor Creek near C Area indicated that no measurable tritium migration could be attributed to the C-Area seepage basin in 1989. Results from a sampler installed on Steel Creek above L Lake indicated 137 Ci of tritium migrated from the P-Area seepage basin during 1989.

Summary of 1989 Liquid Releases and Concentrations

Releases to Surface Waters

Releases of radioactive materials to the Savannah River in 1989 are shown above in Table 5-3. Tritium was the major radionuclide released in the liquid effluents. The quantities released were calculated from measured concentrations in SRS streams, the Savannah River, and at effluent points, as applicable, and from flow rates for the waterways involved. The majority of the concentrations shown in Table 5-3 are calculated, rather than measured because concentrations in the Savannah River are often below detectable levels. Measured concentrations are shown in those cases where the radionuclides are measurable by conventional analytical techniques.

The average concentrations of specific radionuclides in water are shown at three locations—just below SRS after complete mixing, in Beaufort-Jasper drinking water, and in Port Wentworth drinking water. The water treatment plants in Beaufort-Jasper, SC and Port Wentworth, GA are both approximately 100 miles downriver from SRS. As shown in Table 5-3, the maximum offsite concentration of radionuclides occurs in the Savannah River just below SRS. Tritium had the highest concentration of all radionuclides at all locations.

Tritium Releases

Releases of tritium from SRS to the Savannah River are estimated with the three different sets of measurements listed below:

- concentrations at release points
- concentrations in SRS streams (stream transport)
- concentrations in the Savannah River downriver from SRS (river transport)

Point-of-release measurements are calculated from known concentrations contributed to the streams.

Paddlewheel samplers offer continuous monitoring of the Savannah River

Stream transport is calculated from the measured concentration at the last sampling point before entry into the river and known flow rates for the sample period. Figure 5-2, Vol. II, shows the calculated releases of tritium based on the three measurement methods each year since 1960. A release summary of tritium in SRS streams and the Savannah River is presented in Table 5-6, Vol. II.

Results showed that point-of-release and stream transport measurements agreed within 2% and that the point-of-release measurements were within 10% of the river transport measurements. The differences between the release measurements can be attributed to a number of factors, including random and systematic uncertainties associated with the measurements. The point-of-release figures are considered the best release estimate, and are included in the annual dose calculations.

In 1988 and 1989, the percentage of tritium available for transport in liquid effluents by its source is listed below:

Source	% 1989	% 1988
Direct releases from site facilities	21	28
Migration:	79	72
RWBG		
F-, H-, and P-Area seepage basins		
K-Area containment basin		

A tritium release summary from 1960 to 1989 is presented in Table 5-7, Vol. II. Figure 5-2, Vol. II, shows the decrease in tritium releases to the Savannah River since 1964, when the maximum tritium releases occurred. The following process control improvements have led to decreased 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 which is 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 through groundwater

Table 5-4
Commited Dose Comparisons with Applicable Standards and Natural Radiation Sources

Commited Dose (mrem)	Standards (mrem)	% of Standard
Maximum Individual[a]	4 (EPA)	7.5
0.30	100 (DOE)	0.30
	295 (Natural)	0.10
Water Supplies at Beaufort-Jasper and Port Wentworth		
Average Consumption[b]	4 (EPA)	1.5
0.06	100 (DOE)	0.06
	295 (Natural)	0.02
Maximum Consumption[c]	4 (EPA)	3.0
0.12	100 (DOE)	0.12
	295 (Natural)	0.04

[a] This maximum individual is one just downriver from SRS who consumes an average maximum amount of water and fish from the river and spends many hours of shoreline activities. No such individual is known to exist.
[b] Average consumption of 1 L of water per day.
[c] Maximum consumption of 2 L of water per day.

Releases were also reduced by shutdown of R- and L-Area Reactors in 1964 and in 1968, respectively.

Offsite Radiation Doses from Releases to Surface Waters

Table 5-4 (above) shows the calculated committed dose to individuals from releases to surface waters, with a comparison to applicable standards and sources of natural radiation.

Maximum Individual Committed Dose

Table 5-5, right, gives the maximum calculated offsite committed dose to a hypothetical individual from SRS releases of radioactivity to the Savannah River. This hypothetical *maximum individual* is described as a person who consumes an average amount of water (assumed to be untreated river water) and a large amount of fish from the river just below SRS. This person also spends many hours in shoreline activities, swimming, and boating.

The highest potential committed dose to the *maximum individual* in 1989 was 0.30 mrem (0.0030 mSv). This dose is 0.3% of the 100 mrem DOE Revised Interim Radiation Dose Limit for annual exposure and 0.1% of the annual committed dose of 295 mrem (2.95 mSv) received from natural sources of radioactivity.

As shown in Table 5-5 the committed dose to the maximum individual at the site perimeter results primarily from ^{137}Cs. The major dose pathway for the maximum individual at the site perimeter is from the consumption of fish, which accumulate ^{137}Cs.

Downriver Consumption of Drinking Water

Table 5-6 and Table 5-7(on the following pages show

Table 5-5
Maximum Individual Doses–Surface Water Releases

Pathway	Max. Individual[a] mrem	% of Total Dose
Fish	2.24E-01	75.09
Water	7.41E-02	24.84
Shoreline	2.21E-04	0.07
Swimming	4.17E-07	0.0001
Boating	1.25E-06	0.0004
Total	2.98E-01	
Radionuclide	**Max. Individual[a] mrem**	**% of Total Dose**
H-3	7.25E-02	24.31
Sr-90	8.61E-03	2.89
Zr-95, Nb-95	2.86E-07	0.0001
Ru-103, 106	1.13E-05	0.004
I-129	8.94E-04	0.30
Cs-137	2.11E-01	70.84
Ce-141, 144	5.98E-08	0.00002
Pm-147	6.27E-08	0.00002
U-235, 238	7.68E-06	0.003
Pu-239	4.93E-03	1.65
Total	2.98E-01	

[a] Hypothetical person just downriver from SRS. There are no known persons who meet the hypothetical situation.

Table 5-6
Individual Doses from Public Water Supplies at Beaufort-Jasper

Average Consumption

Radionuclide	Individual Dose, mrem[a]	% of Total Dose
H-3	5.36E-02	90.31
Sr-90	1.84E-03	3.10
Zr-95, Nb-95	2.29E-09	0.000004
Ru-103, 106	4.73E-06	0.01
I-129	3.02E-04	0.51
Cs-137	6.12E-04	1.03
Ce-141, 144	4.39E-08	0.0001
Pm-147	1.53E-08	0.00003
U-235, 238	5.20E-06	0.01
Pu-239	2.99E-03	5.03
Total	5.94E-02	

Maximum Consumption

Radionuclide	Individual Dose, mrem[a]	% of Total Dose
H-3	1.06E-01	90.32
Sr-90	3.63E-03	3.10
Zr-95, Nb-95	4.52E-09	0.000004
Ru-103, 106	9.31E-06	0.01
I-129	5.94E-04	0.51
Cs-137	1.21E-03	1.03
Ce-141, 144	8.65E-08	0.0001
Pm-147	3.01E-08	0.00003
U-235, 238	1.03E-05	0.01
Pu-239	5.89E-03	5.03
Total	1.17E-01	

[a] Committed effective dose equivalent.

calculated committed doses to individuals whose entire daily intake of water is supplied by the Beaufort-Jasper and Port Wentworth water treatment plants, downriver of SRS. The committed dose for average water consumption (1 L) from both Beaufort-Jasper and Port Wentworth was 0.06 mrem (0.0006 mSv).

For both water treatment plants, the committed dose for maximum water consumption rates (2 L) was 0.12 mrem (0.0012 mSv). The maximum dose of 0.12 mrem is 3% of the EPA standard of 4 mrem/yr to the body or any organ from public water supplies.

As shown in Figure 5-3, Vol. II, the majority of the dose downriver at the two water treatment plants is attributed to tritium because tritium is not appreciably sorbed on river sediments nor is it removed by conventional water treatment processes.

Collective Dose

Collective committed doses from liquid releases of radioactivity in 1989 are shown by exposure pathway in Table 5-8, Vol II. Committed dose from the water consumption pathway (Beaufort-Jasper and Port Wentworth) occur to discrete population groups. The committed doses 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 5-8, Vol. II, the collective committed dose from liquid releases was 4.8 person-rem (0.048 person-Sv).

Potential Dose from Irrigation Pathway

Although there is no known use of Savannah River water for farm irrigation downriver from SRS, potential offsite dose from the irrigation-food pathways is calculated for information purposes. Potential doses from the irrigation pathway are shown in Table 5-9, Vol. II. The maximum individual committed dose from the irrigation pathway was 0.26 mrem (0.0026 mSv) in 1989.

NONRADIOLOGICAL MONITORING PROGRAM

Surface water is monitored for nonradioactive contaminants at effluent outfalls from site facilities, at locations along six site streams, and at three locations on the Savannah River.

Operational effluents from SRS facilities discharge through 76 active outfalls regulated by SCDHEC under the National Pollutant Discharge Elimination System (NPDES) program. These outfalls are monitored to verify that applicable permit limits are met. A network of stormwater outfalls is also maintained on the site.

Monitoring the streams and river serves as a backup to outfall monitoring to ensure that materials that could adversely affect the environment are characterized if released.

Liquid Effluent Monitoring (NPDES)

Description of Monitoring Program

The physical properties and concentrations of chemicals and metals in SRS effluents are regulated by SCDHEC under the National Pollutant Discharge Elimination System (NPDES) program. In 1989, the NPDES program at SRS included monitoring at 76 permitted outfalls to verify the releases were in compliance.

Applicable Standards

Standards applicable to nonradioactive constituents and physical properties in SRS wastewater discharges are contained in the site's NPDES permit administered by SCDHEC. Monitoring requirements and standards are listed in permit SC 0000175 [SCDHEC85]. Standards may be different from one outfall to another.

Temperature survey of the Savannah River

Table 5-7
Individual Doses from Public Water Supplies at Port Wentworth

Average Consumption

Radionuclide	Individual Dose, mrem[a]	% of Total Dose
H-3	5.25E-02	90.31
Sr-90	1.80E-03	3.10
Zr-95, Nb-95	2.24E-09	0.000004
Ru-103, 106	4.63E-06	0.01
I-129	2.95E-04	0.51
Cs-137	5.98E-04	1.03
Ce-141, 144	4.29E-08	0.0001
Pm-147	1.49E-08	0.00003
U-235, 238	5.09E-06	0.01
Pu-239	2.92E-03	5.03
Total	5.81E-02	

Maximum Consumption

Radionuclide	Individual Dose, mrem[a]	% of Total Dose
H-3	1.04E-01	90.31
Sr-90	3.57E-03	3.10
Zr-95, Nb-95	4.44E-09	0.000004
Ru-103, 106	9.15E-06	0.01
I-129	5.84E-04	0.51
Cs-137	1.19E-03	1.03
Ce-141, 144	8.50E-08	0.0001
Pm-147	2.96E-08	0.00003
U-235, 238	1.01E-05	0.01
Pu-239	5.79E-03	5.03
Total	1.15E-01	

[a] Committed effective dose equivalent.

Monitoring Results

Table 5-10, Vol. II lists the NPDES outfall locations, and a summary of monitoring results is presented in Table 5-11, Vol. II. SRS had a 99.9% NPDES compliance rate in 1989, as compared to a 99.8% compliance rate in 1988. Only nine of the 6,859 analyses performed exceeded permit limits. Table 5-8 (on the following page) summarizes the limits exceeded, the outfall locations, and the probable cause of noncompliance.

Savannah River

Description of Monitoring Program

The Savannah River is monitored continuously at four locations for organic and inorganic contaminants. These sampling sites are located upriver and downriver from the site to provide a means of comparing SRS contribution of pollutants with "background" levels. Included in these background levels are natural sources and contaminants produced by industrial sewage plants, medical facilities, or other industrial facilities upriver from SRS. Sampling locations are shown in Figure 5-5 (following page).

Field measurements of conductivity, dissolved oxygen, pH, and temperature are also taken

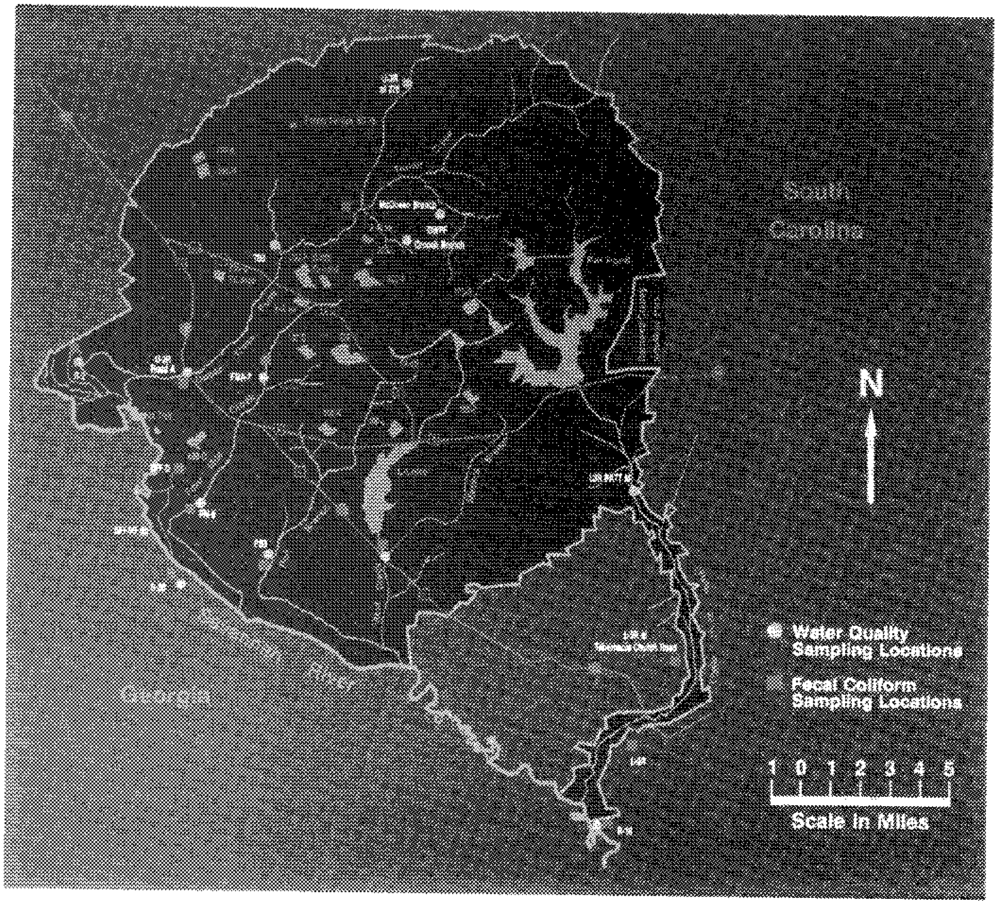


Figure 5-5. Water quality sampling locations

in the Savannah River monthly to monitor the river water quality. Laboratory analyses are conducted for other water quality parameters such as metals, organic and inorganic contaminants.

In addition, the Academy of Natural Sciences of Philadelphia (ANSP) conducts special environmental surveys on the Savannah River through a program that began in 1951.

Applicable Standards

The South Carolina Water Quality Standards for Class B streams define the chemical and biological standards for the Savannah River. The standards define Class B streams as: "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 of the standard are summarized in Table 5-9 (page 108).

Monitoring Results

Savannah River water quality data are presented in Tables 5-12 and 5-13, Vol. II. 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. This may be attributed to the fact that much of the water discharged to the river from SRS has undergone treatment processes so that the water can be used for various purposes (e.g., drinking water). These treatment processes remove coliform from the water before it is released to the river. The averages of the monthly geometric mean of fecal coliform measurements were 683 colonies/100 mL upriver and 144 colonies/100 mL downriver from SRS.

Temperature, dissolved oxygen, and pH field measurements were within the standards required for Class B streams. Analytical results for chemicals and metals were within the ranges observed in previous years.

Savannah River water quality surveys by the Academy of Natural Sciences of Philadelphia (ANSP) consisted of diatometer monitoring and biological during 1989. These surveys and preliminary results are discussed in Chapter 11, "Special Surveys".

SRS Streams

Description of Monitoring Program

The EMS monitors site streams monthly for chemicals, metals, and physical and biological properties. The stream nonradiological monitoring program helps detect materials that may be inadvertently released from sources other than routine release points. Five principal streams traverse the site and a sixth stream, Beaver Dam Creek, receives water primarily from the D-Area powerhouse. D Area also contains heavy-water rework facilities and a process control laboratory. Each stream receives varying amounts of wastewater and rainwater runoff from SRS facilities. Sampling locations are shown in Figure 5-5 (left).

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 by EMS.

Applicable Standards

South Carolina water quality standards for Class B streams, shown in Table 5-9 on the following page, also apply to SRS streams.

Monitoring Results

All analyses of SRS stream samples and measurements in SRS streams met the South Carolina standards for Class B streams.

In previous years, temperatures in Pen Branch exceeded the Class B stream standard due to thermal discharges from K Reactor. However, due to the shut down of K Reactor in 1988, the maximum temperature in Pen Branch was 27°C in 1989, which was within the Class B stream standard.

Fecal coliform counts in Pen Branch at Road A were also lower than 1988 counts. In 1989, the maximum count was 920 colonies/100 mL compared to 1,600 colonies/100 mL in 1988. The geometric mean was 92 colonies/100 mL, compared to 457 colonies/100 mL in 1988. Geometric means for fecal coliform at all other stream locations were lower than 1988 mean values.

Table 5-8
Summary of NPDES Noncompliances

Analysis	Location	Possible Cause
Oil and grease	DW-002 (S Area)	Construction equipment steam cleaning pad
Total organic carbon	X-014 (TNX Area)	Lower than anticipated carbon removal and dilution in ETP process
Trichloroethylene	A-005 (A Area)	Unknown
Benzene	X-014 (TNX Area)	Unknown
Total suspended solids	H-008 (H Area)	Unknown - probable source was unrelated construction activities upstream of the outfall sampling point
Total suspended solids	DW-003 (S Area)	Equipment malfunction
Total suspended solids	K-010 (K Area)	Organic matter and silt were present in the outfall sample point
Oil and grease	DW-002 (S Area)	Unknown
pH	K-010 (K Area)	Unknown - probable source may be related to construction activity of pouring concrete around reactor building

Analytical results for chemicals and metals were within the ranges observed in previous years. Stream water quality data are summarized in Tables 5-14 and 5-15 in Vol. II.

Monitoring for Pesticides and Herbicides

Description of Monitoring Program

Pesticides and herbicides have been monitored since 1976 to assess their concentrations in surface water and sediment from SRS streams and the Savannah River. Water and sediment samples from nine stream locations were analyzed for six pesticides and herbicides during 1989. The six constituents and typical minimum detectable concentrations are listed in Table 5-16, Vol. II.

Monitoring Results

Concentrations of all pesticides and herbicides analyzed in river and stream water and sediment were less than minimum detectable concentrations. Pesticide and herbicide data for stream and river water and stream and river sediment are presented in Table 5-17 and 5-18, Vol. II, respectively.

River and Stream Temperature Surveys

Description of Monitoring Program

Temperature profile surveys are conducted on the Savannah River and several SRS streams as part of a comprehensive study to determine the thermal effects of SRS operations upon the waters of South Carolina. These surveys are required under consent order 84-4-W between SCDHEC and DOE. This consent order states that "the temperature should not exceed 2.8°C above the ambient temperature at the edge of 25% of the cross sectional area and over 33% of the surface area." In 1989, the surveys also provided baseline, seasonal temperatures of the creek mouths prior to a proposed-reactor startup.

Measurements in the creek mouths are taken at 2-ft intervals across the creeks. At each interval, stream temperatures are measured at 1-ft depth intervals from the surface of the creek to the bottom. River measurements are taken at 10 to 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 river surface to the bottom.

The reference ambient temperature, which is used as a control temperature for the river and SRS streams, is determined from a temperature profile 100 yd upriver from Beaver Dam Creek. In addition to temperature profile surveys conducted by SRS, stations established by the USGS continuously collect temperature measurements at the mouth of each SRS stream.

Monitoring Results

The EMS performed four temperature profile surveys in the mouths and upriver from Beaver Dam Creek and Steel Creek during 1989. A survey was not made in the mouth and downriver of Four Mile Creek due to the non-operational status of C Reactor. Table 5-19, Vol. II summarizes the 1989 temperature profile results.

Table 5-9
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°F (32.2°C) after adequate mixing as a result of heated liquids, nor shall a weekly average temperature rise of more than 5 °F (2.8°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.

Dissolved Oxygen. Daily average not less than 5.0 mg/L with a low of 4.0 mg/L, except that specified waters may have an average of 4 mg/L due to natural conditions.

Temperature measurements in both Beaver Dam Creek and Steel Creek exceeded the ambient temperatures but were within the DOE and SCDHEC consent order 84-4-W limits.

1989 HIGHLIGHTS

- In Savannah River samples, alpha activities ranged from 0.07 to 0.12 pCi/L, and nonvolatile beta concentrations ranged from 0.17 to 2.6 pCi/L. Background levels, measured in the Edisto River, were 3.7 pCi/L of gross alpha activity, and 5.7 pCi/L of nonvolatile beta activity.
- The 1989 average concentration of ^{137}Cs in drinking water from the downriver water treatment plants results in a dose of 0.001 mrem/year, which is 0.03% of the 4 mrem/year EPA dose limit from the liquid pathway.
- Tritium activity measured in transport in the river below SRS was 15,600 Ci in 1989. After dilution by SRS streams and the Savannah River, tritium concentrations averaged 2.9 pCi/mL in 1989.
- Measured migration of tritium in 1989 was 4,440 Ci from F-Area seepage basins (33% increase from 1988), 3,600 Ci from H-Area seepage basin 4 and the Solid Waste Storage Facility (2% decrease from 1988), and 3,310 Ci from the other H-Area seepage basins (17% decrease from 1988).
- Collective committed doses from liquid releases of radioactivity in 1989 were calculated by exposure pathway, and by radionuclide. The water consumption pathway (Beaufort-Jasper and Port Wentworth Water Treatment Plants) contributed over 85% of the collective committed dose, while tritium accounted for over 70% of the total dose.
- Savannah River water quality analyses upriver and downriver from SRS showed no significant differences except for fecal coliform, which were higher upriver than downriver from SRS. All pesticides and herbicides had less than minimum detectable concentrations in river and stream water and sediments.

2 Quality Assurance/Quality Control of Environmental Monitoring Programs

SUMMARY—This chapter outlines the quality assurance/quality control program goals and procedures for the radiological and nonradiological monitoring programs at SRS and at offsite subcontracted laboratories. The purpose of the program is to monitor the reliability, accuracy, and precision of all data, and to detect problems in the sample collection, preparation, analysis, or data evaluation phases of the monitoring program.

Key elements in achieving these goals at both SRS and subcontracted laboratories include personnel training, interlaboratory comparisons, compliance audits, use of blind and spiked samples, and careful documentation.

Details of the QA/QC program are described for the Environmental Sampling group, the Environmental Chemistry and Counting Laboratories, and the Data Evaluation group of EMS. QA/QC practices include the calibration of counting instruments, source and background counts for all counting systems, yield determinations of radiochemical procedures, and replicate analyses to check precision.

Finally, the chapter focuses on the QA/QC program for nonradiological monitoring of air, surface water, liquid effluents, and groundwater, primarily conducted by offsite subcontracted laboratories. Program findings are described, and results of two interlaboratory comparisons of subcontractor laboratories are summarized.

INTRODUCTION

"Quality assurance" (QA) for environmental monitoring encompasses any action taken to assure the reliability of monitoring and measurement data. Aspects of quality assurance include procedures, interlaboratory comparison studies, evaluations, and documentation.

"Quality control" (QC) involves the routine application of procedures to obtain the required standards of performance in monitoring and measurement processes. QC activities, including calibration of instruments, control charts, and analysis of replicate and duplicate samples, help ensure that the generated data have known probability limits of accuracy and precision.

The Environmental Monitoring Section (EMS) maintains a quality assurance/quality control (QA/QC) program to monitor the quality of data generated within its environmental monitoring programs. To obtain high quality monitoring data, each aspect of the program, from sample collection to data reporting, must meet specific quality standards.

The first portion of this chapter defines the purpose, objectives, policies, and general elements of the EMS QA/QC program that apply to onsite and offsite laboratories.

The second part of the chapter describes specific QA/QC elements of the environmental sampling, analysis, and data evaluation programs within EMS. The

Table 2-1
Quality Assurance Requirements for Environmental Surveillance Programs

QA plan:

- shall be prepared as a section of the Environmental Monitoring Plan
- shall include monitoring activities consistent with the 18 elements format described in ANSI-ASME NQA-1

Audits:

- shall be performed to verify compliance with QA programs
- shall be performed in accordance with written procedures or checklists, documented and reported

QA program:

- shall follow the elements as described in ANSI-ASME NQA-1 in the 18-criterion structure of 10 CFR Part 50

Environmental surveillance activities:

- shall include calibration of instruments and equipment with standards traceable to the National Institute of Standards and Technology (NIST) or other standards recognized by DOE

final portion of this chapter describes QA/QC nonradiological monitoring programs for laboratories within EMS and under subcontract to EMS.

QA/QC PROGRAM GUIDELINES

The purpose of the EMS QA/QC program is to monitor the scientific reliability, accuracy, and precision of reported laboratory data generated by EMS's radiological and nonradiological monitoring programs and by subcontracted laboratories.

Applicable Standards

The "Westinghouse Savannah River Company Quality Assurance Plan" (WSRC-1-05, dated April 1, 1989) provides overall quality requirements to comply with DOE Order 5700.6B and the Savannah River Site Order DOE-SR5700.6C. These quality requirements are summarized in Table 2-1 (above).

The requirements of WSRC Quality Assurance Plan are implemented in the Westinghouse Savannah River Company (WSRC) Quality Assurance Manual (WSRC-1Q, formerly DPW83-111-1, "Savannah River Plant Quality Assurance Manual").

DOE Order 5400.6 requires EMS to develop a quality assurance plan as a mechanism for applying QA requirements to the environmental monitoring program. This plan, which is currently being developed, will address the 18 elements of the national consensus standard ANSI/ASME NQA-1 (Quality Assurance Program Requirements for Nuclear Facilities), which are highlighted on the facing page (right).

Subcontracted laboratories performing analytical services for EMS are subject to the same quality requirements defined in the "Westinghouse Savannah River Company Quality Assurance Plan", WSRC-1-05.

Objectives

The EMS QA/QC program is designed to detect problems that may exist in the sample collection, preparation, analysis, or data evaluation phases of the environmental monitoring program.

EMS established the following objectives for the internal QA/QC program:

- to routinely assess all standard operating procedures for accuracy, precision, sensitivity, and specificity
- to check the performance of the routine monitoring operations and to ensure that all aspects of the QA program are operative
- to assess routine analyses with an internal blind sample program

- to perform corrective action when necessary
- to meet or exceed laboratory certification standards established by the EPA and the State of South Carolina
- to conduct the EMS QA program in accordance with the WSRC Quality Assurance Manual (WSRC-1Q, formerly DPW-83-111-3, "Savannah River Plant Quality Assurance Manual").

Policies

EMS incorporates the following procedures into the QA/QC program to maintain high quality:

- A minimum of 10% of all samples are used as QA/QC control samples.
- Control charts are used in radiological and nonradiological laboratories.
- EMS routinely participates in interlaboratory programs.
- Periodic calibrations are performed on all field and laboratory instruments using specific sources traceable to the National Institute of Standards and Technology (NIST) or using other standards recognized by DOE.
- Fresh reagents and chemicals are used, when appropriate, in all laboratories.
- QC samples, such as reagent blanks or other appropriate blank, and direct and indirect spikes (samples to which a known concentration of standard solution is added), are analyzed with each batch of routine samples.

Eighteen Elements of the QA Plan

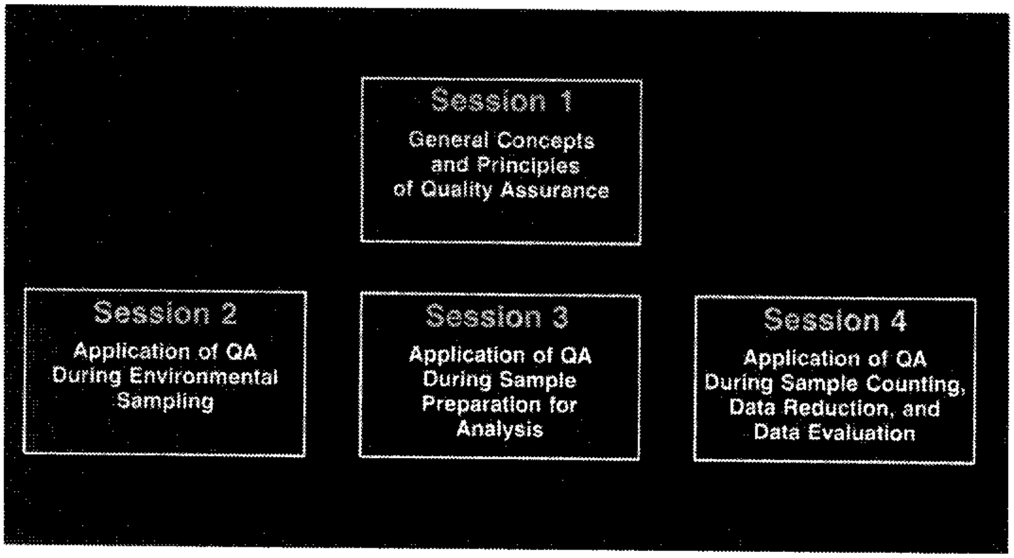
- Organization
- QA Program
- Design Control
- Procurement Document Control
- Instructions, Procedures, Drawings
- Document Control
- Control of Purchased Items and Services
- Identification and Control of Items
- Control of Special Processes
- Inspection
- Test Control
- Control of Measuring and Test Equipment
- Handling, Storage, and Shipping
- Inspection, Test, and Operating Status
- Control of Nonconforming Items
- Corrective Action
- Quality Assurance Records
- Audits

Interlaboratory Comparisons

The purpose of an analytical procedure is to measure the correct concentration of constituents present in standard or reference samples. EMS laboratories and commercial subcontracted laboratories routinely participate in interlaboratory comparisons to track performance accuracy. These comparisons not only test the accuracy of procedures performed by EMS and subcontracted laboratories, but they also compare EMS and subcontracted laboratories with other nationwide laboratories. Below are descriptions of interlaboratory comparisons conducted in 1989.

Quality Assessment Program
The U. S. Department of Energy (DOE) Quality Assessment Program (QAP), an external QA program, tests the quality of environmental data reported to DOE by its contractors. Reference samples for this program are

prepared by the DOE Environmental Measurements Laboratory (EML) and include samples of soil, water, vegetation, animal tissues, and air filters. Analytical results are reported to EML within 90 days and compared with the test results of other participating laboratories. EML evaluates and distributes the results to the participating laboratories.



Four-part QA training course designed specifically for EMS

Quality Assurance Division

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 participating laboratories with water, air, milk, and food samples which contain a variety of radionuclides with activity concentrations near environmental levels. This program enables EMS laboratories to document the precision and accuracy of radiological analysis data, to identify instrument and procedural problems, and to compare analysis performance with other participating laboratories.

Nonradioactive Discharge Monitoring Report Quality Assurance

All EMS-subcontracted laboratories analyzing NPDES samples participate in the EPA nonradioactive Discharge Monitoring Report Quality Assurance (DMR QA) assessment program. Participating laboratories receive performance samples containing constituents normally found in industrial and municipal wastewaters.

These water samples have known chemical parameters such as chemical oxygen demand, and contain known concentrations of constituents such as total suspended solids, oil and grease, and certain trace metals. The EPA provides a final comprehensive report to the program participants. The report contains a statistical analysis of all data and documentation of the "true" sample value with stated "acceptance limits" and "warning limits".

EPA Audit Program

The ambient air monitoring program, subcontracted to Zedek Corporation, participates in the EPA ambient air audit program. The program consists of audits of the sulfur dioxide (SO_2) monitors with a range of SO_2 concentrations. An EPA subcontractor summarizes the "indicated results" reported by SRS, with the EPA "actual" values. Differences and percent differences of these two values are also reported.

Personnel Training

EMS trains analysts and technicians working within specific EMS work groups to ensure that procedures are performed properly. "Hands on" and classroom training are used to teach specific sampling and analytical techniques.

Training is a critical element in maintaining quality and improves the reliability and defensibility of the data. For this reason, all EMS personnel receive annual QA/QC training for environmental monitoring. This training focuses on general QA/QC concepts and their application throughout the monitoring process (above).

Documentation

To ensure valid and defensive monitoring data, EMS documents all information and data generated within the monitoring program as required by DOE Order 1324.2A and the WSRC Quality Assurance Manual (WSRC-1Q).

EMS-generated documents include sampling and analytical procedure manuals, logbooks, chain-of-custody procedures, calibration and training records, analytical notebooks, and validated laboratory data. These records are maintained and stored according to retention times specified in the inhouse document HP-1, "Health Protection Record Retention Schedule."

Compliance Evaluations and Quarterly Report

EMS performs periodic internal evaluations to verify compliance with operating procedures, quality control procedures, and other aspects of the QA program. Table 2-2 (below) is a checklist of specific items to be reviewed during the evaluation. The evaluations are documented to ensure an effective QA/QC program and to identify areas of the monitoring program that require improvement.

EMS also periodically evaluates the performance of subcontracted laboratories by conducting onsite evaluations of the facility. EMS develops an evaluation checklist based on EPA-recommended and approved laboratory procedures and practices. Following the evaluation, EMS documents the observations, findings, and recommendations and presents them to the laboratories. The subcontracted laboratories are then required to respond to the evaluation report within a specified time period. In 1989, EMS performed two onsite evaluations of subcontracted laboratories. The evaluations are discussed in the final section of this chapter.

Table 2-2
EMS Internal Evaluations

Sampling Group
QA/QC sampling team
Field blind samples
Instrument calibration
Chemistry Group
Pipet calibration
Control samples
Blind samples
DOE (QAP) samples
EPS (QAD) samples
Counting Group
Control charts
Instrument calibration
Data Evaluation Group
Monthly Releases Report
Rerun samples
All EMS groups are evaluated for :
Following updated procedures
Documenting information
Training

Since subcontracted laboratories are also required to meet the same QA requirements defined in WSRC QA plan (WSRC-1-05), they are evaluated by the WSRC Site Quality Department to ensure that their QA program meets the WSRC QA requirements. Each laboratory must pass the evaluation before performing any work for WSRC.

Every quarter, the QA/QC coordinator issues an internal QA/QC report for each EMS work group. This report is used to monitor QA/QC activities that determine conformance with QA/QC policies and procedures. The quarterly report contains inter- and intralaboratory comparisons, control charts, training, irregularity and corrective action reports, internal evaluation reports, and QA/QC programs.

QA/QC FOR ENVIRONMENTAL MONITORING ACTIVITIES PERFORMED ONSITE

QA/QC Within Environmental Sampling

Description of Program

In an environmental monitoring program, the objective of sampling is to collect representative samples for quantitative analysis of the radioactive and nonradioactive constituents.

The EMS Environmental Sampling work group maintains the following elements to achieve this QA/QC objective:

- sampling procedures
- field records (logbooks, chain-of-custody forms)
- instrument calibrations
- preventive maintenance
- backup sampling equipment
- housekeeping

In addition, a QC team evaluates six key stream sample collection sites weekly to identify, document, and correct problems at each site. These key sampling points—Upper Three Runs-4, Four Mile-6, Pen Branch-3, Four Mile-3A, Four Mile-2, and P-019 (effluent to Par Pond)—are evaluated because they are the most useful in quantifying releases of contaminants to streams.

Program Improvements in 1989

Procedures

In 1989, EMS reviewed and modified environmental sampling procedures so that each procedure contains the following information:

- specifications for all sampling techniques and equipment
- an outline of field documentation procedures
- specifications for containers and preservation requirements for analytes
- specifications of label requirements for containers
- specifications for interim field sample storage
- specifications for calibrating and operating direct reading field instruments

Blind Sample Program

EMS began a blind sample program for field measurements of pH and conductivity during 1989 to improve quality and reliability of field data measurements. Since surface water monitoring is subject to compliance audits under the Clean Water Act and wastewater discharge permits, accurate field measurements are required to avoid regulatory violations and to provide reliable data to the auditors.

In the blind sample program, the EMS Environmental Chemistry work group prepares blind test solutions having known pH and conductivity values and documents the values in a logbook. Two technicians verify the values, and a supervisor approves them before the solutions are used in the field. These solutions are sent with field sampling personnel when routine samples are collected. Conductivity and pH measurements are taken in the field with the same equipment used for *in situ* measurements. The field sampler records the measurements on a data sheet and returns the remaining solution and the data sheet to the laboratory.

A technician takes a final measurement on the remaining solution. This value is documented and all measurements are submitted to the QA/QC coordinator for evaluation.

The blind sample program documents the accuracy of EMS field measurements and allows continuous monitoring of field measurements and field calibration status so that corrective actions can be initiated. The pH and conductivity field measurement results from the blind sample program are presented in Table 2-1, Vol. II. The 1989 data from this program indicate a high level of accuracy for field pH measurements.

All blind sample pH measurements were within ±0.4 pH units as shown in Figure 2-1 (below). The conductivity blind sample measurements were also accurate within ±5.2% with the exception of three samples. The problem was due to the control solutions and not with the measurements.

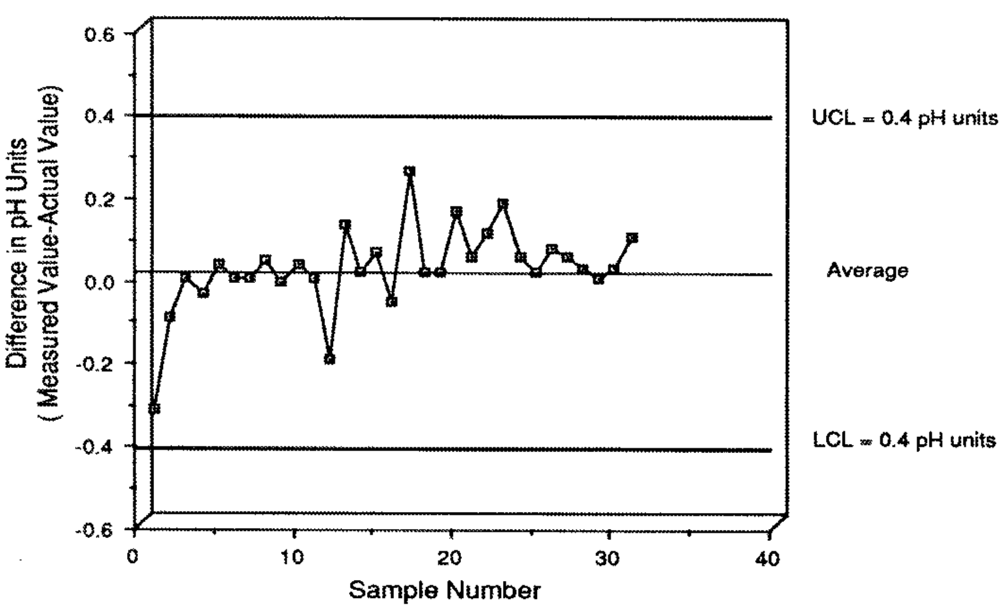


Figure 2-1. Accuracy of blind pH field measurements

QA/QC Within Environmental Chemistry and Counting Laboratories

Description of Program

The objective of standard environmental chemistry and counting laboratories is to prepare and analyze samples to obtain accurate and defensible data. The QA/QC program within the EMS Chemistry and Counting Laboratories is designed to meet this objective. Routine internal checks (e.g., calibrations, control charts, blind sample analysis) and participation in interlaboratory quality assurance programs are specific elements of the QC program.

Procedure and Instrument Checks
EMS uses various radiochemical procedures and radioanalytical instruments to analyze environmental samples. To ensure that procedures are performed correctly and the instruments are working properly, the EMS Chemistry and Counting Laboratories perform the following QC checks:

- obtain source and background counts for all counting systems
- maintain instrument performance histories in logbooks and computer files
- determine yields for radiochemical procedures
- perform precision checks using replicate analyses
- use standards traceable to NIST

Control Charts
Control charts are graphical representations of statistical variation produced by the analytical process. 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. The ±3 standard deviation limit is most often used for control limits; the ±2 standard deviation limit is used for warning limits.

EMS uses control charts to study instrument performance, and accuracy and precision of analytical results. Control charts ensure quality only when the results are used to identify and correct factors that adversely affect the results.

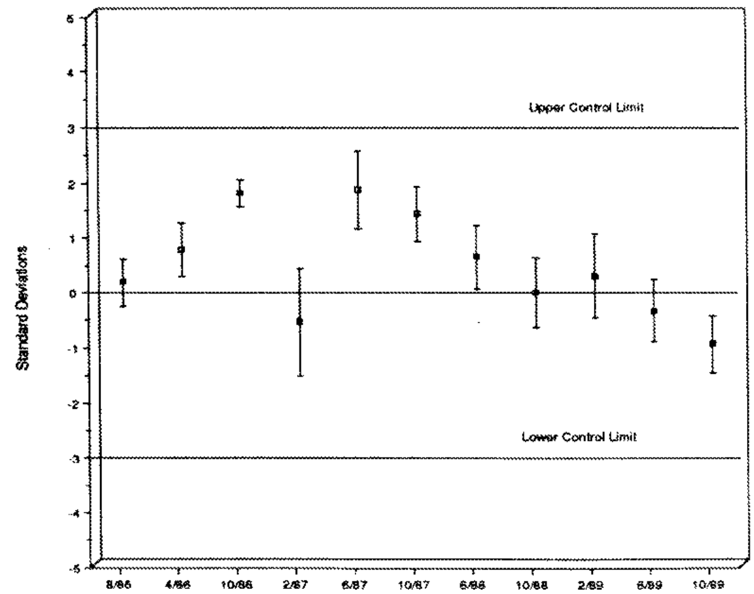


Figure 2-2. Control chart for QAD tritium sample analyses

Instrument Control Charts
Control charts are maintained for all instruments in the Counting Laboratory in the QA/QC program. These control charts track instrument performance and malfunctions. By recording routine source-check and background determinations on control charts, the instrument operator can detect deviations from the "true" value even though the statistical nature of radioactive decay will cause uncertainties in determining source-check and background count rates. An instrument's calibration is considered out of statistical control when:

- any one point is outside of control limits
- any three consecutive points are outside of warning limits

When an instrument is found to be out of control limits, laboratory supervisors and managers are notified. The instrument is inspected and necessary adjustments are made to correct the problem.

Accuracy Control Charts
"Accuracy" control charts are prepared quarterly with data from EPA interlaboratory samples analyzed in the QAD program. Analysis results are plotted quarterly. These control charts provide historical information on the accuracy of measurements. The charts verify both the accuracy of analytical methods and of the resulting data.

Figure 2-2 (above) is an example of QAD samples analysis of tritium in water. The Y-axis is defined as "units of standard deviation" and establishes the deviation from the "true" measurement. The error bars above and below the reported measurement reflect the uncertainty of the value. Warning limits for accuracy control charts are set at ±2 standard deviations, and control limits are set at ±3 standard deviations.

Precision Control Charts

"Precision" control charts reflect the repeatability of analysis and identify any noticeable trends in the data or differences in the analysts' technique. These control charts are developed by compiling recoveries of radionuclide-spiked samples. Gross alpha-spiked vegetation sample recoveries are shown (below) in Figure 2-3, with control limits normally set at 70% and 120% of the spike value. When recoveries fall outside these limits, the problem (e.g., analyst technique) is investigated and the samples are reanalyzed.

'Quality Control Sample' Program

Performance of EMS laboratories is monitored through internal audits using standard samples. Samples consisting of air filters or water samples are prepared with known levels of radionuclides typically found in routine samples. Whenever possible, QC samples are prepared from NIST-traceable material or standardized against NIST material. The QC samples are labeled as "QC Blind" to aid in data retrieval. "QC Blind" samples are analyzed in the Counting Laboratory and the results reported to the QA/QC coordinator. The compiled data verify that procedural controls are maintained by the laboratory.

In 1989, the QC sample program consisted of the following determinations:

- gross alpha and nonvolatile beta
- gamma-emitting radionuclides— ^{60}Co, ^{65}Zn, ^{106}Ru, ^{134}Cs, and ^{137}Cs
- tritium
- strontium-90 and ^{35}S

The results of the internal QC sample program are presented in Tables 2-2, 2-3, 2-4, and 2-5, Vol. II. The accepted ratio for accuracy is 0.8 to 1.2. In general, the ratio of the measured value to the true value indicated accurate analyses. The only exception was the nonvolatile beta samples spiked with ^{137}Cs. These QC samples were consistently lower than the known values. It was discovered that the problem occurred during calibration of the gas-flow proportional counters. Strontium-90/^{90}Y, which overestimates the counter's efficiency to detect ^{137}Cs, was used to calibrate the gas-flow proportional counters.

In addition to the routine blind sample program, EMS also performed a collaborative study with the Analytical Development Division of the Savannah River Laboratory (SRL) to determine ^{137}Cs concentrations in blind water samples. In the study, SRL diluted a primary NIST-traceable ^{137}Cs standard which had 3% uncertainty. EMS then counted the samples for 5,000 seconds on an HPGe detector. The results, presented in Table 2-

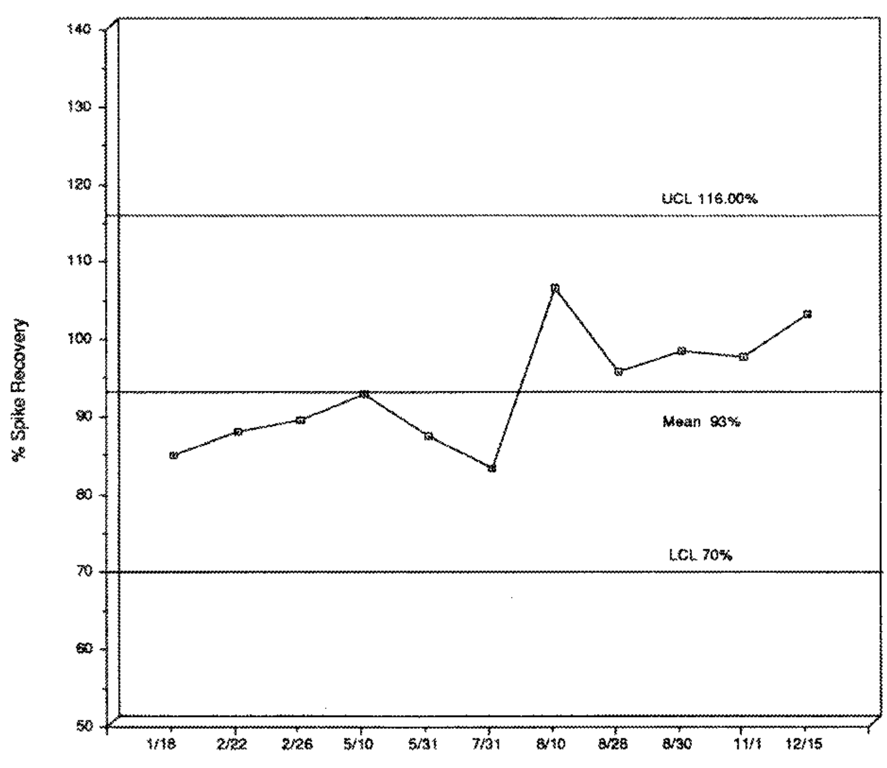


Figure 2-3. Precision control chart for gross alpha analysis in vegetation

6, Vol. II, indicate the analysis was accurate; however, the counting uncertainty was large at the low concentration levels. The high uncertainty of the measurements was attributed to the short counting time.

Interlaboratory Programs
In addition to the internal QC sample program, EMS participates in two interlaboratory quality assurance programs annually. 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 EMS in the QAD and QAP programs are presented in Table 2-7 and Table 2-8, Vol. II.

The ±20% indicator shown in the Volume II tables is a convenient measure of overall relative performance. Participation in the interlaboratory comparison programs is based on the assumption that the QAD and QAP samples have activity levels similar 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 minimum detectable concentration for the analysis, the associated statistical uncertainty of the measurement at the 95% confidence level may exceed the ±20% range. In such cases, the routine analytical process is not designed to quantify those particular radionuclides at the specified activity levels. For this reason, laboratory performance is more precisely determined by evaluating the process to ensure that it remained within the established control limits.

The results reported by EMS in the QAD and QAP programs fell 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 necessary.

QA/QC Within Data Evaluation

Data validation within EMS is the process of evaluating and accepting or rejecting data. The criteria and methods used to validate the data are based on the type and purpose of the measurement. Listed below are criteria used to validate environmental monitoring data:

- documentation of sample identity and handling (e.g., preservation and required analyses)
- use of approved analytical procedures
- use of known control samples and EPA check samples
- results of blanks, duplicates, and blind samples analyses
- precision and accuracy results for replicate and control samples

QA/QC and supervisory personnel validate all data produced within EMS. The verification process includes checking the following criteria:

- The sample must be valid (i.e., labeled properly and documented collection date).
- The analysis must be performed using an approved procedure.
- The result must have an associated uncertainty or limit of detection.
- The result must fall within two standard deviations of historical values excluding outliers from the limit calculation.

If the data do not meet these checks, the sample is tracked back to the Counting and Chemistry Laboratories to determine if any analytical mistakes were made or if the origin of the sample might indicate unusual levels of radioactivity. If the problem is not identified, a sample is reanalyzed to verify the result.

QA/QC FOR NONRADIOLOGICAL MONITORING ACTIVITES

The majority of the nonradiological monitoring program is subcontracted to offsite laboratories, which must have an acceptable QA/QC program and incorporate QA/QC requirements established by WSRC.

Because each nonradiological monitoring program has different purposes and requirements, each laboratory is required to perform specific QA/QC activities. This section will discuss important QA/QC elements within each nonradiological program subcontracted to offsite laboratories.

Ambient Air Quality Program

Description of Program

The ambient air quality monitoring program is conducted by Zedek Corporation, under contract to EMS. Ambient air monitoring stations are equipped with gaseous analyzers that monitor for sulfur dioxide, oxides of nitrogen, and ozone, as well as samplers which monitor for ambient air particulate matter.

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. In addition to quarterly audits, daily zero and span checks are done on each analyzer.

Quarterly audit results are evaluated by two methods: (1) by comparing 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 through 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 is used to determine the data quality and analyzer calibration.

As part of the QA/QC program, Zedek also participates in an annual EPA- interlaboratory audit. For the audit, EPA provides audit devices to measure SO_2, NO, and NO_2. If the results obtained during the audit differ from EPA-determined values by ±10% or more, the monitoring system is examined to determine if the percent difference can be reduced and the instrument is then recalibrated. If the difference is ±15% or more, the instrument is recalibrated and the instrument problems and corrective actions are reported to DOE.

Ambient Air Quality Program Results

During the quarterly ETI audits, the following criteria are used for data evaluation and corrective action for the gaseous analyzers:

Slope:	satisfactory	(≤±15%)
Intercept:	satisfactory	(≤±15%)
Correlation Coefficient:	satisfactory	(0.995 to 1.000)

Calibration of each analyzer is checked quarterly using the appropriate calibration gas. In 1989, all forty calibration tests of gaseous analyzers had less than 15% difference. Clearly, all gaseous analyzers produced satisfactory data throughout the year.

The audit criterion for satisfactory calibration of the total suspended particulate samplers is ±7% difference. All of the samplers, including one control sampler placed adjacent to a primary sampler, are audited on a quarterly basis. Of the 24 tests conducted in 1989, all results showed differences of less than 7%.

Results of the Zedek annual EPA interlaboratory audit and the ETI quarterly audits are presented in Tables 2-9 and 2-10, Vol. II.

NPDES Program

Description of Program

Liquid effluent samples are collected at each permitted SRS outfall 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 analyzed onsite for fecal coliform and biochemical oxygen demand and offsite by a subcontracted laboratory for other constituents.

In 1989, the primary subcontractor for the NPDES program was Normandeau Associates, (NAI). All NPDES analyses performed by NAI are subject to quality control checks using the following methods:

- EMS intralaboratory checks
  - 10-15% duplicate samples
  - blind samples analyzed twice a year
  - periodic blanks
- EMS interlaboratory comparisons
  - 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

Normandeau Associates, Inc. QA/QC Programs

NAI maintains analytical QA/QC programs to ensure the reliability of its analytical data. The established programs, based on the Normandeau Associates 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

NAI 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 maintain quality control within its laboratory.

NAI conducts analytical performance checks by replicating 10% of all samples in a batch and determining the precision of the analysis. Spikes represent another 10% of each batch of samples for determining the accuracy of the analysis. 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 parameter routinely analyzed. Data verification procedures require that 20% of all calculated analytical values be recalculated by another analyst or supervisor. If any calculations are in error, the entire set of sample analyses for that time period must be recalculated.

Performance Results and Compliance Audits

During 1989, NAI analyzed 45 blanks and 215 duplicate and quadruple samples for various parameters. The results indicated less than 5% difference between each duplicate set. In addition, 22 EMS-submitted blind samples, analyzed for various parameters, had ratios of accuracy in the acceptable (0.8–1.2) range. Results of duplicate and blind sample analyses completed during 1989 are presented in Table 2-11 and Table 2-12, Vol. II.

In 1989, SCDHEC performed 12 NPDES compliance audits at SRS during 12 monthly visits in addition to an annual comprehensive audit in November. SCDHEC collected two series of samples from the 76 active NPDES sampling stations and EMS collected duplicate samples from each series for comparison.

SCDHEC also collected samples at each location for dissolved oxygen and chlorine analyses during the annual audit. SRS received a satisfactory rating on all but two sample parameters from over 900 parameters monitored during the comprehensive survey.

Stream and River Water Quality

Description of Program

With the exception of metals analyses, most stream and river water quality analyses are performed by the EMS Chemistry 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 American Public Health Association's *Standard Methods for the Examination of Water and Wastewater (15th edition).*

The following measures are examples of established controls used in the water quality QA/QC program:

- EPA-approved 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.

Operating procedures define the frequency of replicates, spikes, and reagent standardizations. The procedures also provide instruction for using work sheets for method calibration and instrument settings documentation. Each type of analysis has specific QC procedures.

Control charts, similar to those used for the radiological QA/QC program, are being implemented for all water quality analysis instrumentation in the nonradiological laboratories.

The spike recovery in percent is calculated from the true values of NIST standards and documented on control charts. Acceptance limits for the control charts provide an immediate evaluation of the accuracy and precision of each analytical method.

Whenever possible, NIST-traceable standard reference solutions are used to verify the accuracy of calibrated yield determinations. When traceable standards are not available from NIST, standard solutions are prepared according to EPA and American Public Health Association's guidelines [EPA79, SW86] to satisfy QA/QC requirements.

Data verification within the EMS water quality laboratory is documented by authorized signatures on the operational work sheets. All calibration information is documented, and control charts are reviewed to determine that the methods are within control limits. Each mathematical calculation is checked and approved before reporting sample concentration values. Signature approval verifies the accuracy of data transfer to the final report.

A subcontracted laboratory analyzes water samples for metals content. The water quality QA/QC program requires duplicate analyses of 5% of the samples to verify the analytical results between subcontracted laboratories. In 1989, aliquots representing 20% of the samples submitted for metals analysis were split to provide identical samples to two subcontracted laboratories. A higher percentage of duplicates than the required 5% were sent to the laboratories to ensure verification for the small sample load.

ETI, the major subcontractor for water quality analyses, received samples quarterly from each of the 11 water quality monitoring locations. The split sample aliquots from two locations for each quarter were distributed to J. H. Carr and Associates. Both laboratories determined the concentrations of 12 metals. The comparison of analytical data submitted by the two laboratories is provided in Table 2-13, Vol. II.

Groundwater Monitoring Program

Subcontracted companies and laboratories perform sampling, analysis, and data evaluation activities for the groundwater monitoring program. These subcontractors are required to adhere to the "Westinghouse Savannah River Company Quality Assurance Plan" (WSRC-1-05).

Scheduling

Many of the groundwater wells monitored at SRS are regulated under the Resource Conservation and Recovery Act (RCRA), as well as by other state and federal regulations. In addition to monitoring to satisfy regulatory requirements, constituents that may be present in the groundwater are also monitored. Each quarter a groundwater monitoring schedule is developed based on the following criteria:

- New wells are sampled for a comprehensive series of analytes for four consecutive quarters.
- Constituents identified in the initial four quarters of analyses are "flagged" as either "flag 1" or "flag 2", depending on the concentration of the constituent. "Flag 1" means a constituent is above a background or detection limit concentration, while "flag 2" usually means the constituent is above one-half the drinking water standard. "Flag 1" constituents are subsequently analyzed annually and "flag 2" constituents are analyzed semiannually. Analyses that are not flagged are performed once every two years unless a special request is made.
- Wells are analyzed for a comprehensive list of analytes once every two years to identify any new contaminants.

Once the schedule is developed, site custodians review the schedule before a new sampling quarter begins. Additional analytical or sampling requests are added to the monitoring schedule; however, any changes or additions must be accompanied by written documentation. All changes are then logged into the *Groundwater Monitoring Sample Schedule Request Log*.

Groundwater Sampling and Analyses

EMS's Environmental Sampling group and a subcontracted company, GE-HY, collect groundwater samples. Sampling procedures, including the addition of preservatives, packaging and shipment, and chain-of-custody requirements, are consistent with EPA-recommended and Department of Transportation/SCDHEC approved procedures.

Groundwater samples are analyzed by the SRS Analytical Laboratory located in M Area (MA), by the EMS Chemistry Laboratory, and by subcontracted laboratories. The subcontracted laboratories analyzing groundwater samples are certified by SCDHEC.

In 1989, the following six quality control practices were performed under the QA/QC program:

- Blind replicates representing 5% of all samples analyzed were submitted to the primary laboratories, Envirodyne Engineers, Inc. (EEI) during the first quarter, and to General Engineering Laboratories (GE) and metaTRACE, Inc. (MT) during the remaining three quarters. Teledyne Isotopes Laboratories (TE) received 5% blind replicates for all four quarters during 1989.
- Replicates representing the same 5% of the samples were submitted to two additional QA/QC laboratories, Roy F. Weston Analytical Laboratory (WA) in Lionville, PA and Enwright Laboratories in (EW) Greenville, SC, during the first and second quarters of 1989, and to GE and MT during the third and fourth quarters of 1989 for comparative analysis.
- Trip blanks (samples of deionized water that are shipped with groundwater samples) representing 3% of the total number of samples were sent to the primary laboratories for comparative analyses each quarter.
- Blind blanks representing 3% of the total number of M-Area samples were sent to the M Area analytical laboratory quarterly
- EMS sent Environmental Resource Associates (ERA) quality control samples having known concentrations to each of the primary laboratories. Each laboratory received one set of unprepared samples, which they prepared and analyzed.
- Each laboratory conducted an inhouse replicates program by analyzing a duplicate, a reagent blank, and a spiked method blank or check standard with each sample lot (usually 20 or fewer).

In addition to the EMS quality assurance/quality control program, each laboratory maintains an inhouse QA/QC program that includes the following specific elements:

- maintaining chain-of-custody
- applying EPA-recommended preservation techniques and holding times
- using EPA-approved analytical procedures
- using calibration and quality control procedures for analytical instruments
- analyzing samples within the prescribed daily calibration of instrumentation
- adhering to scheduled maintenance procedures for instruments and equipment
- training personnel in use of equipment and methods
- validating and reporting data

Each laboratory also participates in EPA-sponsored interlaboratory programs, which involve analyzing unknown performance evaluation samples, known EPA performance standards, and laboratory check standards.

Evaluation of Groundwater Data

Routine Quality Assurance

Field measurements and laboratory analytical data are transferred onto diskettes in flat ASCII format files that are loaded onto a mainframe database. Data transfer logbooks are maintained to track receipt and transfer of data to the database.

Once in the database, the data are validated using computer programs. Below are several QA/QC checks performed for the groundwater monitoring program:

- The correct well names and sample dates for field and analytical data are verified.
- Completion of all analyses requested on the chain-of-custody forms is verified for each laboratory.
- Identification of data entry problems (e.g., duplicate data, incorrect units, detection limits)

- Quarterly analytical data are compared against historical analytical data and reviewed for transcript errors, instrument errors, or calculation errors.

- Blind replicates and laboratory inhouse replicates are compared for inconsistencies.

- Laboratory blanks and blind blanks having elevated concentrations are identified.

After these checks are performed possible transcription errors and suspect results are documented and submitted to the appropriate analytical laboratory for verification or correction. No changes are made to the database until the laboratory documents the problem and solution. If changes to the database are required, they are documented in the *Groundwater Monitoring Program Changes to the Database Log.*

EMS documents any database changes, suspect results that have been verified by the laboratory, and the analyses performed with blanks having elevated results in a groundwater monitoring report that is published quarterly.

Statistical Treatment of Groundwater Data

In addition to the routine QA checks, a QA/QC statistical analysis program was developed for the groundwater monitoring program in 1989. This program is used to identify problems with analytical procedures and to assess the measurement precision or repeatability of identical chemical analyses. An index known as the Mean Relative Difference (MRD) is used to evaluate a series of replicate samples. The MRD is defined as:

$$\mathrm{MRD} = \left\{ \sum_{j=1}^{n} \frac{(|X_j - Y_j|)/[(X_j+Y_j)/2])}{n} \right\} 100$$

where X_j and Y_j represent the concentration of a given groundwater sample and its replicate for the j^{th} well. This MRD statistic is used for intralaboratory comparisons (MRD_W). The quantities X_j and Y_j could also represent the mean analyte concentrations for the j^{th} well at each of the two laboratories, which allows interlaboratory comparisons (MRD_B).

For intralaboratory comparisons, MRD_W is interpreted as the average absolute difference between an original sample and its replicate. MRD_W is expressed as a percentage of the mean of those two samples.

For interlaboratory comparisons, MRD_B is interpreted as the average absolute difference between laboratories for the j^{th} well. MRD_B is expressed as a percentage of the mean of both laboratories.

The MRD is a measure of precision or repeatability of contaminant concentration measurements by two different laboratories on the same groundwater samples or by the same laboratory on replicate groundwater samples. The MRD is closely related to the reciprocal of the signal-to-noise ratio or relative standard deviation [SHA86].

In 1989, the MRD was used to evaluate replicate analyses of samples performed by metaTRACE, Inc. and General Engineering Laboratories for replicate analyses performed during the second, third, and fourth quarters of 1989. A complete discussion of the use of the MRD and the results are presented in Table 2-14 in Volume II.

Performance Evaluations of Subcontractors

Interlaboratory Comparisons

EMS routinely evaluates the performance of subcontracted laboratories using the following methods:

- evaluating laboratory performance by using EPA Performance Evaluation (PE) samples and EMSL-LV inorganic data evaluations as part of the EPA Water Pollution Study (WP022)

- periodic testing of the precision and accuracy of commonly analyzed inorganic and organic parameters with Environmental Resource Associates (ERA) quality control samples

- onsite laboratory visits and evaluations to ensure that subcontractors maintain technical competence and apply the required QA/QC programs

In 1989, EMS conducted two interlaboratory comparisons for subcontractors performing NPDES, QA, and miscellaneous chemical analyses. Identical samples with known concentration values were sent to the subcontracted laboratories for analysis. The reported analytical data were compared to the known values and range of acceptable values and to the other laboratory's reported values. Each laboratory was then rated for proficiency by calculating the ratio of results within acceptable ranges to the number of analyses performed. The acceptable limits of proficiency were 81-100%.

The first comparison was conducted in May 1989. Normandeau Associates (NAI), subcontractor for the NPDES program, was requested to analyze 47 nonradiological parameters. Environmental Testing, Inc. (ETI), subcontractor for miscellaneous analytical work, was requested to analyze samples for 19 nonradiological parameters. The analysis results in the first comparison revealed that NAI and ETI performed within acceptable levels of proficiency (81%-100%). NAI received a 94% proficiency rating and ETI received an 89% proficiency rating. The correlation of analytical results between the two subcontracted laboratories was good, which verified that solutions used in the test were valid and provided a fair means of evaluating laboratory proficiency. Table 2-15, Vol. II. presents the results of this interlaboratory comparison.

The second comparison was conducted in October 1989. In addition to NAI and ETI, J. H. Carr and Associates, subcontractor for QA and miscellaneous analyses was rated for proficiency. The analysis results in the second comparison revealed that NAI, ETI, and Carr performed within acceptable levels of proficiency (81%-100%). Normandeau was rated with a 93% proficiency; Carr was rated with a 95% proficiency; and ETI was rated with an 87% proficiency. The results of the second interlaboratory comparison are presented in Table 2-16, Vol II.

In 1989, subcontracted laboratories performing analyses for EMS also participated in an EPA-sponsored performance evaluation program. EPA provided samples spiked with known concentrations of constituents of interest to SRS. The EPA forwarded samples to each subcontracted laboratory for analysis of trace metals (aluminum, cadmium, chromium, copper, iron, lead, manganese, nickel, and zinc), nutrients (nitrate-nitrogen and total phosphorus), volatile organics, biochemical oxygen demand, and miscellaneous constituents such as pH, oil and grease, and total suspended solids.

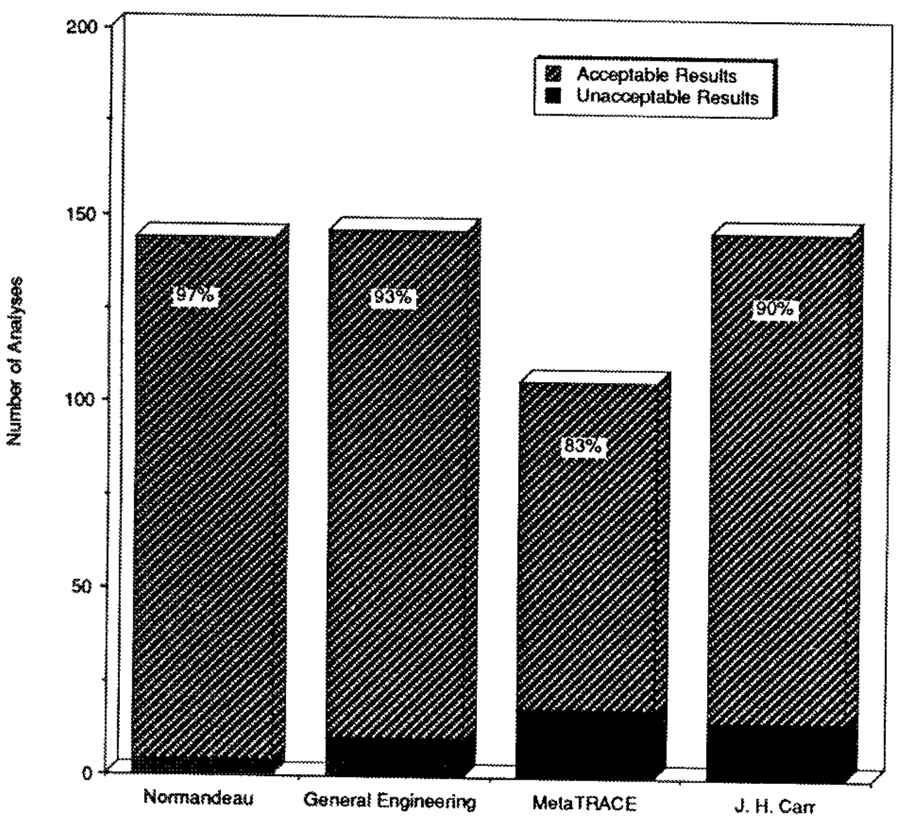


Figure 2-4. EPA (WPO22) proficiency rating

In 1989, Normandeau Associates, J. H. Carr, General Engineering Laboratories, and metaTRACE, Inc. (two laboratories performing groundwater analyses) participated in the evaluation program and received acceptable ratings (81-100%). Figure 2-4 (left) shows the overall proficiency of EMS subcontractors during 1989 for the EPA-sponsored evaluation program. Table 2-3 on the following page further summarizes the evaluation program.

Onsite Evaluations

In 1989, EMS conducted a performance evaluation for two subcontracted laboratories, Normandeau Associates (NPDES program) and metaTRACE, Inc.(groundwater monitoring program). EMS reviewed the QA/QC and

Table 2-3
EPA (WPO22) Proficienty Rating[a]

Subcontracted Laboratory	No. of Analyses	Acceptable	Unacceptable	% Proficiency
Normandeau Associates	146	140	4	97
General Engineering	146	136	10	93
metaTrace	106	88	18	83
J. H. Carr	146	131	15	90

[a]Each laboratory is certified by its respective state and by SCDHEC. To maintain certification, each laboratory must pass an annual review of all certified analyses. In general, a proficiency rating of 81% is considered the minimum acceptable score according to the Contract Laboratory Program (CLP).

laboratory programs during the evaluation. The review was divided into the following 11 areas:

- QA policy
- calibration procedures
- laboratory organization
- data verification
- facilities
- data reports
- sample receipt
- records management
- preventive maintenance
- nonconformance and corrective actions
- analytical procedures

Following the evaluation, a report documenting findings, observations, and recommendations was submitted to both subcontracted laboratories. EMS will conduct a follow-up evaluation in 1990 to ensure that the recommendations in the audit report have been implemented.

1989 HIGHLIGHTS

- In 1989, EMS began a blind sample program for surface water field measurements of pH and conductivity. The sample measurements for pH were within ±0.4 pH units and for conductivity were within ±5.2%.
- QC samples, prepared from NIST-traceable material and analyzed for gross alpha and nonvolatile beta, gamma-emitting radionuclides, tritium, ^{90}Sr, and ^{35}S, fell within the accepted ratio for accuracy of 0.8 to 1.2.
- Of the 24 quarterly tests conducted on total suspended particulate samplers in 1989, all results showed differences less than 7%, the audit criterion for satisfactory calibration.
- During 1989, 45 blanks and 215 duplicate and quadruple samples of liquid effluents were analyzed for various parameters, with less than 5% difference between each duplicate set.
- South Carolina Department of Health and Environmental Control performed 12 NPDES compliance audits at SRS, plus a comprehensive audit in November. Except for two sample parameters, SRS received satisfactory ratings on over 900 parameters that were monitored.
- In 1989, EMS conducted interlaboratory comparisons of the subcontractors, Normandeau Associates, Inc., Environmental Testing, Inc., and J.H. Carr and Associates. All had acceptable limits of proficiency of 81–100%.

3
Methods for Calculating Offsite Radiation Doses

SUMMARY—The purpose of this chapter is to describe the methods and models used to calculate offsite radiation doses from atmospheric and liquid releases at SRS. The chapter also provides definitions for absorbed dose, dose equivalent, effective dose equivalent, collective (population) dose, committed dose, internal dose factors, and environmental dose commitment.

Applicable dose standards for protection of the public are taken from DOE Order 5480.1A, Chapter 11. Chapter 2 of DOE draft Order 5400.xx, contains revised interim standards which incorporate the recommendations and dose models contained in ICRP Publications 26 and 30.

Offsite dose calculations from SRS releases are based on several scenarios for affected individuals and population groups. The applicable dose calculation models are MAXIGASP, which calculates doses 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. Because tritium accounts for a dominant fraction of the offsite dose, modeling of tritium is performed with greater attention to chemical form and environmental behavior.

Finally, the chapter presents simplified representations of the important transport pathways of atmospheric and liquid radioactive materials to humans. Atmospheric transport models which assess routine releases from SRS are implemented in the computer program XOQDOQ. Offsite doses from nonroutine releases are calculated using computer programs available on the Weather Information and Display (WIND) System.

INTRODUCTION

This chapter discusses radiation dose terminology and describes how offsite doses are calculated from releases of radioactive materials to the atmosphere and surface water. The results of these calculations are presented in Chapters 4 and 5 and summarized in the Executive Summary.

RADIATION DOSE TERMINOLOGY: DEFINITIONS AND UNITS

Radiation dose is a calculated quantity that can be used to predict the occurrence, or probability of occurrence, of harm to individuals as a result of their exposure to radiation. In the International Commission on Radiological Protection (ICRP) methodology, radiation-induced health effects are 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 occurrence based on the level of exposure.
- **Nonstochastic health effects** are principally physical impairments such as cataracts in the lens of the eye, nonmalignant damage of the skin, and gonadal cell damage causing fertility impairment. 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" is commonly used. When an organ of the body is exposed to a source of ionizing radiation, the organ is said to receive a radiation dose. This 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,** which is defined to be the quantity of radiation energy absorbed by the organ divided by the organ's 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 absorbed by the organ, 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 that might occur as a result of the organ's irradiation do depend on the radiation type. For this reason, absorbed dose is inadequate for predicting 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.** This quality factor takes the radiation type into account. The ICRP has recommended the following quality factors for the radiation types of concern in this report:

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, which will be used in this report, 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 to the individual's total risk of experiencing stochastic health effects. The effective dose equivalent is defined as the sum of all organ dose equivalents after each one has been multiplied by an appropriate **weighting factor** that expresses the fractional risk of a stochastic health effect associated with one sievert (100 rem) of dose equivalent to that organ. The ICRP weighting factors are shown in Table 3-1 (below).

The **effective dose equivalent** is computed as follows:

Effective dose equivalent =
(0.25 × dose equivalent to gonads
+ 0.15 × dose equivalent to breast
+ . . .
+ 0.30 × dose equivalent to remainder)

The effective dose equivalent combines the individual organ dose equivalents 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.

A estimate of total stochastic risks from radiation is 0.04 fatal cancers and 0.026 genetic effects per sievert of uniform whole body irradiation. The cancers occur in the persons receiving the radiation, whereas the genetic effects occur in their progeny [EPA89]. These risk estimators are based on updated studies of A-bomb survivors and represent a "central" estimate. Because of uncertainties in the analyses, the risk of fatal cancers could range from 0.012 to 0.12 per sievert of uniform whole body irradiation, and the risk of genetic effects through all generations

Table 3-1
Organ-Specific Weighting Factors for Effective Dose Equivalent[a]

Organ	Weighting Factors
Gonads	0.25
Breast	0.15
Red marrow	0.12
Lung	0.12
Thyroid	0.03
Bone surfaces	0.03
Remainder[b]	0.30
Total	1.00

[a] Source: ICRP Publication 26 [ICRP77]
[b] Each of the five remaining organs receiving the highest dose equivalents is assigned a weighting factor of 0.06.

could range from 0.006 to 0.11 per sievert of radiation. The "central" estimate is used by the EPA as the basis for establishing federal standards for radiation dose to the public from emission of radioactive material to the atmosphere.

Because of the way it is defined, the effective dose equivalent multiplied by stochastic risks per sievert (0.04 for fatal cancers and 0.026 for genetic effects), approximates the statistical probability of occurrence of these effects for a given radiation exposure.

Collective (Population) Dose

The term **collective (population) dose** refers to the sum of individual doses received by all members of a population. In this report, the effective dose equivalent (individual dose) is used to calculate the collective dose. The unit of collective effective dose equivalent is the person-sievert (person-Sv) or the person-rem. For example, if each individual the CSRA population (555,100) 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:

555,100 persons	555,100 persons
× 1.0 mrem per year	× 0.01 mSv per year
× 0.001 rem per mrem	× 0.001 Sv per mSv
= 555.1 person-rem per yr	= 5.51 person-Sv per yr

An estimate of the expected number of fatal cancers in the population is calculated by multiplying the collective effective dose equivalent by the individual's total risk per sievert, 0.04. Using the 1989 total collective dose (0.22 person-Sv), the following method estimates the expected number of fatal cancers in the population:

0.22 person-Sv per year
× 0.04 fatal cancers per person-Sv
= 0.009 cancers per year.

This number corresponds to a statistical expectation of one fatal cancer in the population every 110 years (0.009), provided the number of exposed individuals and levels of exposure remain constant over time.

Committed Dose

Committed dose refers to the total dose resulting from an intake that has accumulated over a projected lifetime of an individual. A **committed dose equivalent** refers to an organ's committed dose. The **committed effective dose equivalent** refers to an individual's committed dose from a specified intake.

An individual's radiation dose from an external source is received only while the individual is exposed to the source. When the source of the radiation is a radionuclide inside the body, the situation then becomes 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. After the intake of radioactive material ends, the organs continue to be irradiated from the internal source.

The irradiation rate of the organs will diminish over time because the source is removed by biological processes and by radioactive decay. Since some materials are rapidly eliminated from the body, exposure from emitted radiations is short-lived. Similarly, some materials are radiologically short-lived (their radioactivity decays rapidly), and the irradiation rate of the organs from those materials also diminishes quickly. Other materials, however, are radiologically long-lived and firmly retained within the body. These types of radioactive sources may remain in the body emitting radiation for months or years. As a result, the 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 (radioisotope) of intake and the radiological and biological properties of the radioactive material taken into the body as shown in Figure 3-1 on the following page.

In using mathematical models to calculate committed dose, 50 years—the approximate residual life expectancy of a young adult—has 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 lifetime dose to older individuals.

Internal Dose Factors

Internal dose factors are used to calculate the committed dose equivalent to an organ and the committed effective dose equivalent to an individual. These factors are specific to the radionuclide and to the intake mode (inhalation or ingestion).

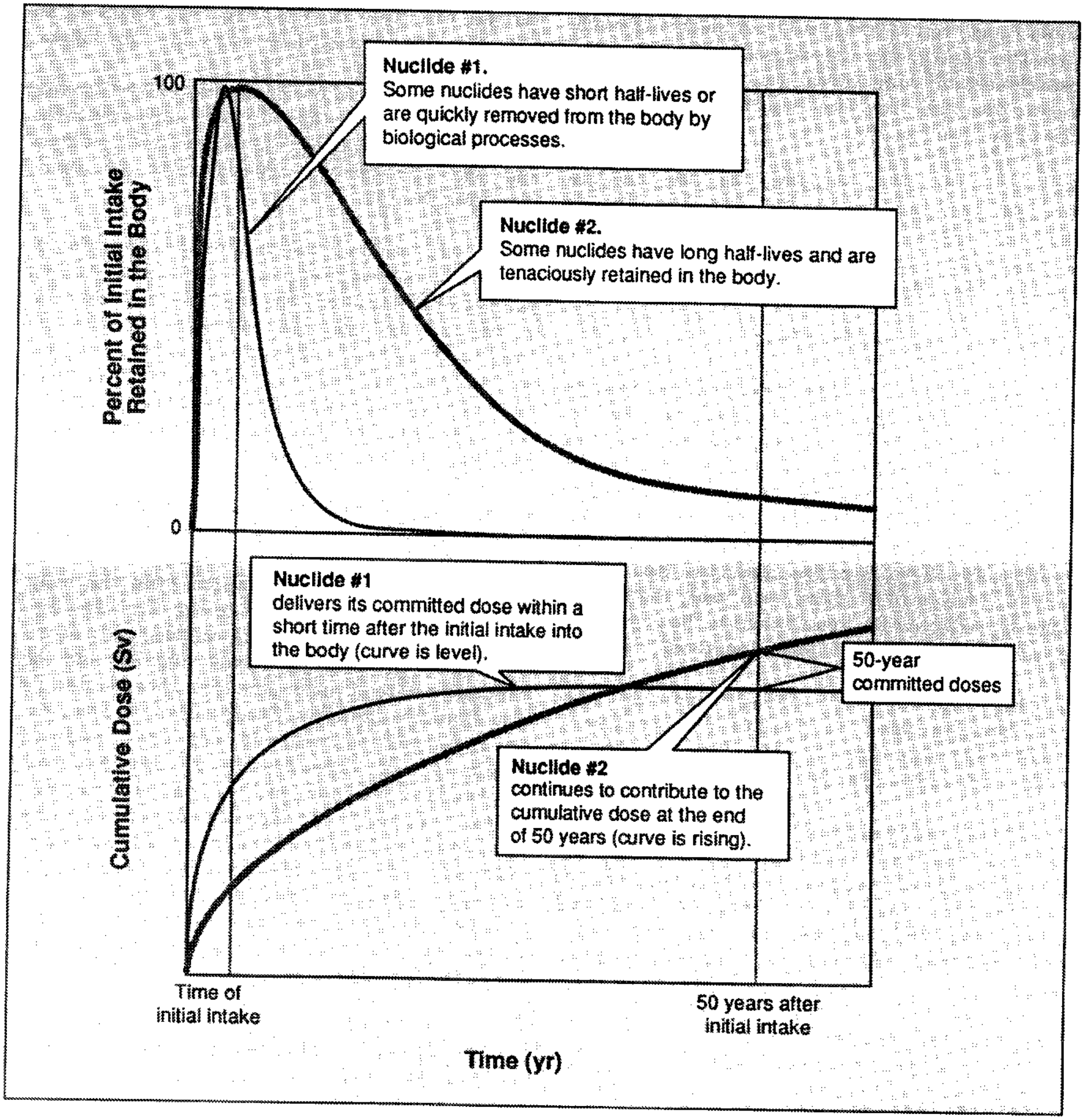


Figure 3-1. Committed dose

Internal dose 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 3-2 (facing page) shows internal dose factors for committed effective dose equivalent to an adult for several radionuclides.

An example of how actual intakes are determined by exposure to environmental media is given below:

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 (time unit for breathing rate)

Table 3-2
Fifty-Year Committed Effective Dose Equivalent for an Adult (mrem/pCi)[a]

Radionuclide	Inhalation	Ingestion
Tritium oxide	9.5×10^{-8}	6.3×10^{-8}
Strontium-90	1.3×10^{-3}	1.3×10^{-4}
Iodine-131	3.2×10^{-5}	5.3×10^{-5}
Cesium-137	3.2×10^{-5}	5.0×10^{-5}
Plutonium-239	5.1×10^{-1}	4.3×10^{-4}

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

The intake of a radionuclide by ingestion depends on levels of the radionuclide in foods and drinking water, and on the individual's consumption patterns.

The actual intake of a radionuclide is multiplied by the appropriate dose factor to provide 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 based on ICRP methodology [ICRP79] for approximately 20 organs of the body. The calculations of dose are based on dose conversion factors for adults. Adult rates of food and drinking water consumption are used to estimate intakes of radionuclides for all members of the population. However, as age-specific dose conversion factors become available for the radionuclides of interest to SRS, they will be incorporated into future calculations. Intake rates of food and drinking water consumption are shown in Table 3-1, Vol. II.

Extended Intakes: Environmental Dose Commitment

When radioactivity is released from a facility to one or more environmental media (e.g., air and water), only a small fraction of it reaches the public, and that fraction is delayed as it moves through the environment. If a certain radionuclide is released beginning January 1 and continues throughout the year at a constant rate until it ceases on December 31, the corresponding intake rate 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. The rate of intake would then begin to decline. However, the rate of intake would not decline to zero immediately because of transit times required for the radionuclide to move through one or more environmental pathways and reach the individual. The intake-rate curve shown in Figure 3-2 on the following page declines gradually from its maximum as the radionuclide is depleted in the environment over time. Figure 3-2 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** (or **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. At SRS, the environmental dose commitment to the population is calculated for a period extending 100 years after the period of release of radioactive materials to the environment.

APPLICABLE DOSE STANDARDS

The DOE radiation standards for the protection of the public in the vicinity of SRS are given in DOE Order 5480.1A, Chapter 11. These standards are based on recommendations of the ICRP and the National Council on Radiation Protection (NCRP).

DOE issued draft Order 5400.xx to update the portions of DOE 5480.1A that address public and environmental radiation protection standards and control practices. DOE 5400.xx, Chapter 2 contains revised interim standards which incorporate the recommendations and dose models contained in ICRP Publications 26 and 30 [ICRP77, ICRP79].

These revised interim standards supersede previous standards that were based on ICRP Publications 2 and 10 [ICRP59, ICRP68]. EPA limits for the atmospheric pathways contained in 40 CFR 61, subpart H [EPA 85] are also included in the draft DOE Order 5400.xx. Table 3-3 (following page) show the revised interim standards and limits for atmospheric pathways that will be used in this report.

In February 1990, DOE Order 5400.5 was promulgated to supersede DOE Order 5480.1 and replace draft DOE Order 5400.xx. DOE Order 5400.5 sets new radiation dose limits and incorporates new EPA limits. However, for the *Savannah River Site Envi-*

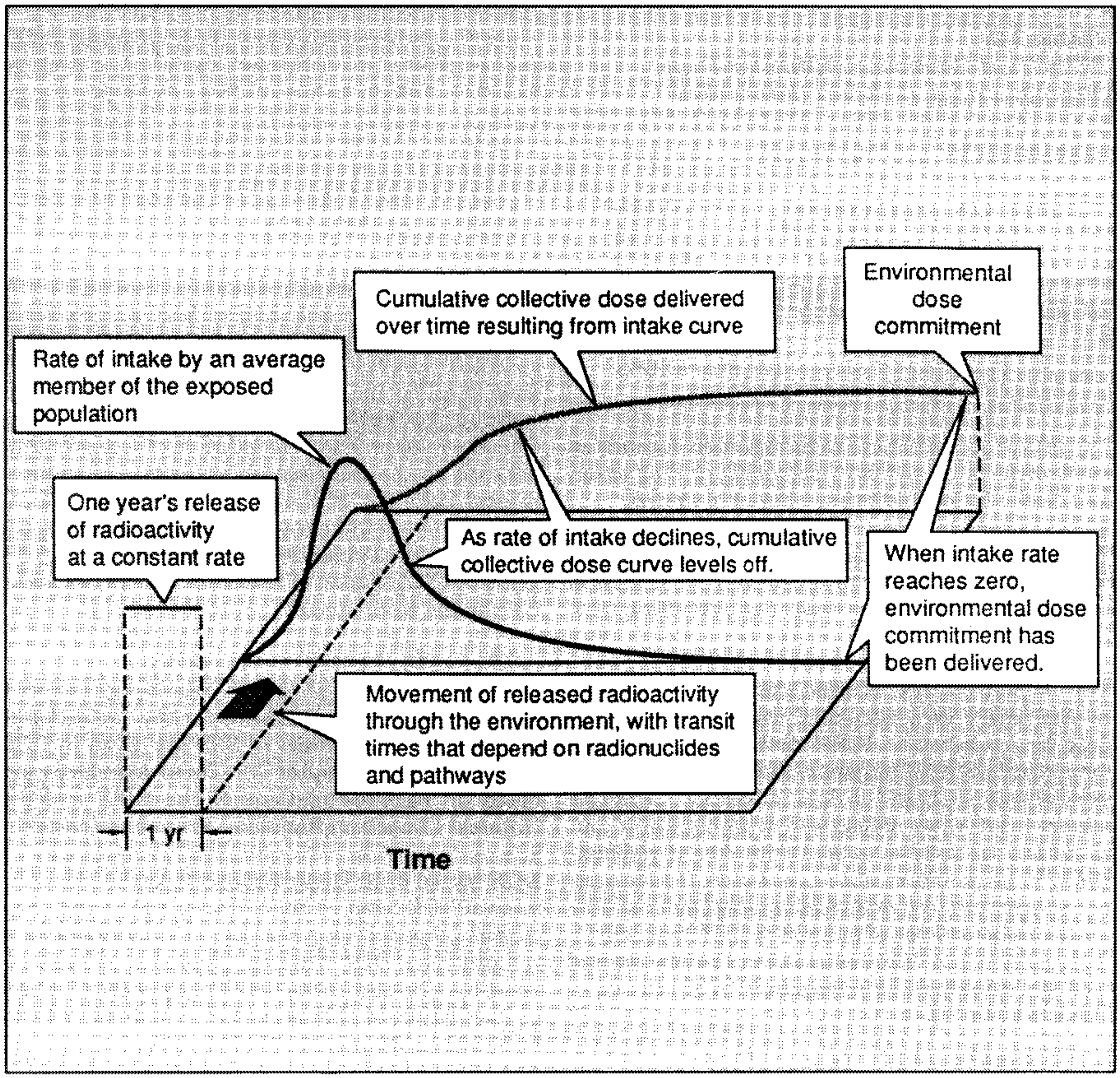


Figure 3-2. Environmental dose commitment

ronmental Report for 1989, dose calculations will be compared to limits given in Table 3-3 (facing page).

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 internal and external environmental radiation.

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]. The SRS dose estimates, based on this criteria, can be compared with the EPA dose standard.

SRS Doses

In this report, offsite doses from SRS releases of radioactive materials (atmospheric and liquid) are given for several scenarios for all affected individuals and population groups.

- The maximum radiation committed dose is given for a hypothetical individual living at the site boundary in the section of highest airborne exposure from SRS atmospheric emissions. This individual eats a maximum amount of meat, milk, and vegetables.
- The average individual's committed effective dose equivalent from SRS atmospheric emissions is provided for the average individual at the site boundary. The dose is based on average consumption and exposure rates.
- The collective committed dose from SRS atmospheric releases is provided for persons living within 50 miles (80 km) of the center of the site. The dose is based on the individual doses within this 50-mile radius.
- The average, maximum, and collective effective committed doses are provided for individuals and population groups down river from SRS. These doses are based on water and fish consumption and from recreational activities on the river.

Since ICRP 30-based dose factors are currently available only for adults, collective doses are calculated as if the entire population consists of adults.

Doses are calculated 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).

The individual and collective committed dose for 1989 SRS releases, calculated by the methods described in this chapter, are compared with the average annual committed dose from natural and medical sources.

These comparisons are provided in Table ES-1 in the Executive Summary. A discussion of radiation from natural and medical sources is provided in the "Perspectives on Environmental Contaminants and Risk" section located in Part I—Environmental Monitoring Perspectives—of this report.

Table 3-3. DOE Revised Interim Radiation Dose Limits[a]

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

	Effective dose equivalent[c] mrem/year	Effective dose equivalent[c] mSv/year
Annual exposure	100	1
Occasional annual exposure[d]	500	5

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

[a] DOE established new Radiation Dose Limits in DOE Order 5400.5, which was promulgated February 8, 1990 and supersedes DOE Order 5480.1A. For the *SRS Environmental Report for 1989*, the limits given in this table were in effect during 1989 and will be referenced throughout the report.
[b] "Routine DOE operations" means normal planned operations and does not include nonroutine releases.
[c] Effective dose equivalent is expressed in rem (or mrem) and the corresponding value of Sv (or mSv).
[d] A subsidiary limit of effective dose equivalent in a year. A dose higher than 100 mrem but not higher than 500 mrem may occur, provided that the dose averaged over a lifetime does not exceed the principal limit of 100 mrem.

RELATIVE EFFECTS OF DIFFERENT CHEMICAL FORMS OF TRITIUM IN THE ATMOSPHERE

The dosimetry and environmental behavior of tritium are discussed in this section because of the prominence of tritium in SRS releases. Tritium regularly accounts for a larger fraction of the offsite collective dose than all other radionuclides released from SRS. In 1989 atmospheric tritium accounted for approximately 75% 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.

Atmospheric tritium releases from SRS operations are 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 human intake and metabolism for exposure to tritium in air differ by four orders of magnitude for the oxide and the elemental forms and since the oxide and elemental form of tritium behave differently in the environment, atmospheric tritium releases are identified by chemical form. Doses from each form are then 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. To account for this efficient uptake of tritium oxide, the doses for tritium oxide are calculated from a model that assumes 100% of the ingested or inhaled tritium oxide is instantaneously absorbed into the body fluids. 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 [ICRP59]. 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 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.

DOSE CALCULATION 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, released during routine operations, are used to verify atmospheric dispersion in the transport models [Mar84]. Comparisons of annual calculated and measured values are presented in Chapter 4.

To calculate annual offsite doses, SRS uses radiation transport and dose models that were developed for the commercial nuclear industry [USNRC77]. 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 collective doses from atmospheric releases.
- LADTAP: calculates both maximum and 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. Modifications were made to incorporate the input of required physical and biological data specific to SRS. The program also allows input for multiple release points. However, the 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 [USNRC77], [Ec80], and [Si80].)

EPA 40 CFR 61 [EPA85] requires the use of the CAAC (Clean Air Act Code, formerly AIRDOS-EPA) computer code to calculate offsite doses from atmospheric releases from existing and proposed facilities. The program is used 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. Two major assumptions result in an overestimate of doses calculated from tritium oxide in food.

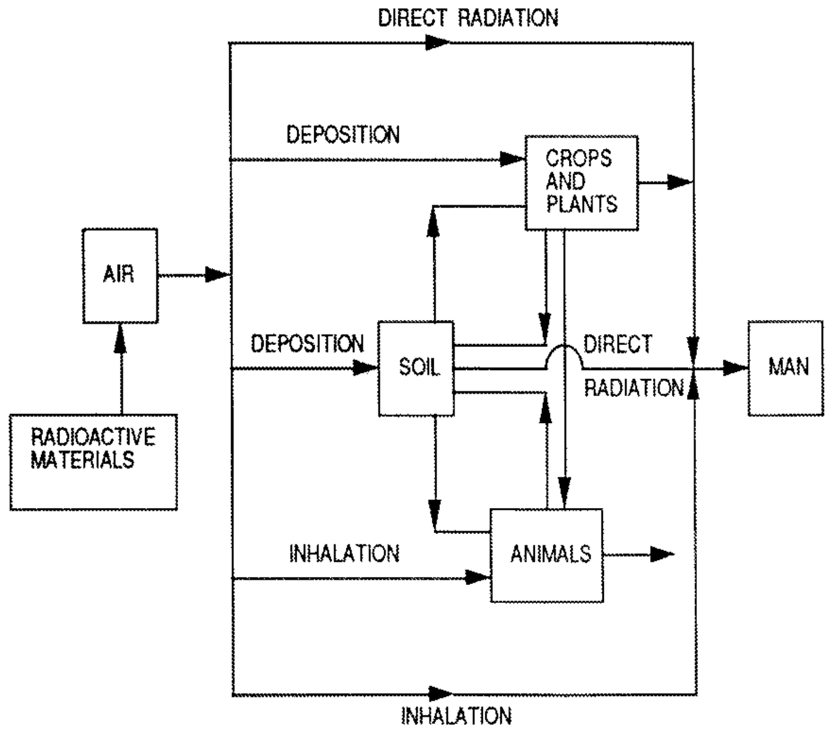


Figure 3-3. Transport of radioactivity to man through various pathways

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 air 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 more humid SRS area. The MAXIGASP and POPGASP codes allow the input of a specific humidity parameter of 11 g H_2O/m^3 air, determined by a review of weather records for Augusta, GA.

The second conservative assumption of the CAAC methodology is that the water content of foods reaches an equilibrium with the content of tritium equal to the tritium content of atmospheric moisture. Using the CAAC code to calculate the 1989 maximum offsite dose from atmospheric releases, a dose of 0.54 mrem is computed using a specific humidity parameter of 8 g H_2O/m^3 air. By substituting a specific humidity parameter of 11 g H_2O/m^3 air and still using the other conservative assumption in the CAAC code, a dose of 0.43 mrem is computed. These computed doses are appreciably higher than the 0.31 mrem dose computed using the MAXIGASP code.

Modeling the Dispersion of Atmospheric Radioactive Releases

Radioactive materials released to the atmosphere are diluted and dispersed within the air mass as they are carried by the prevailing wind. While they are airborne, the radionuclides expose people to intake by inhalation and—in the case of gamma-emitting radionuclides and other penetrating radiations—to external radiation. The radionuclides are gradually removed from the air by radioactive decay and by processes that deposit them on the ground, where some radionuclides may continue to be sources of external radiation. The deposited radionuclides subsequently move through various pathways to man. A simplified representation of the more important transport pathways is given in Figure 3-3(above).

Atmospheric transport models simulate the airborne movement, radioactive decay, and deposition of the radionuclides to predict concentrations in the air near ground level and concentrations on the ground surface at specified downwind locations. These concentrations are used to estimate radiation doses to individuals at those locations, and for some applications, they are used to predict depositions on food crops, pastures, and agricultural soil. Figure 3-4 indicates the conceptual basis of the types of models used to estimate movement of airborne radioactivity.

Meteorological Database

The atmospheric transport of radioactive materials from SRS is calculated based on meteorological ob-

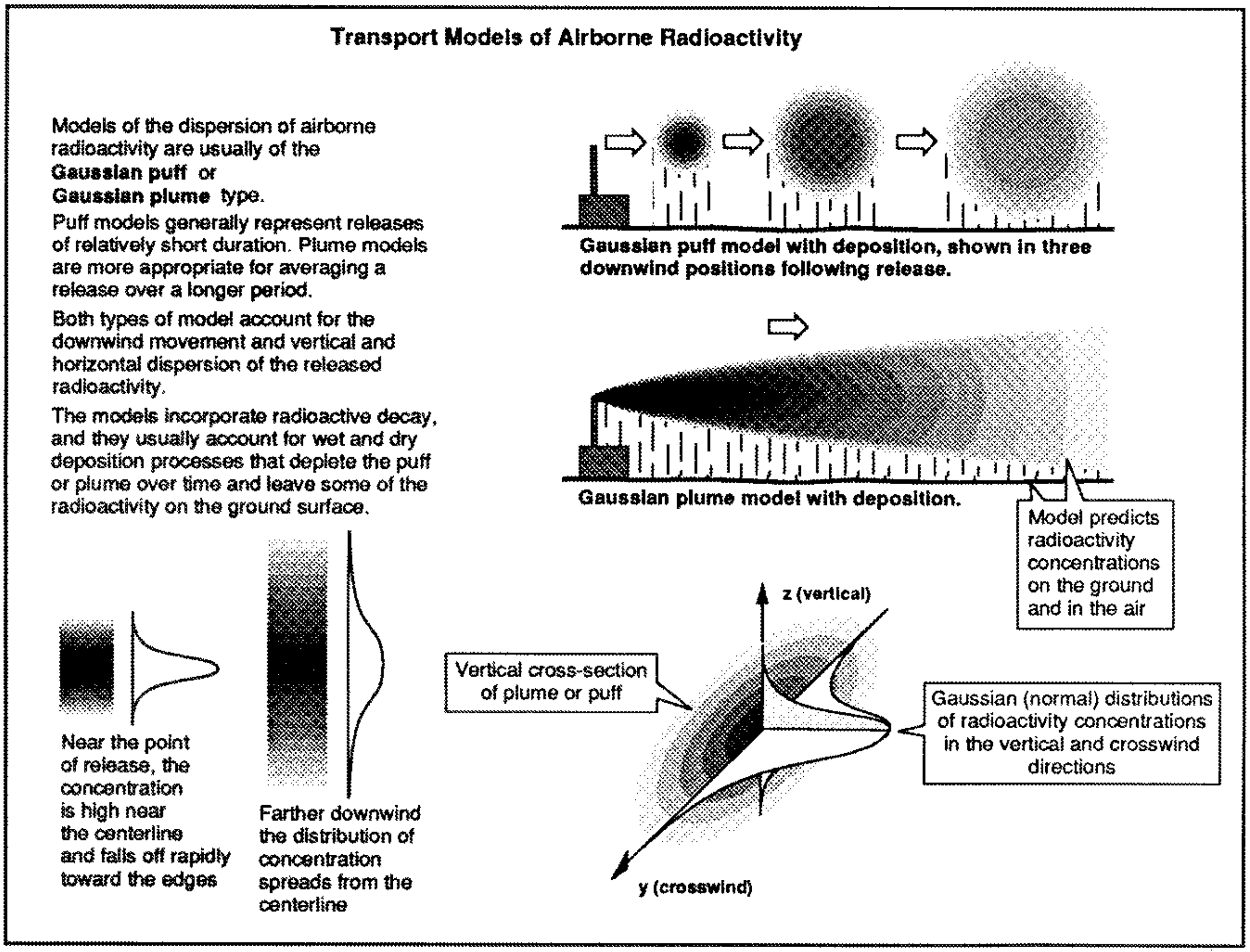


Figure 3-4. Atmospheric transport models are used to calculate releases of radioactivity

servations. Instruments mounted on nine onsite meteorological towers and a 1,200-ft television transmitting tower located 30 km (18.8 miles) northwest of the geometric center of SRS continuously monitor wind and temperature conditions.

For the dose estimates given in this report, calculations of atmospheric transport and deposition are based on meteorological measurements made over a five-year period (1982–1986). These measurements were collected from the meteorological tower located near the center of the SRS (H-Area Separations) and are presented in Table 3-2, Vol. II.

Frequency tables of wind speed and wind direction by atmospheric stability category for SRS (Table 3-2, Vol. II) were prepared using the meteorological measurements. Such meteorological frequency tables are used as input for an atmospheric transport model. This model accounts for the motion of the wind, the vertical and horizontal dispersion of the released radionuclides within the moving air mass, and the removal of the radionuclides from the air by deposition and radioactive decay. The atmospheric transport model calculates an estimate of the radionuclide concentration in air per unit release rate (sometimes called "chi over Q") at prescribed ground-level positions near the point of release. Radionuclide deposition on the ground is also estimated.

These atmospheric transport models are based on methods widely used in the nuclear industry [USNRC73]. The versions used for assessing routine releases from SRS are implemented in the computer program XOQDOQ [Sag77]. 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 this report (Chapter 4, Vol. I).

Dose Calculations for Atmospheric Releases

Offsite individual and collective committed dose from atmospheric releases of radioactivity are calculated by using the MAXIGASP and POPGASP programs. These programs use the following data to calculate doses:

- measured and calculated annual radioactive releases
- average annual radioactive concentrations and deposition factors
- population distribution
- production data for vegetables, crops, milk, and meat

Intakes of radioactivity by individuals and populations are based on population distribution, and adult inhalation and consumption rates for food and water are given in Tables 3-1, 3-2, 3-3, and 3-4, Vol. II.

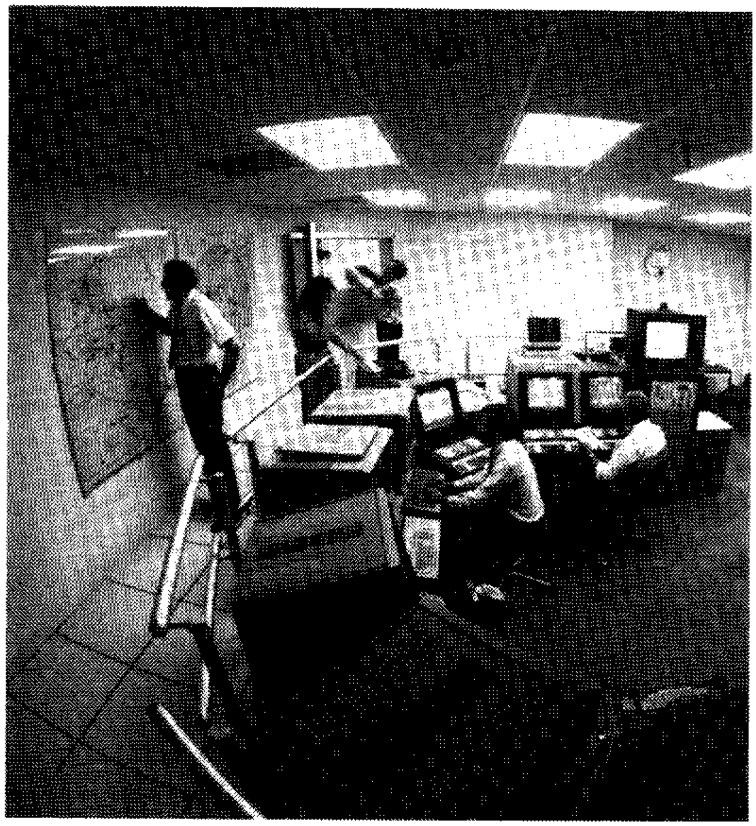
Radioactive intakes by offsite populations are converted to committed dose using the DOE internal effective dose equivalent factors. These effective dose equivalent factors, described previously, provide estimates of a 50-year committed dose for intake of a unit quantity of radioactivity.

The term environmental dose commitment, as explained previously, refers to collective (population) dose which is calculated to account for the continued contribution of internal and external radiation dose to the population near SRS. This dose is calculated exclusively as the result of radioactivity in the environment due to SRS operations. The calculated collective doses in this report include an estimate of environmental dose commitment for a 100-year period following the release of radioactivity.

During nonroutine releases of radioactivity from SRS, atmospheric transport models available on the Weather INformation and Display (WIND) System are used to calculate offsite doses in real-time. The WIND System transport models use real-time observed meteorological data from the onsite meteorological network and forecast data from the National Weather Service to predict the transport of a radioactive puff or plume through the atmosphere. The models use the DOE 50-year committed effective dose equivalent factors based on ICRP Publication 30 [ICRP79] combined with the breathing rate of an active adult to calculate internal dose estimates.

The primary WIND System atmospheric transport model, Puff/Plume (PF/PL) is a Gaussian PF/PL model that assumes the ambient concentrations of the material released form a Gaussian (normal) distribution about a centerline as the material is dispersed throughout the atmosphere. The PF/PL model transports the release along a series of downwind straight-line segments determined from hourly averaged observed and forecasted wind data.

A second model, called Reactor Accident Program, couples an atmospheric transport model based on PF/PL with calculations of radionuclide releases following a reactor accident to estimate the external dose from the gamma-emitting radionuclides and the committed thyroid dose to adults and children from radioactive iodines.



Weather INformation and Display (WIND) System

Modeling the Dilution and Transport of Liquid Radioactive Releases

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 minimum detectable concentrations after dilution with river water. Only tritium oxide and trace amounts of ^{90}Sr and ^{137}Cs are routinely detected in the river. Therefore, it is necessary to employ a mathematical model to account for the offsite doses from all SRS releases to the streams.

Radioactive materials released into streams are dispersed and diluted in the water and transported by the current. They are deposited into sand and sediments on the bottom of the stream, and they enter the aquatic food chain as they are taken up directly from the water or from the sediments by aquatic plants and animals. Radioactivity in drinking water taken from the streams exposes people directly. Stream water used for irrigation or for watering animals may introduce radionuclides into food crops and animal products that people ultimately consume. A simplified representation of the more important transport pathways of radioactive materials in surface water or groundwater is shown below in Figure 3-5 [ICRP65].

Mathematical models of aquatic radionuclide transport quantify these pathways and estimate concentrations of radioactivity in food and drinking water by simulating the movement of the released radioactivity through the water, its transfer to aquatic organisms, and its uptake by terrestrial crops and agricultural animals.

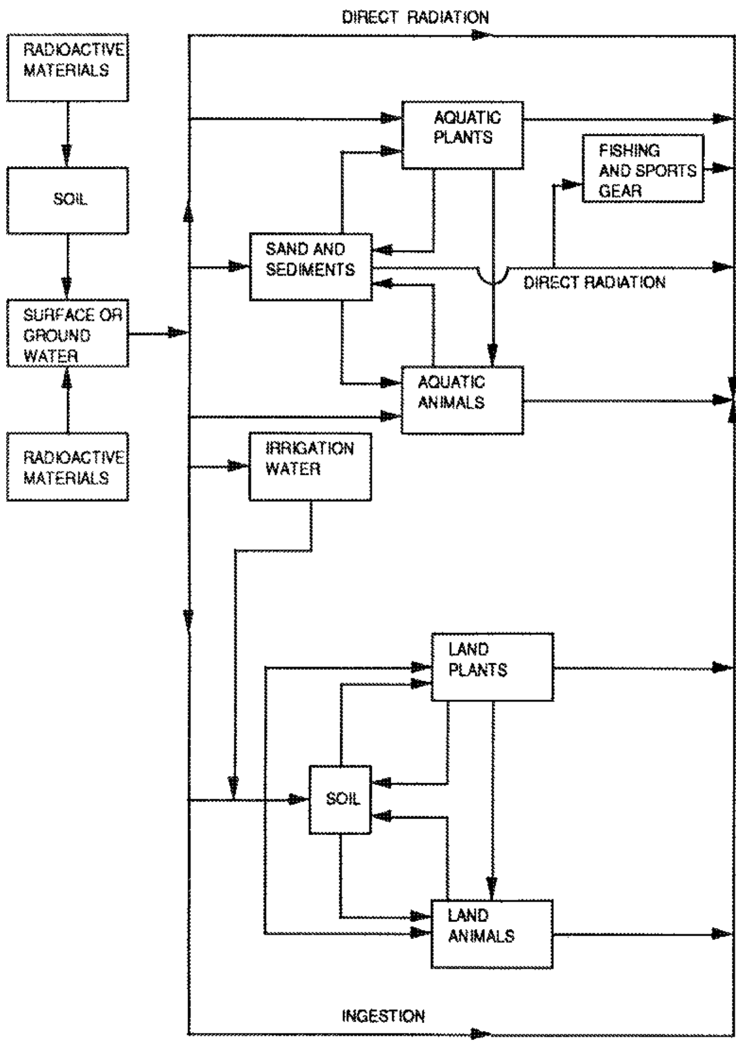


Figure 3-5. Transport of radioactivity released to groundwater or surface waters to man through various pathways

Before 1987, dose calculations for the irrigation water pathway were not included because there was no known use of river water for irrigation downriver from SRS. However, since irrigation along the river by a small farming operation is a possibility, potential doses from this pathway were calculated for 1989.

Flow-Rate Data

Dilution of radioactive materials in the river is based on continuous flowrate measurements made at SRS by the United States Geological Survey (USGS). The average river flow rate in 1989 was 7,832 ft^3/sec, which is 52% higher than the average 1988 flow rate of 5,151 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 Liquid Releases

Calculation of offsite individual and collective committed doses from liquid releases of radioactivity at SRS are provided by the LADTAP program. The following data are used by the LADTAP program to calculate doses [Tu83; Tu83b]:

- annual measured and calculated releases of radioactivity to the river
- average river flow rates
- population data
- sports and commercial fish harvests data
- community water consumption data
- recreational use of the river data

The data used in these calculations, as well as human consumption rates for water and fish, are shown in Tables 3-1, 3-2, 3-3, and 3-5, Vol. II.

HIGHLIGHTS

- The Clean Air Act Code (CAAC), formerly AIRDOS-EPA, is used to demonstrate compliance with the National Emission Standards for Hazardous Air Pollutants (NESHAP).
- 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. Adult intake rates of food and water are also used in the dose calculations.
- Tritium accounts for a major fraction of the offsite collective dose. In 1989, atmospheric tritium accounted for about 75% of site perimeter dose from atmospheric releases, while liquid effluent tritium accounted for about 90% of the dose received from the public water supplies.
- Instrumentation on nine onsite meteorological towers and a 1,200-ft. television transmitting tower located 30 km northwest of SRS continuously monitor meteorological conditions.
- Continuous flow-rate measurements are made on the Savannah River by the United States Geological Survey (USGS). The average river flow rate in 1989 was 7,832 ft^3/sec and 52% higher than the average 1988 flow rate of 5,151 ft^3/sec.

Part III

Environmental Monitoring Programs

4
Air Monitoring Program

SUMMARY—This chapter describes the air monitoring program for radiological and nonradiological constituents released to the atmosphere from SRS facilities during normal operations. Levels of radioactive materials in the air are measured at five monitoring stations onsite, 14 monitoring stations around the site perimeter, 12 stations at 25 miles from the center of the site, and others located 100 miles from the site.

Gross alpha, nonvolatile beta, plutonium, gamma-emitting radionuclides, and tritium are measured by analyzing filter papers, charcoal filters, and tritium absorbers. Ambient gamma radiation levels at and around SRS are continuously measured at 454 locations using TLDs. Tritium is the only monitored radionuclide of SRS origin that is routinely detected in offsite air. A committed dose of 0.11 mrem (0.0011 mSv) from atmospheric releases was calculated for the average individual living at the SRS perimeter during 1989. This dose is 0.44% of the NESHAP standard of 25 mrem/year whole body dose.

In the nonradiological monitoring program, five stations around the site continuously monitor air quality and atmospheric emissions from the SRS coal-fired power plants and other process stacks. Emissions of sulfur dioxide, oxides of nitrogen and total particulate matter less than 10 microns were within applicable SCDHEC standards in 1989.

INTRODUCTION

A primary pathway of receiving dose from radiation results from radionuclides in the air. These radionuclides may be present naturally or they may be present as a result of atmospheric emissions of radionuclides. For this reason, SRS maintains an extensive network of air monitoring stations to determine the concentrations of radioactive materials in the air from atmospheric releases as well as from environmental gamma radiation.

In addition to monitoring radioactivity in air, SRS monitors nonradioactive emissions and ambient air quality to ensure that all emissions (radioactive and nonradioactive) are within applicable standards.

RADIOLOGICAL MONITORING PROGRAM

Radioactivity in Air

Description of Monitoring Program

Concentrations of radioactive materials in the air are measured at five monitoring stations on the site, 14 monitoring stations at the site perimeter, and 12 stations at distances of approximately 25 miles from the center of the site (called 25-mile-radius stations). The site perimeter stations and the 25-mile-radius stations are strategically located to permit continuous sampling within each 30° sector around SRS.

The locations of the monitoring stations were selected to optimize the probability of detecting any routine or nonroutine release of airborne radioactivity from the SRS regardless of wind direction. The locations of the air monitoring stations are shown in Figure 4-1 on the following page.

Additional air monitoring stations are located in Savannah and Macon, GA, and in Columbia and Greenville, SC (100-mile-radius stations). These locations are so distant from SRS that the contributions from SRS atmospheric releases to measured air concentrations are negligible (see Figure 4-1, Vol. II). These stations serve as reference points for determining background radioactivity concentrations from natural sources and from worldwide fallout.

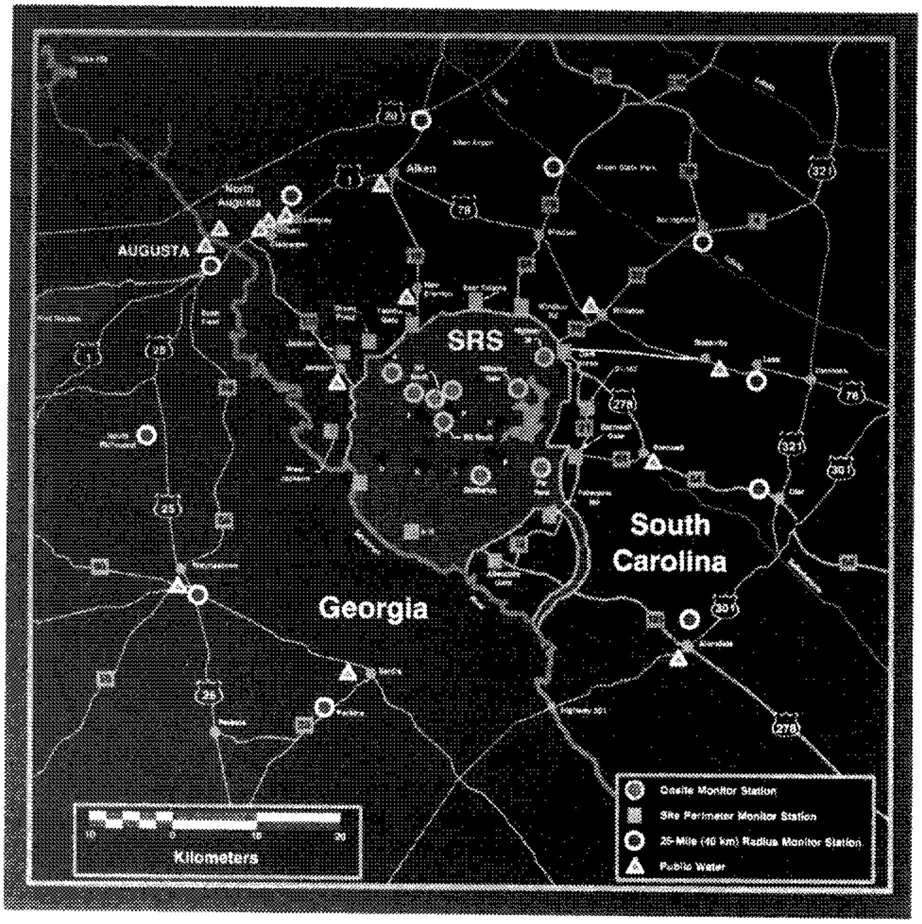


Figure 4-1. Continuous air monitoring stations

conditions of continuous exposure for one year. The dose received may be due to inhalation of the radionuclide, absorption through the skin, and external exposure from the radionuclide in the surrounding environment. The DCGs for radionuclides released to the atmosphere from SRS operations are listed in Table 4-1 (right).

The DOE draft Order 5400.xx also includes the Environmental Protection Agency's (EPA) National Emission Standards for Hazardous Air Pollutants (NESHAP), "Standards for Radionuclides" (40 CFR 61 subpart H), which apply to federal facilities. The NESHAP standards state that air emissions of radionuclides shall not result in a whole body dose greater than 25 mrem/year to any member of the public.

At the monitoring stations airborne radioactive materials are measured by drawing air samples through the appropriate air media—filter paper, charcoal filters, and tritium absorbers. The filter papers and charcoal filters are collected and replaced weekly; the tritium absorbers are changed every two weeks. The collection media are then analyzed for radionuclide content. A complete discussion of sample collection and analytical procedures is found in Chapter 1 of this report.

Applicable Standards

Concentration limits for radionuclides in air, called Derived Concentration Guides, (DCGs), are given in DOE draft Order 5400.xx [DOE88]. These guides are based on recommendations in the International Commission on Radiological Protection Publications 26 and 30 [ICRP77; ICRP79].

The DCG for a radionuclide is defined as the air concentration of that radionuclide that is calculated to result in a committed dose of 100 mrem under

Monitoring Results

Atmospheric monitoring results are presented in Table 4-1, Vol. II. 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.

Gross Alpha and Nonvolatile Beta

Determinations of gross alpha and beta-gamma radioactivity measure the total concentration of all alpha-emitting and beta-gamma-emitting radionuclides in the sample. Small amounts of particulate alpha and beta-gamma radioactivity are released to the atmosphere from SRS, primarily from F- and H-Area facilities. However, the contributions, in the area surrounding SRS, are generally obscured by contributions from worldwide fallout. Average gross alpha and nonvolatile beta concentrations measured on SRS during 1989 were essentially the same as the average concentration measured offsite. These average concentrations are shown in Table 4-2 (right).

Table 4-1
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	3,000,000	Xe-131m	2,000,000	Pu-239	0.02
Kr-87	20,000	Xe-133	500,000	Am-241	0.02
Kr-88	9,000	Cs-134	200	Cm-242	0.7
Sr-89	300	Xe-135	80,000	Am-243	0.02
Sr-90	9	Cs-137	400	Cm-244	0.04

[a] Values of DCGs are from the DOE draft Order 5400.xx. In cases where different chemical forms have different DCGs, the lowest DCG for the radionuclide has been listed. These DCGs are defined as the air concentration of that radionuclide that will give a 50-year committed dose of 100 mrem under conditions of continuous exposure for one year.

The maximum onsite gross alpha concentration of 5.3 fCi/m³ was detected in an air sample from F Area, while the maximum onsite nonvolatile beta concentration of 89 fCi/m³ was detected in an air sample from the Burial Ground South sampling location.

Figure 4-2 (following page) indicates the historical influence of fallout from weapons tests on particulate nonvolatile beta activity in air. Elevated nonvolatile beta concentrations were observed at all locations following atmospheric testing of nuclear weapons. The increased concentrations in May through July 1986 reflect increased beta-gamma activity in the air as a result of the Chernobyl incident.

In general, some increase in nonvolatile beta activity in air also occurs at all locations in the spring as a result of the mixing of the stratosphere with the troposphere. This mixing moves additional quantities of radioactivity from the stratosphere to the troposphere, closer to the earth's surface. Depending on prevailing meteorological conditions, this phenomenon usually occurs between January and June.

Table 4-2
Average Activity Concentration (fCi/m³)[a]

Location	Alpha	Beta
Onsite	1.4	18
Site perimeter	1.1	17
25-mile radius	1.1	17
100-mile radius	1.6	17

[a] 1,000 fCi/m³ = 1 pCi/m³

Plutonium

Average concentrations of ^{239}Pu in air for 1989, for the four groups of monitoring locations are given in Table 4-3 (below). Concentrations measured at the site perimeter and offiste locations reflect background concentrations. Higher values of plutonium were detected at the onsite monitoring stations near F and H Areas and the Radioactive Waste Burial Ground.

Table 4-3
Average Plutonium Concentrations in the Vicinity of SRS (aCi/m³)[a]

Location	Pu-238[b]	Pu-239[b]
Onsite	46	12
Site perimeter	5.0	2.1
25-mile radius	5.0	1.8
100-mile radius	3.0	1.8

[a] 1,000,000 aCi/m³ = 1 pCi/m³
[b] DOE DCG for ^{239}Pu in air is 20,000 aCi/m³ and 30,000 aCi/m³ for ^{238}Pu

Plutonium-239 concentrations onsite ranged from less than 20 aCi/m³ to 100 aCi/m³. This maximum concentration, measured at the F-Area monitoring station, was attributed to startup of a special plutonium process in F Area.

Onsite concentrations of ^{238}Pu ranged from 1.0 aCi/m³ in 3/700 Area to 679 aCi/m³ in F Area. Concentrations of ^{238}Pu averaged 46 aCi/m³ at onsite monitoring locations. Concentrations of ^{238}Pu at the site

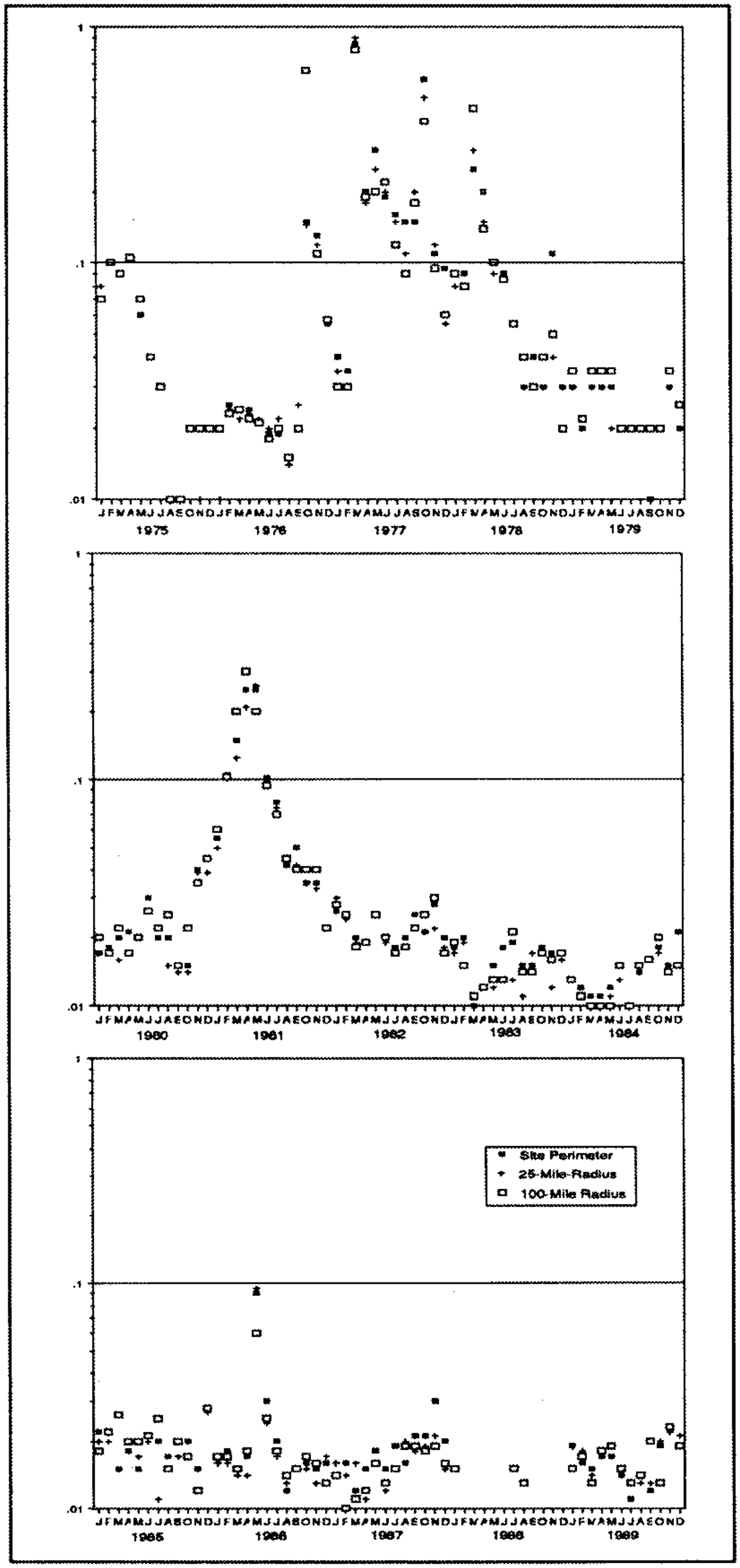


Figure 4-2. Average nonvolatile beta in air, 1975—1989

perimeter, 25-mile radius, and 100-mile radius did not differ significantly from one another, as shown in Table 4-3.

The observed ratio of abundance of ^{238}Pu to ^{239}Pu in all samples from the three sampling locations indicates that the plutonium was not completely isolated from other alpha-emitting radionuclides during sample preparation. For this reason, these data should be considered useful as an upper limit of ^{238}Pu. The value of this data is largely qualitative and should not be interpreted quantitatively.

Gamma-Emitting Radionuclides

The major gamma-emitting radionuclide routinely detected in air was ^{7}Be, a naturally occurring radionuclide formed by the interaction of cosmic rays with oxygen and nitrogen in the upper atmosphere. In 1989, maximum concentrations of naturally occurring ^{7}Be ranged from 119 to 9,820 fCi/m^3.

Tritium

The average concentrations of tritium in air measured in 1989, for the four groups of monitoring locations, are given in Table 4-4 (above right). The average concentrations showed a decreasing trend with distance from the site.

Onsite tritium concentrations in air ranged from 5.6 to 4,360 pCi/m^3. The maximum value, detected at the H-Area station, was 4.4% of the DOE DCG for tritium in air (100,000 pCi/m^3). The 1989 average onsite concentration was 22% less than the 1988 average tritium concentration of 840 pCi/m^3.

1989 Atmospheric Releases and Site-Perimeter Concentrations

Radioactivity released to the atmosphere from SRS facilities during normal operations is monitored at the effluent release points. The monitoring results are used to calculate the total quantities of radionculides released from SRS. The 1989 calculated atmospheric releases are shown in Table 4-5 (right).

Table 4-4
Average Tritium Concentrations in the SRS Vicinity

Location	Tritium-1989 (pCi/m^3)	Tritium-1988 (pCi/m^3)
Onsite	643	840
Site perimeter	37	54
25-mile radius	14	17
100-mile radius	9	12

Average concentrations of radionuclides in air at the site boundary are calculated from the atmospheric release quantities. These calculations use computer codes to implement standard meteorological dispersion equations [USNRC73]. The calculated average concentrations at the site perimeter are shown in Table 4-5.

Since tritium is the only monitored radionuclide of SRS origin that is routinely detected in offsite air, measured tritium concentrations can be used to confirm the calculated site perimeter concentrations. The average concentration of tritium measured at the site perimeter monitoring stations, 37 pCi/m^3, is 43% lower than the 65 pCi/m^3 calculated value shown in Table 4-5. It appears that the calculated concentrations for 1989 are a reasonably conservative estimation of the offsite effect from releases of radioactive materials.

It is noted that noble gases are not routinely monitored at ambient air stations because of sampling and analysis complexity. However, the dose from release of noble gases, which is determined from calculated release quantities and from standard dose calculation models, was small (<1%) in 1989 compared to atmospheric dose from tritium (81%), as shown in Figure 4-2 located in Volume II.

Table 4-5
1989 Radioactive Atmospheric Releases and Calculated Concentrations of Radionuclides

Nuclides	Curies Released Emission Source	Calculated Avg. Conc. Site Perimeter (pCi/m^3)
Gases and Vapors:		
H-3 (oxide)	2.18E+05	6.5E+01
H-3 (elemental)	9.16E+04	2.7E+01
H-3 (total)	3.09E+05	9.2E+01
C-14	1.80E+01	5.4E-03
Kr-85	4.17E+04	1.2E+01
I-129	5.19E-02	1.4E-05
I-131	3.64E-04	3.8E-07
Particulates:		
Sr-89, 90	1.14E-03	3.1E-07
Zr-95	5.80E-05	1.6E-08
Nb-95	1.28E-04	3.4E-08
Ru-103	7.00E-06	1.9E-09
Ru-106	3.26E-03	8.8E-07
Cs-134	9.20E-05	2.5E-08
Cs-137	9.56E-04	2.6E-07
Ce-141	1.00E-06	2.7E-10
Ce-144	7.62E-04	2.1E-07
U-235, 238	5.05E-03	1.2E-09
Pu-238	8.61E-04	2.3E-07
Pu-239	1.30E-03	3.7E-07
Am-241,243	2.01E-04	5.4E-08
Cm-242,244	2.80E-05	7.5E-09

Offsite Radiation Doses from Atmospheric Releases

Offsite radiation committed doses from atmospheric releases during 1989 were calculated for individuals nearest the site and for the population within 50 miles (80 km) from the center of the site. Meteorological data covering five-year periods are updated about every five years and are used in calculating offsite radiation doses. This collection of data has not been updated since 1986; therefore, meteorological data from 1982 through 1986 were used to perform 1989 dose calculations. These calculations utilized computer codes to implement models of the various pathways of exposure. Chapter 3 contains descriptions of the models and codes.

Maximum Individual Committed Dose

Table 4-6 on the following page presents the calculated dose by pathway and by radionuclide to a hypothetical individual located at the site perimeter at the points of maximum exposure. With an assumed average dietary intake, the dose to this indi-

Table 4-6
Maximum Individual Doses at the Site Perimeter from Atmospheric Releases

By Pathway

Pathway	Average Consumption Maximum Individual Dose, mrem[a]	Average Consumption % of Total Dose	Maximum Consumption Maximum Individual Dose, mrem[a]	Maximum Consumption % of Total Dose
Plume	1.63E-04	0.09	1.63E-04	0.05
Ground	2.06E-04	0.11	2.06E-04	0.07
Inhalation	9.05E-02	49.41	9.05E-02	28.78
Vegetation	5.97E-02	32.59	1.59E-01	50.56
Milk	1.61E-02	8.79	4.55E-02	14.47
Meat	1.65E-02	9.01	1.91E-02	6.07
Total	1.83E-01		3.14E-01	

By Radionuclide

Radionuclide	Average Consumption Maximum Individual Dose, mrem[a]	Average Consumption % of Total Dose	Maximum Consumption Maximum Individual Dose, mrem[a]	Maximum Consumption % of Total Dose
Gases and Vapors:				
H-3	1.50E-01	81.95	2.39E-01	76.05
C-14	4.97E-03	2.72	1.05E-02	3.34
Ar-41	0.00E+00	0.00	0.00E+00	0.00
Kr,Xe isotopes	1.63E-04	0.09	1.63E-04	0.05
I-129	2.07E-02	11.31	5.33E-02	16.96
I-131	7.79E-07	0.00	1.74E-06	0.00
Particulates:				
Sr-90	4.18E-05	0.02	1.01E-04	0.03
Ru-106	1.72E-04	0.09	2.19E-04	0.07
Cs-134, 137	4.50E-05	0.02	7.32E-05	0.02
U-235, 238	2.50E-07	0.00	2.86E-07	0.00
Pu-238	2.17E-03	1.19	3.39E-03	1.08
Pu-239	4.14E-03	2.26	6.53E-03	2.08
Am-241,243	5.83E-04	0.32	9.22E-04	0.29
Cm-242,244	4.19E-05	0.02	6.60E-05	0.02
Total	1.83E-01		3.14E-01	

[a] Committed effective dose equivalent.

vidual is 0.18 mrem (0.0018 mSv). If maximum intake of all types of food (milk, meat, and vegetables) is assumed, the dose is 0.31 mrem (0.0031 mSv) or 1.2% of the NESHAP standard of 25 mrem/year whole body dose to any member of the public.

Average Individual Committed Dose

Table 4-7 (right) shows the calculated committed dose to the average individual at the site perimeter by pathway. These doses, based on the 1989 atmospheric releases, were calculated for persons with normal living habits residing at 320 locations equidistantly spaced along the site perimeter. These committed doses were then averaged over the 320 locations to give the values in Table 4-7.

The major pathways contributing to individual doses from atmospheric releases are from inhalation and consumption of vegetation. A committed dose of 0.11 mrem (0.0011 mSv) was calculated for the average individual at the site perimeter assuming average dietary intake. This dose is 0.44% of the NESHAP standard of 25 mrem/year whole body dose.

Comparisons of the committed doses for the maximum and average individuals to applicable standards and natural sources of radiation are summarized in Table 4-8 (right).

Table 4-8
Doses from SRS Atmospheric Releases Compared with Applicable Standards/Natural Radiation

Committed Dose	Standards[a]	% of Standard
Avg. Individual	25 (NESHAP)	0.44
0.11 mrem	100 (DOE)	0.11
	295 (Natural)	0.03
Max. Individual	25 (NESHAP)	1.2
0.31 mrem	100 (DOE)	0.31
	295 (Natural)	0.11

[a] in mrem

<u>Collective Dose</u>
Doses were also calculated for individuals residing within 50 miles (80 km) of SRS. These individual doses were then summed to obtain the collective doses shown in Table 4-2, Volume II. The collective dose for the population of 555,100 individuals residing within 50 miles of the site in 1989 was 17 person-rem (0.17 person-Sv). This dose is 0.01% of the dose of approximately 160,000 person-rem received annually by this same population from natural sources of radiation.

Table 4-7
Average Individual Dose at the Site Perimeter from Atmospheric Releases

By Pathway

	Average Individual Dose, mrem[a]	% of Total Dose
Plume	9.72E-05	0.09
Ground	1.24E-04	0.12
Inhalation	5.21E-02	49.07
Vegetation	3.49E-02	32.87
Milk	9.39E-03	8.84
Meat	9.57E-03	9.01
Total	1.06E-01	

By Radionuclide

	Average Individual Dose, mrem[a]	% of Total Dose
Gases and Vapors:		
H-3	8.65E-02	81.47
C-14	2.96E-03	2.79
Ar-41	0.00E+00	0.00
Kr, Xe isotopes	9.72E-05	0.09
I-129	1.25E-02	11.77
I-131	3.94E-06	0.00
Particulates:		
Sr-90	2.51E-05	0.02
Ru-106	1.03E-04	0.10
Cs-134, 137	2.70E-05	0.03
U-235, 238	1.35E-06	0.00
Pu-238	1.30E-03	1.22
Pu-239	2.28E-03	2.15
Am-241, 243	3.49E-04	0.33
Cm-242, 244	2.51E-05	0.02
Total	1.06E-01	

[a] Committed effective dose equivalent

Environmental Gamma Radiation

Description of Program

Ambient gamma radiation levels at and around SRS are continuously measured at 454 locations with Panasonic thermoluminescent dosimeters (TLDs). The TLDs provide a quick and reliable method to determine external gamma radiation doses to population groups within an 8,000-square-mile area of SRS in the event of an unplanned release of radioactivity.

The TLD monitoring stations include onsite locations, site-perimeter stations, 25-mile-radius locations, 100-mile-radius stations, South Carolina cities and towns and Georgia cities and towns. The number of stations and their locations are shown in the following table:

Location	TLD Stations
Onsite	117
Site Perimeter	193
SC Cities and Towns	92
GA Cities and Towns	52

Half of the locations in South Carolina and Georgia are inside buildings, with the other half outdoors. The TLDs at the remaining locations are also outdoors. Two TLDs are placed at each indoor location, and five TLDs are placed at each outdoor location. The TLDs are collected for analysis, and replaced, every three months. Control sets of TLDs also accompany the field TLDs to evaluate systematic or transport errors. Monitoring locations are shown in Figure 4-3 (below) and in Figure 4-2, Vol. II.

Program Changes in 1989

TLD measurements for the 100-mile-radius locations are reported differently in 1989 than in previous years. Table 4-2 in Volume II presents the monitoring results from two monitoring stations at each 100-mile-radius location. Previous years, data from both stations were averaged to provide one result.

Monitoring Results

Ambient radiation fields vary significantly from one location to another because of differences in the terrestrial and cosmic components of natural background radiation. An example of such differences is different concentrations of the decay products of radium and thorium in the soil, which results in different measured radiation levels.

Table 4-9 (right) compares offsite 1989 TLD results with offsite TLD results for 1988. Summaries of all TLD data are presented in Tables 4-3, 4-4, 4-5, 4-6, and 4-7, Vol. II.

Onsite measurements were taken at fences around the various SRS operating facilities. Some of these onsite radiation levels were above offsite, background levels. The maximum was 2.2 mR/day (803 mR/year), measured at a Solid Waste Storage Facility in H Area that stores high-level radioactive waste.

Expansion of Monitoring Network

In addition to the existing sampling stations, 12 site perimeter stations are being installed and tested. These stations will supplement the site's emergency response capability by continuously measuring and periodically reporting gamma radiation levels and tritium concentrations from each 30° sector around SRS. The gamma monitors are capable of detecting radiation levels from 10 μR/hr to 1,000 R/hr. The tritium ion chambers can detect tritium concentrations from 1×10^{-6} pCi/m^3 to 1×10^{-2} pCi/m^3. The stations are expected to be completed in 1990.

The monitors will be housed in temperature-controlled buildings. Each monitoring station will transmit data at least once per day through a U.S. Geological Survey satellite telemetry system. Should an emergency occur, the monitors will be set to transmit data at 5 to 10-minute intervals. The data will then be transmitted to the WIND (Weather INformation and Display) system and integrated into the overall emergency response system.

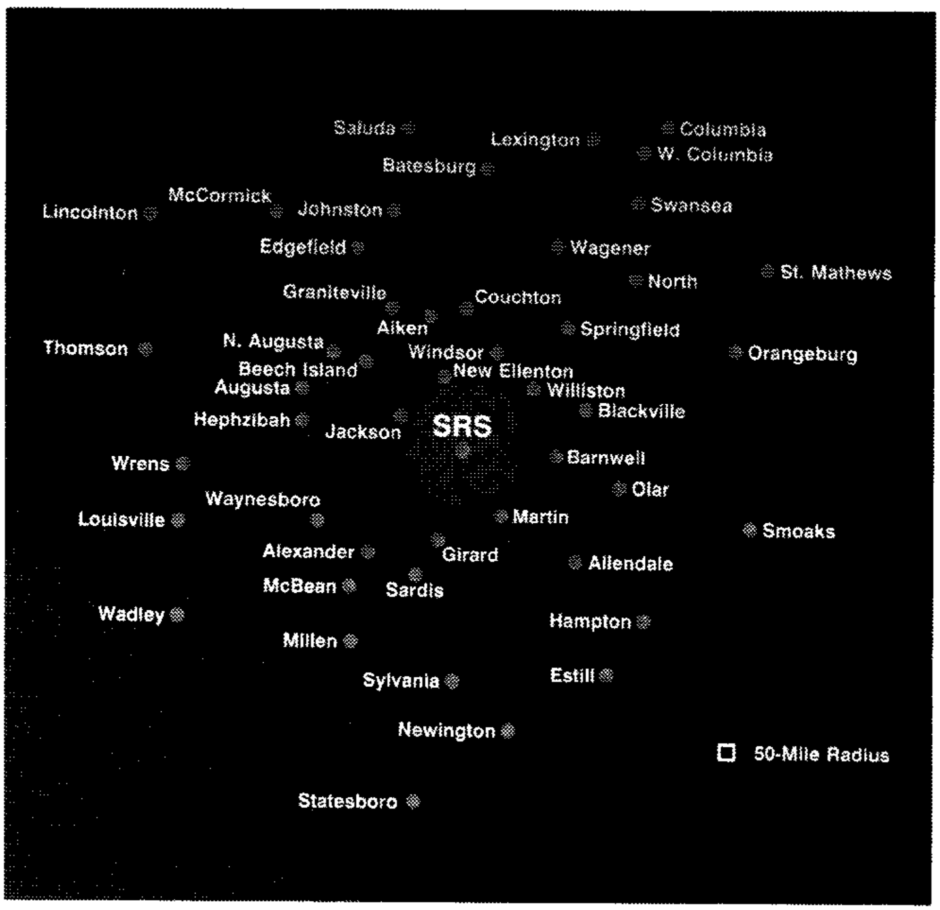


Figure 4-3. TLD badges are placed at locations in Georgia and South Carolina within the 100-mile radius of SRS

Table 4-9
Comparison of 1988 and 1989 TLD Ambient Radiation Measurements

TLD Monitoring Station Locations	No. of Locations	Maximum (mR/yr) 1989	Maximum (mR/yr) 1988	Minimum (mR/yr) 1989	Minimum (mR/yr) 1988	Average (mR/yr) 1989	Average (mR/yr) 1988
Site Perimeter	193	142	124	22	47	51	62
25-mile radius	12	110	102	33	51	62	73
100-mile radius	8	110	131	44	66	77	99
South Carolina							
Inside buildings	40	183	201	26	55	112	111
Outside buildings	40	146	168	37	62	105	106
Georgia							
Inside buildings	22	179	201	37	58	98	117
Outside buildings	22	142	150	44	66	87	106

NONRADIOLOGICAL MONITORING PROGRAM

Atmospheric Emissions

Major nonradiological emissions of concern from stacks at SRS facilities include sulfur dioxide (SO_2), oxides of nitrogen (NO_x), and total particulate matter less than 10 microns (PM_{10}). Stacks that have such emissions at SRS include both powerhouse stacks and process stacks.

Five coal-fired power plants located at SRS burned a total of 227,017 tons of coal in 1989. This is lower than the 373,935 tons of coal burned in 1988. The location, number of boilers, and capacity of each boiler for these plants are listed in Table 4-10 (right).

The four D-Area boilers use pulverized coal; all 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 analyzing for sulfur, carbon, ash, water, and BTU output.

Six additional onsite process stacks also release nonradioactive materials, including SO_2, NO_x, and PM_{10}.

Description of Monitoring Program

Each power plant stack is monitored for nonradioactive emissions. Six process stacks are also monitored, including three 313-M Area stacks, one 321-M Area stack, and two 291 stacks in F and H Areas.

Compliance with the SO_2 emissions standard at power plants is determined by the analysis of coal to be burned. The determination of expected SO_2 emissions is made using results of analyses of the coal for sulfur, carbon, ash, water, and BTU output.

The day-to-day control of PM_{10} and NO_x is maintained with opacity meters in all SRS powerhouse stacks. Air compliance tests are also used to determine compliance with standards for PM_{10} and NO_x. These air compliance tests are performed every two years for each boiler by air emissions specialists under contract with SRS.

Applicable Standards

Permits issued by the South Carolina Department of Health and Environmental Control (SCDHEC) regulate nonradioactive emissions from SRS stacks. Specific environmental permits are referenced in Appendix B.

Table 4-10
SRS Power Plant Boiler Capacities

Location	No. of Boilers	Boiler Capacity 10^6 BTU/hr
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

Table 4-11
Air Emission Standards

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

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

Air emissions standards are listed in Table 4-11 (above). In February 1986, a regulation limiting the opacity of NO_x to 20% went into effect, as indicated in Table 4-11. However, stacks existing before January 1, 1986 and powerhouse stacks built before February 11, 1971 are exempt. These existing stacks are subject to a 40% NO_x opacity limit. All SRS process stacks, including the four 300-M stacks and the 291-F stack, are subject to the 40% limit.

Monitoring Results

Atmospheric emissions of SO_2, NO_x, and PM_{10} from power plants at SRS were within applicable SCDHEC standards in 1989. The sulfur content of coal burned at SRS in 1989 averaged 2.6%, which yielded an average of 2.0 lb SO_2/10^6 BTU input. This is 57% of the South Carolina standard.

Measurements of opacity meters indicated that SRS powerhouse stacks were within limits for NO_x and PM_{10} more than 99% of the time in 1989. All SRS boilers subject to the air compliance tests in 1989 were within compliance.

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 stack opacity to borderline compliance.

A number of programs, including an 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 October 1990.

Ambient Air Quality

Description of Monitoring Program

Five stations around the site continuously monitor the quality of air at SRS by measuring PM_{10}, SO_2, NO_x, and ozone (O_3) concentrations. SRS operates these stations in accordance with EPA and SCDHEC requirements. The locations of SRS monitoring stations and the analyses performed at each station during 1989 are shown in Figure 4-4 (below).

South Carolina and Georgia also monitor ambient air quality near SRS as part of the network associated with the Clean Air Act Amendments of 1970. Georgia and South Carolina also monitor for lead, carbon monoxide and gaseous fluorides; however, SRS dose not monitor these parameters because the potential release is insignificant compared to the standard.

Applicable Standards

A comparison of Georgia and South Carolina air quality standards is listed in Table 4-12 (right).

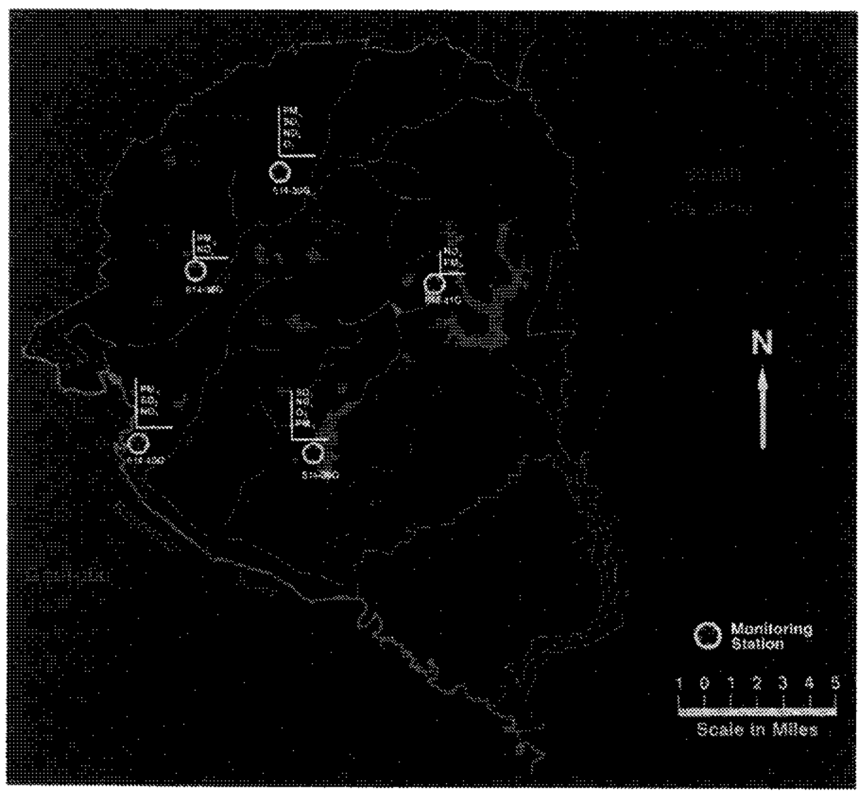


Figure 4-4. Ambient air quality monitoring locations on SRS

Monitoring Results

Table 4-12 presents the maximum air quality measurements from SRS ambient air monitoring stations and compares them to Georgia and South Carolina ambient air quality standards.

The measurements indicate that air quality near SRS is within standards set by Georgia, South Carolina, and EPA. SRS monitoring data are presented in Table 4-8, Vol. II. Measurements for 1989 by the South Carolina and Georgia sampling network from selected locations in the SRS vicinity are presented in Tables 4-9 and 4-10, Vol. II.

Table 4-12
SRS Ambient Air Quality Compared to South Carolina and Georgia Air Quality Standards

Air Quality Standard	South Carolina	Georgia	SRS Maximum	% of Standard[a]
Sulfur dioxide (ppb)				
3 hour	500[b]	500	71	14
24 hour	140[b]	140	40	29
Annual	30	30	3	10
Particulate matter <10µ (µg/m³)				
24 hour	150	150	56	37
Annual geometric mean	50	75	21	42
Ozone (ppb)				
1 hour	120	120	96	80
Nitrogen dioxide (ppb)				
Annual	50	50	8	16

[a] Compared to the most restrictive standard.
[b] Not to be exceeded more than once a year.

1989 HIGHLIGHTS

- The same average gross alpha and nonvolatile beta concentration were measured at the onsite, site perimeter, 25-mile, and 100-mile-radius sampling locations during 1989.
- Ambient radiation levels above background were detected in 1989 at the fences around operating facilities. The maximum was 2.2 mR/day near a waste facility in H Area.
- Onsite tritium oxide concentrations in air ranged from 5.6 to 4,400 pCi/m^3. The maximum value is 4.4% of the DOE Derived Concentration Guide for tritium in air (100,000 pCi/m^3).
- To supplement the site's emergency response capability, 12 more site perimeter stations are being installed and tested for measuring gamma radiation levels and tritium concentrations at each 30° sector around SRS.
- In 1989, five coal-fired power plants at SRS burned 227,017 tons of coal. This is almost 40% less than that burned in 1988.
- All SRS process stacks met the 40% nitrogen oxide opacity requirement in 1989, except for the 291-F stack, which occasionally exceeded the limit.

Appendix A: Listing of Environmental Monitoring Reports

RTS

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
WSRC-RP-89-59-1[a]	Jan–Dec 1988	Savannah River Site Environmental Report

[a] On April 1, 1989, Westinghouse Savannnah River Company assumed responsibility as the prime contractor for the Savannah River Site. The nomenclature for onsite and offsite environmental monitoring reports issued after April 1, 1989 will reflect this change.

Appendix B: Environmental Permits

PERMIT NO.	TYPE	TITLE
0080-0042-01	AIR	71.1 MMBTU/Hr Coal Boiler #1, 784-A
0080-0042-02	AIR	71.1 MMBTU/Hr Coal Boiler #2, 784-A
0080-0042-03	AIR	600 KW Diesel Generator, 794-A
0080-0042-04	AIR	400 KW Diesel Generator, 773-A
0080-0042-05	AIR	200 KW Diesel Generator, 703-A
0080-0042-06	AIR	400 KW Diesel Generator, 503-2A
0080-0042-07	AIR	150 KW Diesel Generator, 751-A
0080-0042-CB	AIR	250/225 KW Diesel Generator, 754-4A
0080-0042-CC	AIR	455 KW Diesel Generator, 720-2A
0080-0042-CD	AIR	1250 KW Diesel Generator, 754-54A
0080-0042-CE	AIR	1250 KW Diesel Generator, 754-54A
0080-0043-01	AIR-VOID	43.8 MMBTU/Hr Coal Boiler
0080-0043-02	AIR-VOID	43.8 MMBTU/Hr Coal Boiler
0080-0043-03	AIR	150 KW Diesel Generator, 108-4C
0080-0043-04	AIR	150 KW Diesel Generator, 108-1C
0080-0043-05	AIR	1000 KW Diesel Generator, 108-2C
0080-0043-06	AIR	1000 KW Diesel Generator, 108-2C
0080-0043-07	AIR	225 KW Diesel Generator, 105-C
0080-0043-08	AIR	365 KW Diesel Generator, 183-2C
0080-0044-01	AIR	396 MMBTU/Hr Coal Boiler #1, 484-D
0080-0044-02	AIR	396 MMBTU/Hr Coal Boiler #2, 484-D
0080-0044-03	AIR	396 MMBTU/Hr Coal Boiler #3, 484-D
0080-0044-04	AIR	396 MMBTU/Hr Coal Boiler #4, 484-D
0080-0044-05	AIR	150 KW Diesel Generator, 501-D
0080-0044-06	AIR	1.1 Ton/Hr Reject System, 484-D
0080-0044-07	AIR	300 Ton/Hr Coal Crusher, 484-D
0080-0045-01	AIR-VOID	71.7 MMBTU/Hr Coal Boiler #1, 784-F
0080-0045-02	AIR-VOID	71.7 MMBTU/Hr Coal Boiler #2, 784-F
0080-0045-03	AIR-VOID	71.7 MMBTU/Hr Coal Boiler #3, 784-F
0080-0045-04	AIR-VOID	71.7 MMBTU/Hr Coal Boiler #4, 784-F
0080-0045-05	AIR	Uranium Dissolution, 221-F
0080-0045-06	AIR	200 KW Diesel Generator #1, 254-5F
0080-0045-07	AIR	200 KW Diesel Generator #2, 254-5F
0080-0045-08	AIR	175 KW Diesel Generator #1, 772-F
0080-0045-09	AIR	175 KW Diesel Generator #2, 772-F
0080-0045-10	AIR	350 KW Diesel Generator, 254-19F
0080-0045-11	AIR	350 KW Diesel Generator, 235-F
0080-0045-12	AIR	350 KW Diesel Generator, 254-4F
0080-0045-13	AIR	250 KW Diesel Generator, 254-1F
0080-0045-14	AIR	200 KW Diesel Generator, 254-74F
0080-0045-15	AIR	600 KW Diesel Generator, 292-F
0080-0045-16	AIR	665 KW Diesel Generator, 271-4F
0080-0045-17	AIR	300 KW Diesel Generator, 221-FB
0080-0045-18	AIR	415 KW Diesel Generator, 772-1F
0080-0045-19	AIR	300 KW Diesel Generator, 292-2F
0080-0045-20	AIR	300 KW Diesel Generator, 254-9F

PERMIT NO.	TYPE	TITLE
0080-0045-21	AIR	1000 KW Diesel Generator, 221-F
0080-0045-22	AIR	600 KW Diesel Generator, 254-10F
0080-0045-23	AIR	350 KW Diesel Generator, 254-8F
0080-0045-CJ	AIR	455 KW Diesel Generator, 720-F
0080-0045-CI	AIR	Cement & Fly-Ash Silo
0080-0046-01	AIR	71.7 MMBTU/Hr Coal Boiler #1, 784-H
0080-0046-02	AIR	71.7 MMBTU/Hr Coal Boiler #2, 784-H
0080-0046-03	AIR	71.7 MMBTU/Hr Coal Boiler #3, 784-H
0080-0046-04	AIR	Type "O" Waste Incinerator
0080-0046-05	AIR	Separation Process, 221-H
0080-0046-06	AIR	200 KW Diesel Generator, 234-4H
0080-0046-07	AIR	200 KW Diesel Generator, 299-1H
0080-0046-08	AIR	200 KW Diesel Generator, 241-74H
0080-0046-09	AIR	250 KW Diesel Generator, 254-1H
0080-0046-10	AIR	275 KW Diesel Generator, 254-3H
0080-0046-11	AIR	300 KW Diesel Generator, 221-HB
0080-0046-12	AIR	300 KW Diesel Generator #1, 254-5H
0080-0046-13	AIR	300 KW Diesel Generator #2, 254-5H
0080-0046-14	AIR	300 KW Diesel Generator, 232-H
0080-0046-15	AIR	300 KW Diesel Generator, 234-H
0080-0046-16	AIR	500 KW Diesel Generator #2, 232-H
0080-0046-17	AIR	500 KW Diesel Generator, 254-H
0080-0046-18	AIR	600 KW Diesel Generator, 292-H
0080-0046-19	AIR	1000 KW Diesel Generator, 221-H
0080-0046-20	AIR	500 KW Diesel Generator, 254-8H
0080-0046-21	AIR	400 KW Diesel Generator, 254-9H
0080-0046-CJ	AIR	455 KW Diesel Generator, 720-H
0080-0046-CE	AIR	150 KW Diesel Generator, 241-96-H
0080-0046-CF	AIR	1000 KW Diesel Generator
0080-0046-CG	AIR	765 KW Diesel Generator, 233-H
0080-0046-CH	AIR	Fuel Process Facilities
0080-0046-CD	AIR	Alt. Tanks 48H & 49H
0080-0047-01	AIR	194.5 MMBTU/Hr Coal Boiler
0080-0047-02	AIR	194.5 MMBTU/Hr Coal Boiler
0080-0047-03	AIR	1000 KW Diesel Generator, 108-1K
0080-0047-04	AIR	1000 KW Diesel Generator, 108-2K
0080-0047-05	AIR	150 KW Diesel Generator #1, 108-4K
0080-0047-06	AIR	150 KW Diesel Generator #2, 108-4K
0080-0047-07	AIR	225 KW Diesel Generator
0080-0047-CA	AIR	365 KW Diesel Generator, 183-K
0080-0047-CB	AIR	800 KW Diesel Generator, 107-K -A
0080-0047-CB	AIR	800 KW Diesel Generator, 107-K -B
0080-0048-01	AIR	194.5 MMBTU/Hr Coal Boiler, 184-P
0080-0048-02	AIR	194.5 MMBTU/Hr Coal Boiler, 184-P
0080-0048-03	AIR	1000 KW Diesel Generator, 108-1P
0080-0048-04	AIR	1000 KW Diesel Generator, 108-2P
0080-0048-05	AIR	150 KW Diesel Generator, 108-4P
0080-0048-06	AIR	150 KW Diesel Generator, 108-4P
0080-0048-07	AIR	225 KW Diesel Generator, 152-7P
0080-0048-CA	AIR	365 KW Diesel Generator, 183-2P
0080-0049-01	AIR	1000 KW Diesel Generator, 108-1L
0080-0049-02	AIR	1000 KW Diesel Generator, 108-2L

PERMIT NO.	TYPE	TITLE
0080-0049-03	AIR	400 KW Diesel Generator, 191-L
0080-0049-04	AIR	150 KW Diesel Generator #1, 108-4L
0080-0049-05	AIR	150 KW Diesel Generator #2, 108-4L
0080-0049-06	AIR	225 KW Diesel Generator, 152-7L
0080-0049-CA	AIR	365 KW Diesel Generator, 183-2L
0080-0055-01	AIR	Uranium Metal Cleaning with Nitric Acid, 313-M
0080-0055-02	AIR	Aluminum Tube Cleaning with Nitric Acid, 321-M
0080-0055-03	AIR	200 KW Emergency Power Diesel, 320-M
0080-0055-04	AIR	400 GPM Air Stripper
0080-0055-CA	AIR	50 GPM Air Stripper
0080-0060-01	AIR	750 KW Diesel Generator, 673-T
0080-0060-02	AIR	300 KW Diesel Generator, 673-T
0080-0060-03	AIR	300 KW Diesel Generator, 672-T
0080-0060-04	AIR	20 Lbs/Hr Incinerator, 677-T
0080-0060-05	AIR	Process to decompose Tetraphenylborate into Aqueous
0080-0060-06	AIR	1000 KW Emergency Diesel Generator, 654-1T
0080-0060-07	AIR	300 KW Emergency Diesel Generator, 654-T
0080-0066-01	AIR	540 Ton Cement Silo
0080-0066-02	AIR	540 Ton Fly Ash Silo
0080-0066-03	AIR	540 Ton Mixer
0080-0066-04	AIR	84 Ton New Cement Storage Silo
0080-0066-05	AIR	2000 KW Diesel Generator, 292-S
0080-0066-06	AIR	2000 KW Emergency Power Diesel Generator, 292-S
0080-0066-CB	AIR	DWPF Vitrification Process, 221-S
0080-0066-CC	AIR	187 KW Diesel Generator, 980-S
0080-0079-01	AIR	180 KW Diesel Generator, ATTA Facility
0080-0080-01	AIR	425 KW Diesel Generator
0080-0080-02	AIR	Slag Silo
0080-0080-03	AIR	Three Fly-Ash/Cement Silo
0080-0080-04	AIR	Weight Hopper
0080-0080-05	AIR	Two Pre. Air Blend.
0080-0080-06	AIR	Pre. Feed Storage Bin
0080-0080-07	AIR	Two Grout Mixers (1 in service)
LS89002	DOMESTIC WATER	Temporary Modular Offices, 100-C
LS-1-W	DOMESTIC WATER	Water Line, Tritium Facilities Support Building, 235-H
LS-4-W	DOMESTIC WATER	Water Line, Office Building, 703-41A
LS-7-W	DOMESTIC WATER	Water Line, Naval Fuels Material Facility, 221-17F, 221-18F
LS-8-W	DOMESTIC WATER	Water Line, 703-4A, 703-6A, 703-34A
LS-11-W	DOMESTIC WATER	Water Line, Naval Fuels Material Facility, 247-F
LS-23-W	DOMESTIC WATER	DWPF TC Emergency Water Supply
LS-25-W	DOMESTIC WATER	Chemical Feed Facility Water System, 100-C
LS-43-W	DOMESTIC WATER	Technical Area Water Main Bypass, 773-14A
LS-54-W	DOMESTIC WATER	Domestic Water Line, 707-H
LS-55-W	DOMESTIC WATER	Domestic Water Supply for Chemical Feed Facilities, G Area
LS-56-W	DOMESTIC WATER	Domestic Water Supply for Chemical Feed Facilities, H Area
LS-57-W	DOMESTIC WATER	Domestic Water Line Relocation and Service Line Install, 735-11A
LS-59-W	DOMESTIC WATER	Water System, DWPF Ice House

PERMIT NO.	TYPE	TITLE
LS-60-W	DOMESTIC WATER	Domestic Water Line for 704-S Administration Building, DWPF
LS-61-W	DOMESTIC WATER	Domestic Water Line to Feed DWPF Sanitary Treatment Plant
LS-81-W	DOMESTIC WATER	Domestic Water for Construction Office Building, C Area
LS-82-W	DOMESTIC WATER	Domestic Water For Sanitary Treatment Facility, U Area
LS-106-W	DOMESTIC WATER	DWPF Auxiliary Pump Pit Water Lines, S-511
LS-115-W	DOMESTIC WATER	Water Line, Crafts and Engineers, CAB/Central Shop
LS-118-W	DOMESTIC WATER	Water Line, 719-4A
LS-119-W	DOMESTIC WATER	Water Line, 730-M
LS-139-W	DOMESTIC WATER	Replacement Tritium Facility Domestic Water, 233-H, 249-H
LS-178-W	DOMESTIC WATER	Computer Repair Building Domestic Water, 722-5A
LS-185-W	DOMESTIC WATER	Domestic Water Main, 901-A
LS-187-W	DOMESTIC WATER	ETF-F Lift Station Domestic Water
LS-232-W	DOMESTIC WATER	Temporary Domestic Water for FPF and RTF Facilities
LS-233-W	DOMESTIC WATER	Temporary Domestic Water for F- and H-Area ETF Construction Office
LS-238-W	DOMESTIC WATER	ECF/CAS Security Upgrade Facilities, 720-H and 701-3H
LS-264-W	DOMESTIC WATER	Central Shops Construction Division Quality Office Building
LS-265-W	DOMESTIC WATER	Domestic Water Supply for Equipment Storage and Health Protection Facility, 221-25F
41225	DOMESTIC WATER	3/700-A Area Water Line from New Domestic Wells
48061	DOMESTIC WATER	Temporary Water System, 905-104L, 904-105L
111626	DOMESTIC WATER	Upgrade Gaseous Chlorination Facility, D and G Areas
200092	DOMESTIC WATER	Deep Wells, 905-104L, 904-105L
200279	DOMESTIC WATER	Install Domestic Deepwell 905-120P (Well, P Area)
201715	DOMESTIC WATER	Domestic Deepwell, Railroad Classification Yard, 905-107G
202915	DOMESTIC WATER	Water Supply and Well System, DWPF Construction Support Area
203427	DOMESTIC WATER	Sodium Hypochlorite System, 280-F
203467	DOMESTIC WATER	Sodium Hypoclorite System, 280-H
203628	DOMESTIC WATER	Replace Pistol Range Well
203638	DOMESTIC WATER	Replace Allendale Barricade Well
203786	DOMESTIC WATER	Drinking Water Well 905-114G, 681-3G
204138	DOMESTIC WATER	Replace Domestic Deepwell, 905-94K
204198	DOMESTIC WATER	Replace Domestic Deepwell, 905-66H
205217	DOMESTIC WATER	Upgrade Instrumentation 280-1F and 280-1H
205877	DOMESTIC WATER	Augusta Barricade Water Well, 905-116G
206575	DOMESTIC WATER	Domestic Water Deepwells and Distribution Line, A Area
207005	DOMESTIC WATER	Activated Carbon Treatment System, 3/700 Area
208177	DOMESTIC WATER	Phosphate Feed System, B Area
208425	DOMESTIC WATER	ATTA Domestic Water System
208434	DOMESTIC WATER	Domestic Water System, Barricades, 701-8G, 701-12G, 701-13G
208866	DOMESTIC WATER	Domestic Water Well for Aiken Barricade Gate House, 701-5G

PERMIT NO.	TYPE	TITLE
209454	DOMESTIC WATER	TNX Domestic Water System and Well
210657	DOMESTIC WATER	Drinking Water Well and Distribution System, 905-39F
212745	DOMESTIC WATER	DWPF Domestic Water Wells 1 and 2
400347	DOMESTIC WATER	Domestic Water Headers, TNX Area
400367	DOMESTIC WATER	Fuel Production Facility Water System, 225-H
401118	DOMESTIC WATER	Domestic Water for NWTF
401446	DOMESTIC WATER	Production Control Facility for 200-Area Process, 772-1F
402186	DOMESTIC WATER	DWPF Domestic Water Distr. System
402925	DOMESTIC WATER	DWPF Temporary Domestic Water
404608	DOMESTIC WATER	717-K Domestic Water
404618	DOMESTIC WATER	705-C Domestic Water
405556	DOMESTIC WATER	Domestic Water System, 200-H
405566	DOMESTIC WATER	Domestic Water System, 200-F
406137	DOMESTIC WATER	Interim Storage and Redrumming Facility, Domestic Water, 709-1G, 709-2G
400737	DOMESTIC WATER	DWPF Water Line, Z Area
402874	DOMESTIC WATER	Segregated Domestic Water Supply, 3/700 Area, Phase I
403434	DOMESTIC WATER	Segregated Domestic Water Supply, 3/700 Area, Phase II
405184	DOMESTIC WATER	Water Line, 773-41A, 773-42A
408285	DOMESTIC WATER	Domestic Water Service for Sanitary Waste Treatment Facility, TNX
408595	DOMESTIC WATER	Domestic Water Line, Construction Office Building, 300-M
409484	DOMESTIC WATER	Water Line, Reactor Simulator Facility, 707-C
409955	DOMESTIC WATER	Helicopter Facility Domestic Waterline
410406	DOMESTIC WATER	Drinking Water System, 777-A
411357	DOMESTIC WATER	ETF-H Lift Station Domestic Water
411995	DOMESTIC WATER	Water Distribution System, 340-M, 341-M
412917	DOMESTIC WATER	ETF Drinking Water System, 241-84H, 241-81H
203590	DOMESTIC WATER	100-L Area Fire Station, 709-1G
411337	DRINKING WATER	Install Sodium Hypochlorite System, 780-A
IWP-087A	IND. SOLID WASTE	Sanitary Landfill Expansion
IWP-175	IND. SOLID WASTE	Experimental Sewage Sludge Application Sites (Road F, 1953 Sandy, Kato Road, Par Pond, K Area, 40 Acre Hardwood, Lower)
IWP-210	IND. SOLID WASTE	D-F Steamline Erosion Control Site
IWP-211	IND. SOLID WASTE	200-H Erosion Control Site
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-219	IND. SOLID WASTE	200-F Erosion Control Site
12,076	IND. SOLID WASTE	Sanitary Sludge Land Application, F and H Borrow Pits
LS-42-S	IND. WASTEWATER	Inert L Facility Loading Dock Sewer Relocation, 234-H
LS-112-S	IND. WASTEWATER	Fire Training Facility Process Sewer, 904-D
LS-186-S	IND. WASTEWATER	FPF Process Sewer Line
SC 88-D-005	IND. WASTEWATER	F/H ETF Diffuser (Permit Application to South Carolina Water Resources Commission)

PERMIT NO.	TYPE	TITLE
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
9886	IND. WASTEWATER	M-Area 50 GPM Air Stripper
9974	IND. WASTEWATER	Concrete Batch Plant, S Area
10287	IND. WASTEWATER	Evaporator Equalization Tank Back-up System
11755	IND. WASTEWATER	Septic Tank 100-Area Fire Station
14214	IND. WASTEWATER	Batch Mixer System-FMF Wastewater Treatment Facility Modification
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 WeirBox Structures)
14520	IND. WASTEWATER	"As Built" F/H ETF Tank 50
15256	IND. WASTEWATER	Evaporator Recycle Line for F/H ETF
15467	IND. WASTEWATER	Upgrade Process Sewers, 211-F and 211-H
10,253	IND. WASTEWATER	M-Area 330 GPM Air Stripper
10,287	IND. WASTEWATER	Liquid Effluent Treatment Facilities, 300-M
10,349	IND. WASTEWATER	672-T TNX Process Sewer to Outfall X-008
10,358	IND. WASTEWATER	S-Area Oil Separator
10,389	IND. WASTEWATER	M-Area Drain Line
10,469	IND. WASTEWATER	735-11A Lab Building Process Sewer System Neutralization Facility
10,475	IND. WASTEWATER	Non-Contact Cooling Water Diversion, 300-M Area
10,696	IND. WASTEWATER	Interim Sludge Storage Tank, M Area
10,765	IND. WASTEWATER	Wastewater Neutralization Facility, 704-U
10,778	IND. WASTEWATER	Wastewater Treatment Facility, Naval Fuel (FMF)
10,920	IND. WASTEWATER	SREL Wastewater Disinfection Facility
10,949	IND. WASTEWATER	Trade Waste Flow Equalization Tank, 607-18A
10,955	IND. WASTEWATER	DWPF Concrete Batch Plant Wastewater Treatment Pond, S Area
11,406	IND. WASTEWATER	Fire Brigade Training Facilities Oil Separator, 411-D
11,411	IND. WASTEWATER	DWPF Treated Effluent Line
11,413	IND. WASTEWATER	DWPF Chemical Treatment Facility, S Area
11,497	IND. WASTEWATER	Production Control Facility Sanitary/Process Sewer, 772-1F
11,498	IND. WASTEWATER	Flow Monitoring Station for NPDES Outfall, L-007
11,588	IND. WASTEWATER	Powerhouse Effluent Diversion to Ash Basins, D and H Areas
11,589	IND. WASTEWATER	Powerhouse Effluent Diversion to Ash Basins, K and P Areas
11,760	IND. WASTEWATER	Wastewater for PCB Clean-up, 320-M
11,971	IND. WASTEWATER	Carbon Bed Piping for Organics Removal Demonstration Project, TNX
12,622	IND. WASTEWATER	Organics Removal Facility, TNX
12,633	IND. WASTEWATER	Effluent Treatment Plant, TNX

PERMIT NO.	TYPE	TITLE
12,683	IND. WASTEWATER	Z-Area Saltstone Manufacturing Facility
12,773	IND. WASTEWATER	L-Lake Thermal Barrier Curtain
12,782	IND. WASTEWATER	Replacement Tritium Facility Process Sewer
12,870	IND. WASTEWATER	Effluent Treatment Facility, F/H Area
12,888	IND. WASTEWATER	Metallurgical Laboratory Neutralization Facility, 723-A
12,894	IND. WASTEWATER	Filtrate Hold Tank Covers, M Area
12,922	IND. WASTEWATER	Naval Fuels Material Facility Modifications
12,973	IND. WASTEWATER	P-Area Neutralization Facility, 183-2P
13,105	IND. WASTEWATER	ETF Process Sewer Lines, F/H Area
13,154	IND. WASTEWATER	Flow Measurement Device, L Area
13,286	IND. WASTEWATER	Portable Chromium Removal System, SRL
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
13,431	IND. WASTEWATER	Flume at M-004 Outfall
13,456	IND. WASTEWATER	"As Built" L Tank
13,457	IND. WASTEWATER	L-Tank Mercury Removal
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
14,020	IND. WASTEWATER	Mercury and Organic Removal Facility for F/H ETF
14,068	IND. WASTEWATER	M-Basin Closure Wastewater Treatment Facility, M-Area Basin
14,100	IND. WASTEWATER	Repair Ash Basin Dike, 488-1D
14,338	IND. WASTEWATER	H-and Z-Area Inter-Area Salt Solution Transfer Line ("As Built" Permit to Transfer Solution from Tank 50 in H Area)
14,379	IND. WASTEWATER	Upper Three Runs Creek Diffuser (F/H ETF Outfall H-016)
14,624	IND. WASTE WATER	Existing F/H Area Process Sewer Lines
14,832	IND. WASTEWATER	Supernatant (Supernate) Transfer System and Polymer Addition System in M-Area Liquid Effluent Treatment Facility
15,892	IND. WASTEWATER	F/H ETF Interim pH Adjustment System (Caustic and Acid Supply)
84-2Z-209	MAIN. DREDGING	Maintenance Dredging in Raw Water Intake Canal on Savannah River, South Carolina Water Resources Commission
84-2Z-209	MAINT. DREDGING	Maintenance Dredging in Raw Water Intake Canal (681-5G) on Savannah River, Corps of Engineers
LS-10-S	SAN. WASTE	Sanitary Sewer System, Naval Fuels Material Facility, 248-F
LS-2-S	SAN. WASTEWATER	Sanitary Sewer Line, Tritium Facilities Support Building 235-H
LS-3-S	SAN. WASTEWATER	Sanitary Sewer System, Office Building, 703-41A
LS-32-S	SAN. WASTEWATER	Sanitary Sewer Line, Wackenhut Building, TC/U Area
LS-35-S	SAN. WASTEWATER	Sanitary Sewer Relocation, 735-11A
LS-52-S	SAN. WASTEWATER	Sanitary Sewer, 707-H
LS-53-S	SAN. WASTEWATER	Sanitary Sewer Line, Construction Office Building
LS-62-S	SAN. WASTEWATER	717-F Sanitary Sewer Relocation for DWPF

PERMIT NO.	TYPE	TITLE
LS-78-S	SAN. WASTEWATER	Sanitary Sewer Line for Construction Office Building, C Area
LS-79-S	SAN. WASTEWATER	Sanitary Sewer Line - Electrical Office Building, Construction Central Shops
LS-80-S	SAN. WASTEWATER	Sanitary Sewer Line, Receiving and Stores Warehouse Construction Central Shops
LS-98-S	SAN. WASTEWATER	Sanitary Sewer Addition, S Area
LS-129-S	SAN. WASTEWATER	Sanitary Sewer, 719-4A
LS-134-S	SAN. WASTEWATER	DWPF Sanitary Sewer Line Modification
LS-149-S	SAN. WASTEWATER	Sanitary Sewer, TNX ETP
LS-158-S	SAN. WASTEWATER	Sanitary Sewer, 3/700 Construction Facility
LS-168-W	SAN. WASTEWATER	A-Area Sanitary Sewer
LS-206-S	SAN. WASTEWATER	Sewer Pipe and Manhole, 704-1T, TNX
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, 720-2A
LS-244-S	SAN. WASTEWATER	ECF/CAS Security Upgrade Facilities, 701-3H and 720-H
LS-256-S	SAN. WASTEWATER	Grinder Pump for F-Area Equalization Basin (Macerator), 607-18F
LS-275-S	SAN. WASTEWATER	Sanitary Sewer for Equipment Storage and Health Protection Facility, 221-25F
8611-P	SAN. WASTEWATER	Septic Tank and Tile Field, CS Area, 709-1G
8881	SAN. WASTEWATER	Flow Equalization Basin, 700-A
8928	SAN. WASTEWATER	FMF Sanitary Waste Treatment Plant, M Area
9256P	SAN. WASTEWATER	Septic Tank and Tile Field, Landfill Monitoring Building 642-G
9326	SAN. WASTEWATER	Sanitary Wastewater Treatment Plant, F, H, P and G Areas
9694	SAN. WASTEWATER	Sanitary Sewer System, 773-41A, 773-42A
9888	SAN. WASTEWATER	DWPF Sanitary Waste Treatment Plant
9940	SAN. WASTEWATER	Sanitary Sewer System, Reactor Simulator Facility, 707-C
9983	SAN. WASTEWATER	Sanitary Treatment Plant, 100-C Area
9998	SAN. WASTEWATER	Septic Tank And Drain Field for F/H ETF
15005	SAN. WASTEWATER	Sanitary Treatment Plant, 700-A Area
15049	SAN. WASTEWATER	Equalization Basin for Sanitary Treatment Facilities, Central Shops
15416	SAN. WASTEWATER	Sanitary Flow Equalization Basin for 100-K Area
15417	SAN. WASTEWATER	Sanitary Flow Equalization Basin for 100-P Area
15418	SAN. WASTEWATER	Sanitary Flow Equalization Basin for 100-L Area
15444	SAN. WASTEWATER	Sanitary Lift Station to Serve Building 341-M
15740	SAN. WASTEWATER	Sanitary Sewer System Exapnsion, C-Area Lift Station
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
10,236	SAN. WASTEWATER	Lift Station, Change Station Facility, 241-58H
10,314	SAN. WASTEWATER	DWPF Construction Site Sanitary Sewer System
10,499	SAN. WASTEWATER	DWPF Sanitary Sewer System, 200-S
10,521	SAN. WASTEWATER	Chemical Feed Facility, A Area

PERMIT NO.	TYPE	TITLE
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
10,530	SAN. WASTEWATER	TNX Sanitary Wastewater Treatment Plant, 607-4G
10,825	SAN. WASTEWATER	Sanitary Sewer Lift Station, 607-19-A
10,906	SAN. WASTEWATER	Sanitary Sewer, 341-M
11,407	SAN. WASTEWATER	Sanitary Waste Transfer Station 321-M Change Room Renovation
11,442	SAN. WASTEWATER	Lift Station - Force Main, 241-82H
11,615	SAN. WASTEWATER	Sanitary Treatment Plant, U Area
11,847	SAN. WASTEWATER	Effluent Weir, TNX
11,847	SAN. WASTEWATER	Effluent Weir for Sanitary Treatment System, TNX
12,383	SAN. WASTEWATER	Fuel Production Facility Sanitary Sewer, 225-H
12,386	SAN. WASTEWATER	Sanitary Sewer, 730-M
12,452	SAN. WASTEWATER	Bromide Feed System, 607-19L
12,453	SAN. WASTEWATER	Bromide Feed System, 607-18F
12,498	SAN. WASTEWATER	F-Area STP-Phase III
12,695	SAN. WASTEWATER	Replacement Tritium Facility Sanitary Sewer
12,725	SAN. WASTEWATER	F-Area STP-Phase III, 607-F
12,910	SAN. WASTEWATER	Sanitary Treatment Facility, H Area
13,155	SAN. WASTEWATER	Naval Fuels Flow Measurement Device, Outfall F-003(A)
13,156	SAN. WASTEWATER	716-2A Sanitary Sewer
13,157	SAN. WASTEWATER	Computer Repair Building Sanitary Sewer, 722-5A
13,173	SAN. WASTEWATER	Sanitary Sludge Land Application, K-Area and Par Pond Borrow Pits
13,175	SAN. WASTEWATER	Flow Equalization Basin, Building 607-22A
13,291	SAN. WASTEWATER	H-Area Septic Tank and Tile Field (Commercial Toilet Trailer)
13,430	SAN. WASTEWATER	Sanitary Sewage Treatment Facility, 607-21F
13,717	SAN. WASTEWATER	Wastewater Treatment Facility, Z Area (Septic Tank System)
14,311	SAN. WASTEWATER	Interim Sodium Hypochlorite Disinfection for 607-7C
14,312	SAN. WASTEWATER	Interim Sodium Hypochlorite Disinfection for 607-17K
14,313	SAN. WASTEWATER	Interim Sodium Hypochlorite Disinfection for 607-17L
14,314	SAN. WASTEWATER	Interim Sodium Hypochlorite Disinfection for 607-7P and 607-23P
14,315	SAN. WASTEWATER	Interim Sodium Hypochlorite Disinfection for 607-7F and 607-21F
14,316	SAN. WASTEWATER	Interim Sodium Hypochlorite Disinfection for 607-7H and 607-21H
14,317	SAN. WASTEWATER	Interim Sodium Hypochlorite Disinfection for 831-1S and 832-2S
14,318	SAN. WASTEWATER	Interim Sodium Hypochlorite Disinfection for 607-15D
14,319	SAN. WASTEWATER	Interim Sodium Hypochlorite Disinfection for 607-1B
14,320	SAN. WASTEWATER	Interim Sodium Hypochlorite Disinfection for 607-9A
14,321	SAN. WASTEWATER	Interim Sodium Hypochlorite Disinfection for SREL Water Fowl Lab
14,322	SAN. WASTEWATER	Interim Sodium Hypochlorite Disinfection for 607-18G
14,323	SAN. WASTEWATER	Interim Sodium Hypochlorite Disinfection for 607-17F (NF)

PERMIT NO.	TYPE	TITLE
14,324	SAN. WASTEWATER	Interim Sodium Hypochlorite Disinfection for 607-40T
14,407	SAN. WASTEWATER	Increased Sanitary Wastewater Treatment Capcity, 607-15D
14,443	SAN. WASTEWATER	Septic Tank and Tile Field, H Area
15,506	SAN. WASTEWATER	Sanitary Flow Equalization Basin for Naval Fuels Facility
15,419	SAN. WASTEWATER	Sanitary Lift Station, Replacement Tritium Facility, 200-H Area
15,530	SAN. WASTEWATER	100-C Area Sanitary Flow Equalization Basin
GW-02-894	UNDERGD. STORAGE	Gasoline Station Building 715-2G and Gas TK Re placement, Sitewide (UST)

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 using environmental technical standards based on recommendations of standards-setting organizations such as the NCRP, ICRP, FRC, and the AED.

1959 - Began distribution of annual environmental monitoring report to the public

1960 - Established radionuclide release guides for specific SRS streams

1961 - Established Savannah River Ecology Laboratory operated by the University of Georgia

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 ^{131}I from all SRS stacks

1965 - Began 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 first radioactive dose calculations for offsite public from SRS releases in annual environmental monitoring report

1972 - Prepared a report on SRS thermal distributions in SRS waters and in the Savannah River

1972 - Technical standards took "As Low As Reasonably Achievable" approach for environmental releases and this was applied to release guides on an annual basis

1972 - Technical standards set for offsite dose to maximum individual were 10 mrem/year to whole body, gonads and bone marrow, 30 mrem 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 epidemiological 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 on site 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 sitewide environmental studies in the annual environmental 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

1989 - Westinghouse Savannah River Company assumed responsibility as the primary contractor for the Savannah River Site

1989 - SRS was officially included on the National Priority List and became regulated under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)

Appendix D: Radionuclide and Chemical Nomenclature

Nomenclatures and Half-lives for Radionuclides

Radionuclide	Symbol	Half-life[a]
Americium-241	^{241}Am	458 y
Americium-243	^{243}Am	7.95E3 y
Antimony-125	^{125}Sb	2.7 y
Argon-41	^{41}Ar	1.83 h
Berrylium-7	^{7}Be	53 d
Carbon-14	^{14}C	5,730 y
Cerium-141	^{141}Ce	33 d
Cerium-144	^{144}Ce	284 d
Cesium-134	^{134}Cs	2.05 y
Cesium-137	^{137}Cs	30 y
Cobalt-58	^{58}Co	71.3 d
Cobalt-60	^{60}Co	5.26 y
Curium-242	^{242}Cm	163 d
Curium-244	^{244}Cm	17.6 d
Iodine-129	^{129}I	1.7E7 y
Iodine-131	^{131}I	8.05 d
Krypton-85	^{85}Kr	10.76 y
Krypton-88	^{88}Kr	2.8 h
Manganese-54	^{54}Mn	303 d
Niobium-95	^{95}Nb	35 d
Osmium-185	^{185}Os	94 d
Phosphorus-32	^{32}P	14.3 d
Polonium-210	^{210}Po	138.4 d
Plutonium-238	^{238}Pu	87.4 y
Plutonium-239	^{239}Pu	2.4E4 y
Potassium-40	^{40}K	1.26E9 y
Promethium-147	^{147}Pm	2.62 y
Ruthenium-103	^{103}Ru	39.6 d
Ruthenium-106	^{106}Ru	367 d
Selenium-75	^{75}Se	120.4 d
Strontium-89	^{89}Sr	52 d
Strontium-90	^{90}Sr	28.1 y
Tritium	^{3}H	12.3 y
Uranium-235	^{235}U	7.1E8 y
Uranium-238	^{238}U	4.5E9 y
Xenon-133	^{133}Xe	5.27 d
Xenon-135	^{135}Xe	9.16 h
Yttrium-90	^{90}Y	64 h
Zirconium-95	^{95}Zr	65 d

[a] m = minute; h = hour; d = day; y = year

Nomenclatures for Elements and Chemical Constituents

Constituent	Symbol
Aluminum	Al
Antimony	Sb
Arsenic	As
Barium	Ba
Berryllium	Be
Cadmium	Cd
Calcium	Ca
Carbon	C
Chlorine	Cl
Chromium	Cr
Cobalt	Co
Copper	Cu
Fluorine	F
Iron	Fe
Lead	Pb
Lithium	Li
Magnesium	Mg
Manganese	Mn
Mercury	Hg
Nickel	Ni
Nitrogen	N
Nitrate	NO_3
Nitrite	NO_2
Oxygen	O
Ozone	O_3
Phosphorus	P
Phosphate	PO_4
Potassium	K
Radium	Ra
Rhenium	Re
Selenium	Se
Silver	Ag
Sodium	Na
Sulfate	SO_4
Sulfur Dioxide	SO_2
Thallium	Tl
Vanadium	V
Zinc	Zn

Nomenclatures for Common Chemical Analyses

Analysis	Symbol
Biological Oxygen Demand	BOD
Chemical Oxygen Demand	COD
Particulate Matter <10 microns	PM_{10}
Polychlorinated Biphenyl	PCB
Total Dissolved Solids	TDS
Total Organic Carbon	TOC
Total Organic Halogens	TOH
Total Organic Halogens	TOX
Total Phosphates	TPO_4
Total Suspended Solids	TSS

Appendix E: Drinking Water Standards

Analyte	Level	Units	Status	Reference
Americium-241	4	pCi/L	proposed	EPA, 1986
Antimony-125	300	pCi/L	final	EPA, 1977
Arsenic	0.05	mg/L	final	CFR, 1987
Barium	1	mg/L	final	CFR, 1987
Barium-140	90	pCi/L	final	EPA, 1977
Benzene	0.005	mg/L	final	EPA, 1987
Beryllium-7	6,000	pCi/L	final	EPA, 1977
Cadmium	0.01	mg/L	final	CFR, 1987
Carbon-14	2,000	pCi/L	final	EPA, 1977
Carbon tetrachloride	0.005	mg/L	final	EPA, 1987
Cesium-134	20,000	pCi/L	final	EPA, 1977
Cesium-137	200	pCi/L	final	EPA, 1977
Chlordane	0.002	mg/L	proposed	EPA, 1989
Chloroethene (Vinyl chloride)	0.002	mg/L	final	EPA, 1987
Chloroform[a]	0.1	mg/L	final	CFR, 1987
Chromium	0.05	mg/L	final	CFR, 1987
Chromium-51	6,000	pCi/L	final	EPA, 1977
Cobalt-58	9,000	pCi/L	final	EPA, 1977
Cobalt-60	100	pCi/L	final	EPA, 1977
Dibromochloropropane	0.0002	mg/L	proposed	EPA, 1989
1,4-Dichlorobenzene (p-Dichlorobenzene)	0.075	mg/L	final	EPA, 1987
1,2-Dichloroethane	0.005	mg/L	final	EPA, 1987
trans-1,2-Dichloroethene	0.1	mg/L	proposed	EPA, 1989
1,1-Dichloroethylene	0.007	mg/L	final	EPA, 1987
2,4-Dichlorophenoxyacetic acid	0.1	mg/L	final	CFR, 1987
1,2-Dichloropropane	0.005	mg/L	proposed	EPA, 1989
Endrin	0.0002	mg/L	final	CFR, 1987
Ethylbenzene	0.7	mg/L	proposed	EPA, 1989
Fluoride	4	mg/L	final	CFR, 1986
Gross alpha	15	pCi/L	final	CFR, 1987
Heptachlor	0.0004	mg/L	proposed	EPA, 1989
Heptachlor epoxide	0.0002	mg/L	proposed	EPA, 1989
Iodine-129	1	pCi/L	final	EPA, 1977
Iodine-131	3	pCi/L	final	EPA, 1977
Iron-55	2,000	pCi/L	final	EPA, 1977
Iron-59	200	pCi/L	final	EPA, 1977
Lead	0.05	mg/L	final	CFR, 1987
Lindane	0.004	mg/L	final	CFR, 1987
Manganese-54	300	pCi/L	final	EPA, 1977
Mercury	0.002	mg/L	final	CFR, 1987
Methoxychlor	0.1	mg/L	final	CFR, 1987
Nickel-59	300	pCi/L	final	EPA, 1977

[a] The level for total trihalomethanes is set at 0.1 mg/L. Because bromated methanes are rarely detected in SRS groundwater, EHP presumes that most of the trihalomethanes present in site groundwater are chloroform.

Analyte	Level	Units	Status	Reference
Nickel-63	50	pCi/L	final	EPA, 1977
Nitrate (as N)	10	mg/L	final	CFR, 1987
Nitrite (as N)	0.001	mg/L	proposed	EPA, 1989
Nonvolatile beta	50	pCi/L	proposed	EPA, 1986
PCBs	0.0005	mg/L	proposed	EPA, 1989
Pentachlorophenol	0.2	mg/L	proposed	EPA, 1989
Potassium-40	300	pCi/L	proposed	EPA, 1986
Radium-226	4	pCi/L	proposed	EPA, 1986
Radium-228	8	pCi/L	proposed	EPA, 1986
Ruthenium-103	200	pCi/L	final	EPA, 1977
Ruthenium-106	30	pCi/L	final	EPA, 1977
Selenium	0.01	mg/L	final	CFR, 1987
Silver	0.05	mg/L	final	CFR, 1987
Silvex	0.01	mg/L	final	CFR, 1987
Strontium-89	20[b]	pCi/L	final	EPA, 1977
Strontium-90	8	pCi/L	final	EPA, 1977
Styrene	0.005	mg/L	proposed	EPA, 1989
Technetium-99	900	pCi/L	final	EPA, 1977
Tetrachloroethylene	0.005	mg/L	proposed	EPA, 1989
Tin-113	4,000	pCi/L	proposed	EPA, 1986
Toluene	2	mg/L	proposed	EPA, 1989
Total radium	5	pCi/L	final	CFR, 1987
Toxaphene	0.005	mg/L	final	CFR, 1987
1,1,1-Trichloroethane	0.2	mg/L	final	EPA, 1987
Trichloroethylene	0.005	mg/L	final	EPA, 1987
Tritium	20	pCi/mL	final	CFR, 1987
Uranium-234	28	pCi/L	proposed	EPA, 1986
Uranium-235	28	pCi/L	proposed	EPA, 1986
Uranium-238	28	pCi/L	proposed	EPA, 1986
Xylenes	10	mg/L	proposed	EPA, 1989
Zinc-65	300	pCi/L	final	EPA, 1977
Zirconium-95	200	pCi/L	final	EPA, 1977

[b] This is the lower of two levels given for strontium-89.

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EPA (U.S. Environmental Protection Agency), 1989. "National Primary and Secondary Drinking Water Regulations (Proposed Rule)," *Federal Register*, May 22, 1989, pp. 22062-22160, Washington, DC.

Appendix F: Errata

The following information was incorrectly reported in the *Savannah River Site Environmental Report for 1988*, WSRC-RP-89-59-1:

On page xi of the Preface, it was incorrectly stated that "Preparation and Publication of the report is mandated by Draft DOE Order 5400.xx". The correct statement is, "Preparation of the report is mandated by DOE Order 5400.1."

On page xxi and page 131 of Volume I, it was incorrectly reported that 83 mCi of ^{238}Pu was released from an F-Area facility. The amount of ^{238}Pu released from this facility was 83 µCi.

On page 34, Table 3-2,Volume II, the units given for calculated release quantities were incorrectly reported as pCi/cm^3, the correct unit is pCi/m^3.

On page 120 of Chapter 7 in Volume I, the FDA action level was incorrectly reported as 1.0 µg Hg/g for daily intake of mercury in edible fish. The correct FDA action level is 0.5 µg Hg/g.

On page 136 of Chapter 10 in Volume I, it was incorrectly reported that the 1988 average ^{137}Cs concentration upriver from SRS was 0.004 pCi/L. The correct 1988 average concentration was 0.013 pCi/L.

6 Groundwater Monitoring Program

SUMMARY—The groundwater monitoring program at SRS samples over 1,000 wells to obtain data for radioactive and nonradioactive contaminants to quantifiy the effects of SRS operations on groundwater quality.

This chapter describes the monitoring programs, applicable standards, hydrogeology, and groundwater movement at SRS, and then discusses the monitoring results from 16 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 Z Area.

The Environmental and Health Protection Department (EHP) monitors concentrations of total radium, gross alpha, nonvolatile beta, and tritium at selected at selected wells in the radiological groundwater monitoring program.

The nonradiological 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 annually, semiannually, or quarterly by contract laboratories that have been approved by the South Carolina Department of Health and Environmental Control (SCDHEC) to conduct the analyses.

Beginning in 1989, a contracted analytical laboratory monitored concentrations of specific radionuclides from wells in A, F, H, TNX, and Z Areas. Savannah River Laboratory Interim Waste Technology transferred monitoring of selected wells within the Radioactive Waste Burial Grounds to EMS. Wells within the 16 areas that have chemical constituents and radioactivity levels above their respective drinking water standards are identified.

INTRODUCTION

Groundwater is a primary pathway by which contaminants may migrate from waste sites at SRS to streams and rivers flowing offsite. The study and monitoring of groundwater at SRS have been a major effort since the site's inception in 1952.

Groundwater is subsurface water found in the pores of rocks and unconsolidated material. If there is also air in the pores, the material is unsaturated, and the water flows downward clinging to the particle surfaces. If there is no air present, the material is saturated, and the water flows between the particles or in cracks toward areas of lower hydraulic head. A further discussion of groundwater movement is included in the hydrogeology section of this chapter.

Groundwater at SRS is recharged by precipitation. Groundwater reaches the surface naturally through discharges into springs, creeks, and rivers. In addition, plants absorb groundwater through their roots and release it to the atmosphere through their foliage. Human activity such as pumping groundwater for water use can be a major source of groundwater movement to the surface.

In order to determine the extent of possible contamination at SRS, geologists and hydrologists use wells to sample the groundwater near waste sites. The strategy that underlies the actual placement of wells at a site is quite complex; however, the theory behind their placement is simple. Rainwater moving through the waste site dissolves material from the waste and moves it downward through the unsaturated zone to the water table. In the water table, the potentially contaminated water moves downgradient toward the discharge point. Wells placed to intercept the water that has passed through the waste site are called downgradient wells. Wells placed to intercept groundwater before it moves under the site are called upgradient wells. Wells sampling water moving next to the site are called sidegradient wells. Any contamination of the downgradient wells not present in the upgradient wells of the site is assumed to be the product of that site. The placement of the section of the well through which water enters (the screen zone) is crucial because water and contamination travel vertically as well as horizontally.

The water from SRS wells is sampled according to a schedule that is revised every year in light of regulatory requirements and historical data on groundwater contamination. This schedule includes frequency of sampling as well as constituents of concern. Scientists review these data, comparing them to past results. The tables in this report are a summary of the data collected in 1989. The text highlights those results that were above drinking water standards set by the EPA. These standards are under constant reevaluation by the EPA and other public and private organizations and have been developed by years of regulatory review.

The weight one attaches to these data is difficult to assess. Sampling methods, laboratory procedures, and the placement of wells and screen zones can affect monitoring results, and the accuracy of instruments used to measure water quality varies. In fact, below a certain level the results of the instruments are not valid, and when results are lower than these levels, the laboratories report them as below the detection limit (indicated by < in the tables). A single reported excursion above a drinking water standard may be an anomaly or a natural occurrence. Therefore, it is important to look for patterns in the data and to understand the nature of the waste site that the well monitors.

DESCRIPTION OF THE GROUNDWATER MONITORING PROGRAM

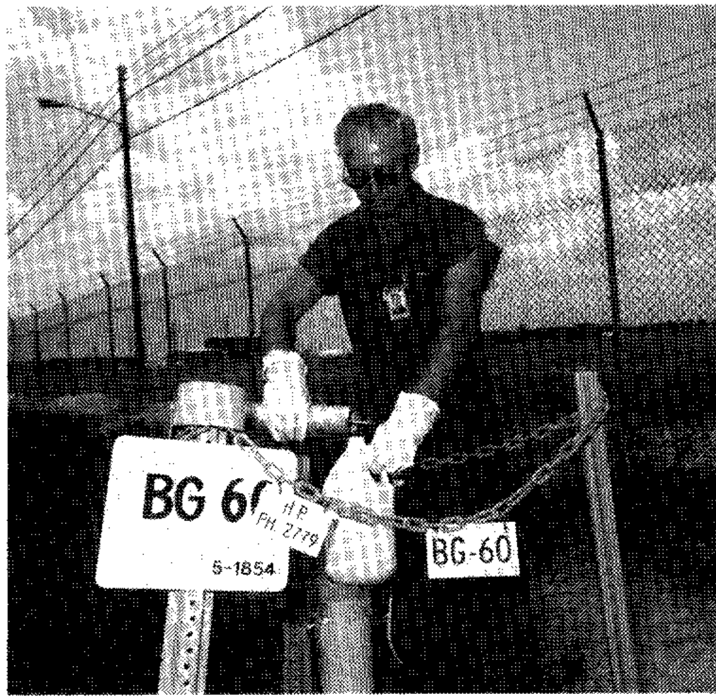
The environmental monitoring program at the Savannah River site (SRS) includes the groundwater monitoring rogram, which gathers data to quantify any effect of SRS facilities on groundwater quality. Facilities monitored include waste disposal sites, chemical storage areas, tanks, sewers, spills, and certain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

- assist SRS in complying with environmental regulations and Department of Energy 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 of the Environmental Monitoring Section (GW/EMS) within the Environmental and Health Protection Department (EHP), the Environmental Technology Section of the Savannah River Laboratory (SRL/ETS), and the operating departments of SRS. The Site Groundwater Coordinator, in the Environmental Protection Section (EPS), is responsible for ensuring SRS compliance with applicable federal, state, and local regulations and for guidance regarding groundwater matters. SRL/ETS provides technical support to EPS and the operating departments. The operating departments take primary responsibility for compliance with environmental laws by initiating projects to obtain data and by preparing and submitting reports and data analyses. GW/EMS provides services to assist the operating departments in meeting their responsibilities. These services include activities related to drilling, sampling, analysis, and reporting.

The GW/EMS also maintains contracts with subcontractors to provide field or laboratory services as needed and coordinates these activities to meet the needs of the groundwater program. This centrally coordinated program ensures consistent adherence to SRS procedures and specifications as presented in form WSRC-3Q, Hydrogeologic Data Collection (formerly DPSOP 254; presently being revised).

Representatives from GW/EMS, EPS, and SRL/ETS 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.



Collection of a groundwater sample from a monitoring well outside the Radioactive Waste Burial Ground

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 radiological and nonradiological monitoring programs. The radioactive monitoring program began in the early 1950s and primarily monitors gross alpha, nonvolatile beta, chemical cesium, gamma emitters (^{144}Ce, ^{60}Co, ^{51}Cr, ^{134}Cs, ^{137}Cs, ^{131}I, ^{103}Ru, ^{106}Ru, ^{107}Ru, ^{125}Sb, ^{95}Zr/Nb), ^{89}Sr, ^{90}Sr, and tritium at selected sites. Many of these analyses are conducted in the EMS laboratories at SRS. Groundwater monitoring for nonradioactive constituents began in 1975 with four wells at the Sanitary Landfill; in 1989, nonradioactive constituents were monitored in approximately 1,000 wells. EHP also monitors for volatile organics in A and M Areas for the Raw Materials Engineering and Technology Department and monitors selected wells within the Radioactive Waste Burial Grounds for the Interim Waste Technology Section of SRL.

All samples collected for analysis of nonradioactive constituents and those collected for offsite analysis of radioactive constituents are shipped to laboratories under contract to conduct the required analyses. Samples are screened for total radioactivity prior to shipment to determine appropriate packaging. Contract laboratories are certified by the South Carolina Department of Health and Environmental Control (SCDHEC). The results of the analyses, submitted on computer disks, are screened after 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, with changes 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 SRS annual environmental report. The database also allows for data to be extracted for specific studies.

APPLICABLE MONITORING STANDARDS

Analytical results from samples taken from SRS monitoring wells are compared with federal primary drinking water standards (40 CFR 141-142), and results above these standards are discussed in this chapter. 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). Primary drinking water standards for radioactive and nonradioactive constituents are given in Appendix E located in the back matter of this report. Some standards have not been formally accepted and are identified as proposed standards in the appendix. A constituent is evaluated by its proposed standard only if there is no accepted standard.

Several constituents without drinking water standards are described in the text as elevated when their values exceed certain levels. These constituents and their comparison values include conductivity at concentrations equal to or greater than 100 μmhos/cm, alkalinity values equal to or greater than 100 meq/L, and total dissolved solids values equal to or greater than 200 mg/L. Sulfate, which may indicate waters influenced by coal pile runoff, is described as elevated if concentrations reach or exceed 25 mg/L. In addition, pH values equal to or below 4.0 or equal to or above 8.5 are noted. The selection of these values for comparison is somewhat arbitrary; however, these levels have been deliberately set higher than the concentrations found in natural groundwater in the SRS vicinity. The occurrence of elevated alkalinity, conductivity, and pH within a single well could be caused by leaching of the grouting material used in well construction.

The groundwater monitoring results tables in Volume II comprise the routine analyses tables and the other analyses tables. The format of the routine analyses tables permits the reporting of only one result for each analyte at each well for each quarter. Thus, the computer program that creates the tables chooses the first analytical result it encounters for each analyte, although there may be two or more results for an analyte in one quarter. The additional results, called second analysis results, represent laboratory analytical replicates, blind replicates, requests for reanalysis, and comparison analyses conducted by more than one laboratory.

In routine analyses tables, second analysis results replace first analysis results for an individual well under the following conditions: if the first analysis result for an analyte is below the applicable standard in all four quarters and the second analysis result is above the standard, the second analysis result is reported; if the first analysis result is above the applicable standard and the second analysis result is at least 10 times greater than the first analysis result, the second analysis result is reported.

The maximum results for the routine analyses are taken from the routine analyses tables (i.e., from first analysis results and from second analysis results that have been substituted as a result of the previously stated conditions). All first and second analyses results for the other analyses are printed in the other analyses tables. The maximum results for the other analyses are taken from both first and second analyses results.

In the routine analyses tables, a date is given for each quarter in which analyses were performed. Each date serves as a column heading and is the date on which field data (sampling method, water elevation, pH, conductivity, and alkalinity) were collected. Usually all laboratory analyses are conducted on the same sample that provides the field data; however, some or all of the analytical results may come from samples collected on other dates in the same quarter.

Volume II contains analytical data summary tables for all monitored wells and figures showing their locations.

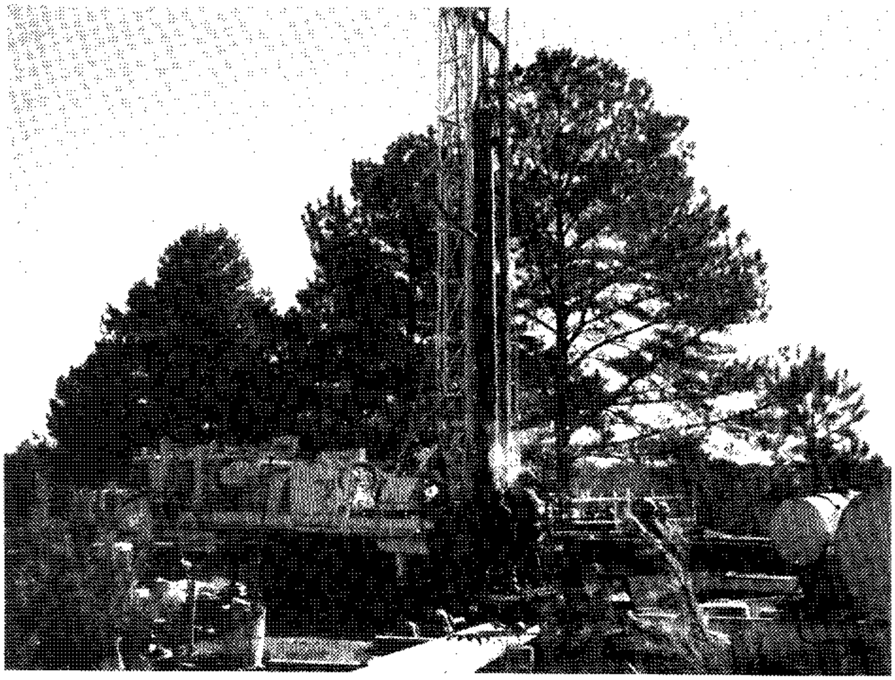
CHANGES IN THE MONITORING PROGRAM DURING 1989

Two SRS locations were added to the Resource Conservation and Recovery Act Facility Investigation program in 1989: the K-Area Sludge Land Application Site (formerly the K-Area Borrow Pit Site; 761-4G), monitored by the three wells of the KSS series, and the Par Pond Sludge Land Application Site (formerly the Par Pond Borrow Pit Site; 761-5G), monitored by the three wells of the PSS series.

The IDB, IDP, and IDQ well series, installed in 1987–1988 to characterize potential sites for new waste management facilities, were monitored for the first time in 1989. These wells were installed by the Savannah River Laboratory (SRL). Also monitored for the first time in 1989 were four wells of the SCA series. This series monitors the groundwater beneath the Vitrification (Canyon) Building of the Defense Waste Processing Facility (DWPF) in S Area.

Four new well series were installed in 1989 at the following SRS locations: 9 wells of the CSD series were installed to monitor diesel fuel contamination from the Diesel Fuel Storage Facility, located in the southwestern portion of the Central Shops Area; 2 wells of the P26 series were installed as pump test wells for the Congaree Formation and the water table in TNX Area; 12 wells of the TNX series were installed to monitor various spills in TNX Area; and 8 wells of the YSC series were installed in Y Area (the northwest portion of Z Area) for site characterization for the Waste Solidification and Disposal Facility.

Thirty-eight new wells were added to existing well series and were sampled for the first time in 1989 at the following SRS locations: the Metals Burning Pit (four ABP series wells), the Metallurgical Labora-



SRS increased the groundwater monitoring program during 1989 through the installation of many new monitoring wells

tory Seepage Basin (five AMB series wells), the Miscellaneous Chemical Basin (three MCB series wells), the Motor Shop Oil Basin (one AOB series well), and the SRL Seepage Basins (two ASB series wells) in A Area; the A-Line and Canyon Buildings (one FCA series well) in F Area; the Road A Chemical Basin (Baxley Road; one BRD series well); and the Radioactive Waste Burial Grounds (21 BGO series wells). In addition, approximately 45 MSB series plume definition wells were added in A and M Areas under the Phase III and III-A Well Drilling Programs and were sampled for the first time in 1989.

One of the new ASB wells near the A-Area SRL Seepage Basins (ASB 9C) is also part of the M-Area Plume Definition program. The new ABP, BGO, BRD, and MCB wells are Resource Conservation and Recovery Act wells. Eight new wells were added to existing well series but were not sampled in 1989: the Vitrification (Canyon) Building (four SCA series wells) in S Area and the Old TNX Seepage Basin (two XSB series wells) and the TNX Burying Ground (two TBG series wells) in TNX Area. Two new production wells, FSB 1TA and HSB 1TB, were installed at the F-Area and H-Area Seepage Basins, respectively.

Thirty-six monitoring wells were abandoned in 1989 at the following SRS locations: the Acid/Caustic Basin (two FAC series wells), the hydrology cluster (six FC series wells), and the Seepage Basins (five F series wells and three FMC series wells) in F Area; the Seepage Basins (seven H series wells) in H Area; the Radioactive Waste Burial Grounds (12 BG series wells); and the DWPF (one RSS series well) in S Area.

In addition to regulatory and well monitoring changes within the program during 1989, several other changes also occurred. The SRL Interim Waste Technology Section transferred the responsibility for monitoring the IDB, IDP, and IDQ wells to the Environmental Protection Department in 1989. General Engineering Laboratories of Charleston, South Carolina, and metaTRACE of St. Louis, Missouri, contracted to analyze groundwater samples at the start of second quarter 1989. These laboratories replaced Envirodyne Engineers of St. Louis, Missouri. Quality control standards (National Bureau of Standards—traceable standards), prepared by Environmental Resource Associates of Arvada, Colorado, were sent to both General Engineering and metaTRACE, as well as to the M-Area Laboratory, as part of the quality assurance process. Teledyne Isotopes of Westwood, New Jersey, became the primary laboratory for individual radioisotope analyses during the year.

HYDROGEOLOGY AT SRS

Geologic Setting

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 of the Savannah River. The SRS stratigraphy (see Figures 6-1 and 6-2 on the following pages) comprises about 1,000 ft of unconsolidated sands, clayey sands, and sandy clays, which are underlain by dense crystalline metamorphic rock or consolidated sediments in the Triassic basin. The geologic stratigraphy applicable to SRS (described from bottom strata to top strata) is as follows.

Rocks of the Cape Fear Formation, which constitutes a regional aquitard, represent the lower-most portion of the Upper Cretaceous Epoch. The Middendorf and Black Creek Formations and the Steel Creek Member of the Peedee Formation sequentially overlie the Cape Fear Formation. Rocks of Paleocene age include the Ellenton Member of the Rhems Formation and the Williamsburg Formation. Very few clean sands occur in Paleocene rocks, which constitute a regional aquitard.

Rocks of the Eocene-age Congaree Formation are generally capable of yielding several hundred gallons of water per minute to wells at SRS. Overlying the Congaree Formation are rocks of the Santee Formation. The Caw Caw Member of the Santee Formation is a local aquitard and it has been called the "green clay" in SRS hydrologic writings. The McBean Member overlies the Caw Caw and is commonly a limey mudstone but may be locally permeable. An unnamed sand member is locally a water producer.

Overlying the Santee Formation are Eocene-age rocks of the Dry Branch Formation. These rocks are composed of sands, clays, and fossiliferous limestones. Sandy units of the Dry Branch Formation are important water producers. The uppermost Eocene-age rocks at SRS are those of the Tobacco Road Formation. This formation consists primarily of clayey sands with a few clean sands or clays. Post-Eocene rocks are represented by gravels, sands, and clays and are included in an informal stratigraphic unit called the "Upland Unit."

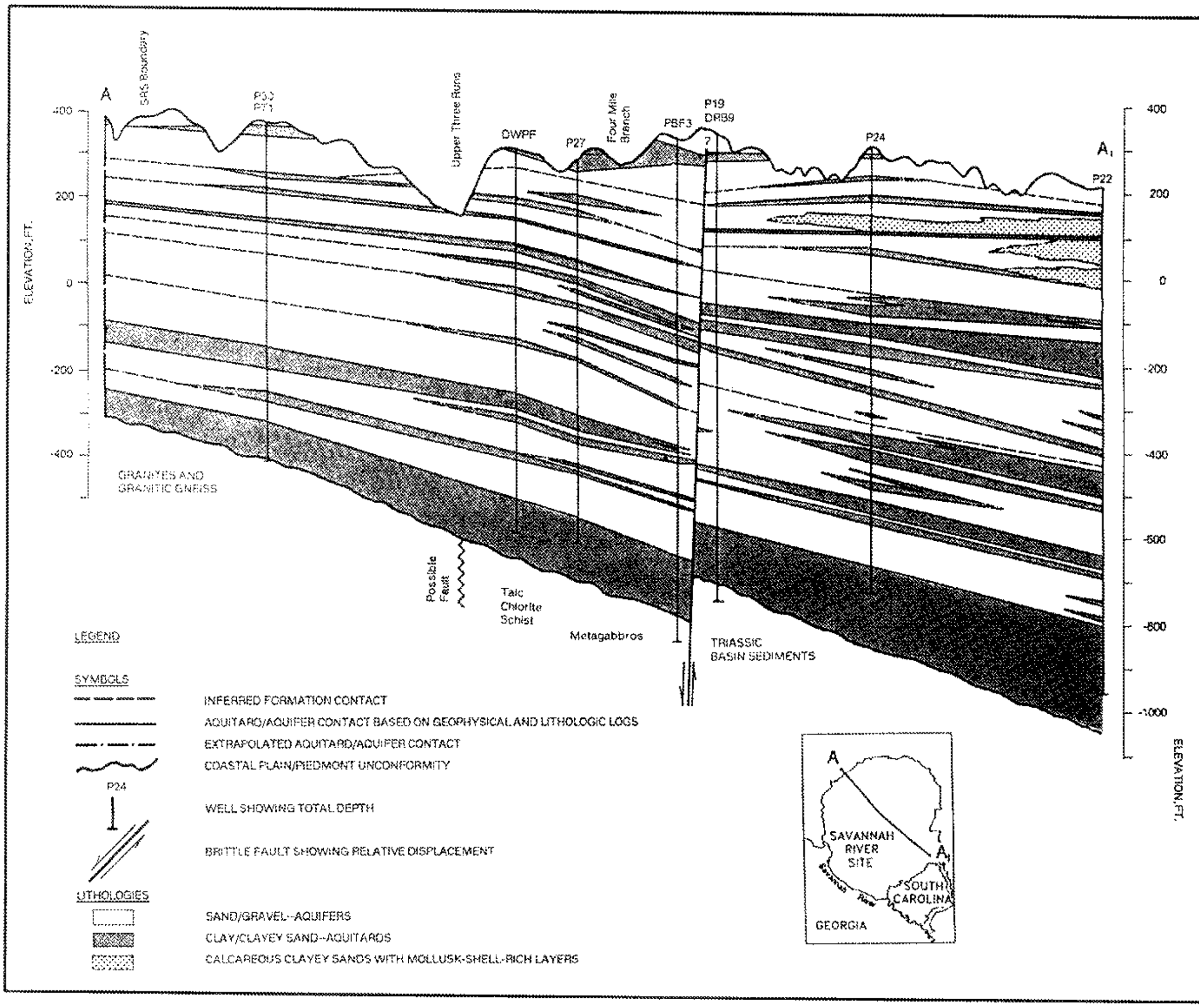


Figure 6-1. Geologic cross-section of SRS

Laterally extensive clays within the Black Creek Formation divide permeable sands in the Cretaceous sediments into two regionally important primary aquifers. The third aquifer at SRS corresponds approximately to sands of the Congaree Formation. Other Coastal Plain sediments transmit water on a local scale but do not yield water to wells in sufficient quantity to be used as primary aquifers. Portions of the Santee and the Dry Branch Formations generally yield low amounts of water to wells; thus, they could be marginally classified as aquifers. Clay-rich confining layers constitute aquitards because they retard the interchange of water between sandier portions of formations but do not actually prevent it.

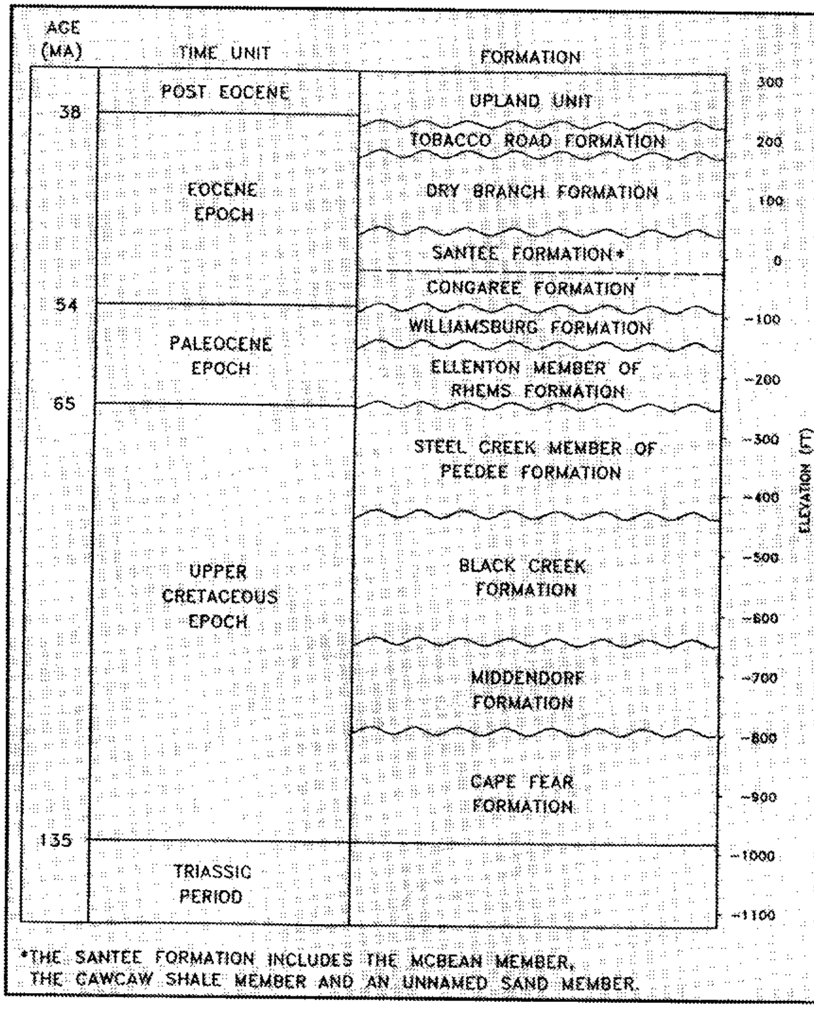


Figure 6-2. SRS stratigraphic units

Groundwater Movement

Groundwater movement is controlled by the permeability of the ground and the gradient of the groundwater. In materials such as the Coastal Plain sediments at SRS, the permeability of the ground varies greatly. Aquifers, such as sand bodies, are relatively permeable and as such allow water to pass through them easily. Aquitards, such as clay bodies, are much more impermeable and restrict the movement of water. If water is in an aquifer constrained by aquitards consisting of horizontal layers of clay or other material, the water will move more horizontally than vertically. If water is within homogeneous material with no difference between the horizontal and vertical permeabilities, the water will move downgradient, regardless of whether the direction is horizontal or vertical.

The gradient of the groundwater is a measure of the difference in hydraulic head moving the water in the saturated zone. The hydraulic head at a point in the aquifer represents the total potential energy of the water at that point relative to some reference point. Each well is screened within a certain zone, and the water in the well equilibrates with the hydraulic head of the water in that zone. The elevation of the top of the water in the well is measured to determine the hydraulic head of the water in the zone monitored. By comparing the water levels in adjacent wells screened in the same aquifer, the horizontal direction of groundwater flow can be determined. The horizontal gradients in the water table are relatively steep near the discharge streams and are relatively flat near groundwater divides between the discharge streams. Groundwater flows downgradient to the discharge point.

Most of the wells in this report are screened in the water table, the uppermost saturated zone. This saturated material ranges from relatively impermeable clay to relatively permeable sand. The direction of flow of water in the water table is controlled by the horizontal and vertical permeabilities and gradients. If the water table is within a sand layer that has a large horizontal gradient and is underlain by an aquitard, the direction of movement will be dominantly horizontal. If the water table is within an aquitard that is underlain by an aquifer of lower

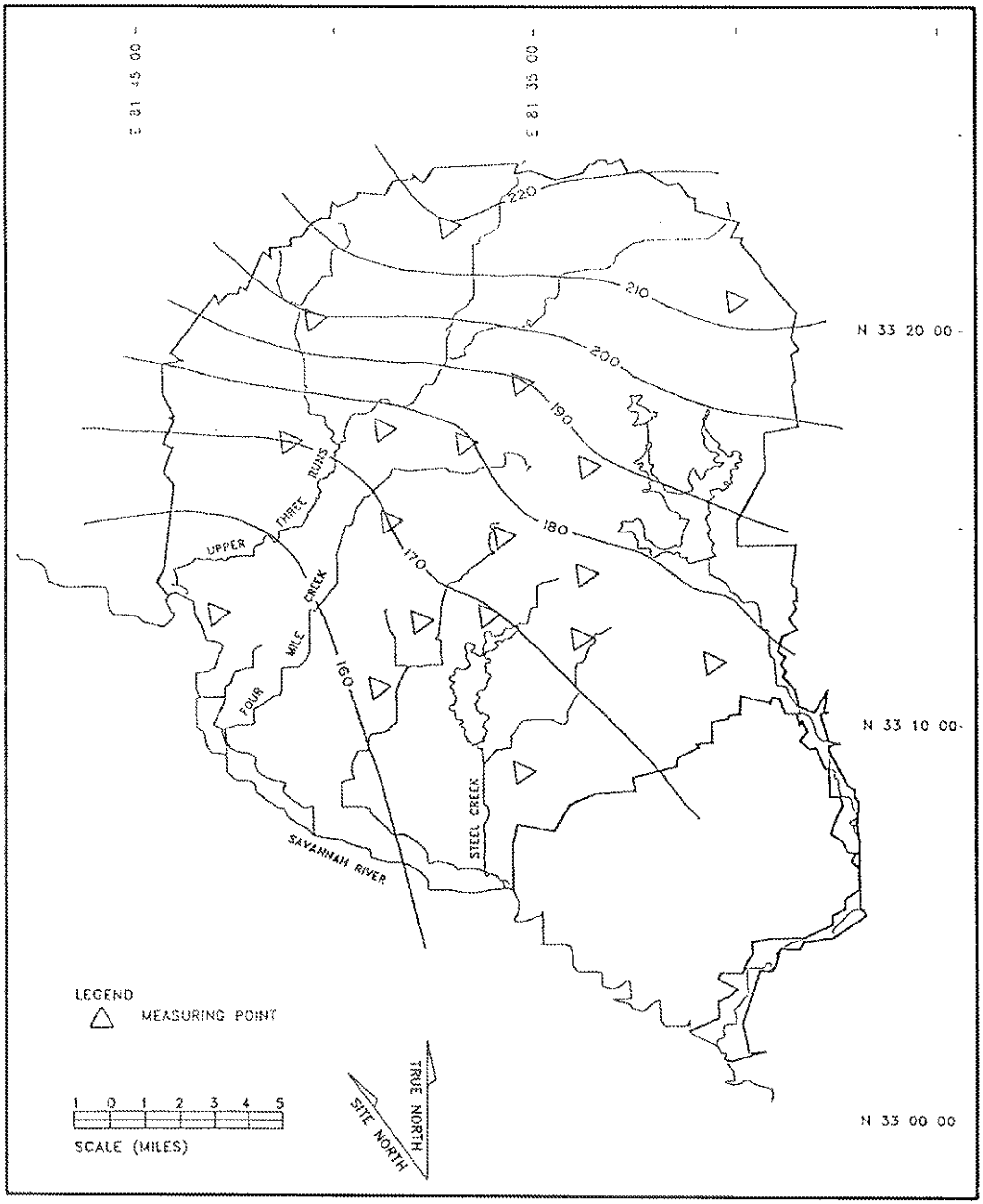


Figure 6-3. Piezometric map of the Upper Cretaceous aquifer

hydraulic head, the direction of movement will be dominantly downward to the aquifer and then continued horizontally.

In this report the wells are categorized as to whether they are upgradient, sidegradient, or downgradient of the site. These characterizations are based upon the horizontal groundwater gradient at the site and are determined from water-level elevations. It is important to consider only wells screened in the same vertical zones when determining the horizontal gradient because wells screened above and below an aquitard can have different hydraulic heads that will not accurately reflect horizontal gradients. At some sites there are insufficient wells or the horizontal gradients are too low to make a determination of the horizontal flow direction. At other sites, particularly where the water table occurs in a thick clay, the horizontal gradient of the water-table surface has no clear pattern.

In general, if the horizontal flow is much greater than the vertical flow and the wells are properly screened in the water table, any contamination of the groundwater from SRS operations should be detected in the downgradient wells. The sidegradient wells may be affected by the site, and the upgradient wells should reflect water unaffected by the site.

At SRS, the horizontal direction of groundwater movement is governed largely by the depths of incisions of the creeks that allow discharge of the water to the surface. The valleys of perennial streams allow discharge from the shallow formations. The valleys of major tributaries of the Savannah River govern flow direction in formations of intermediate depth, and the valley of the Savannah River governs the flow in deep formations. Generally, groundwater in the Upper Cretaceous formations flows toward the Savannah River and that in the Congaree Formation flows toward Upper Three Runs Creek or the Savannah River, depending on proximity (see Figures 6-3 above left and 6-4, facing page).

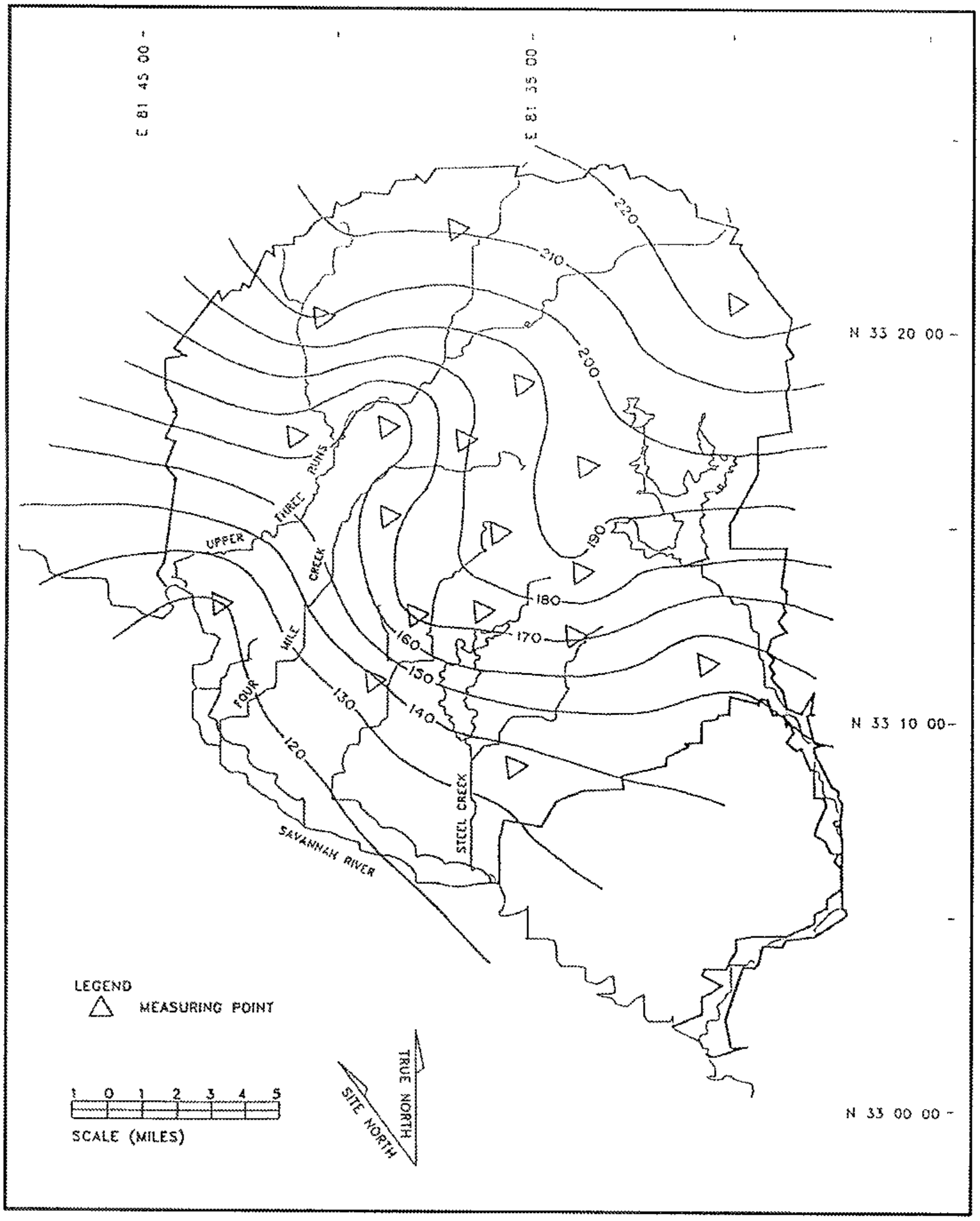


Figure 6-4. Piezometric map of the Congaree Formation aquifer

The vertical direction of groundwater movement is controlled by the permeability of the aquitards and the relative difference in hydraulic head of the water on either side of an aquitard. Aquitards are not continuous across SRS (see Figures 6-1 and 6-2 shown previously).

Generally, in the northwestern part of SRS aquitards are less continuous, permitting vertical flow of groundwater. Where aquitards are more continuous, as they are in the southeastern portion of SRS, groundwater moves more horizontally. Along the Pen Branch fault, aquitards (and aquifers) are offset; that is, aquitards are effectively discontinuous, increasing the likelihood of vertical interchange of water from aquifer to aquifer. Beneath much of SRS, hydraulic head decreases with depth, allowing water to move downward. However, in and near the valleys of Upper Three Runs Creek and the Savannah River, the hydraulic head of the water above the Paleocene confining layer is lower than the hydraulic head below this layer because of discharge into these valleys. In these areas water moves upward across this zone (Figure 6-5, following page).

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 site. Other wastes discharged to the basins included 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 to Savannah River Site streams.

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. Most of the basins are dry except during periods of prolonged precipitation. An Interim Status Closure Plan was submitted to the South Carolina Department of Health and Environmental Control on June 30, 1989, proposing clean closure of the basins in F, H, K, and P Areas.

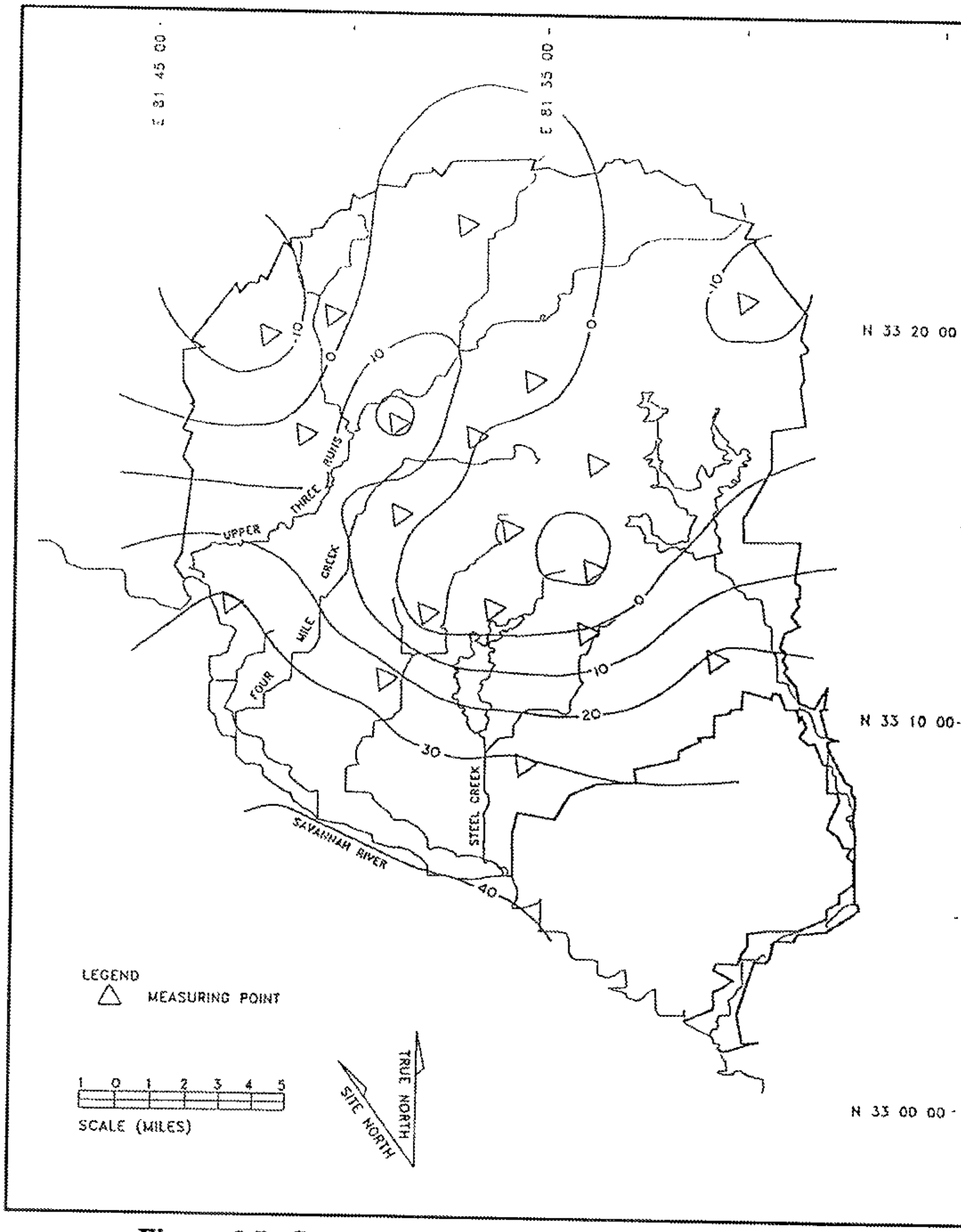


Figure 6-5. Contoured head differential map between the Upper Cretaceous and Congaree Formation aquifers

Burning/Rubble Pits

From 1951 to 1973, burnable wastes such as paper, wood, plastics, rubber, oil, degreasers, and drummed solvents were received and burned monthly in one or more of the burning/rubble pits in A, C, Central Shops, D, F, K, L, P, and R Areas. In 1973, the burning of waste stopped, and the pits were covered with a layer of soil. Rubble wastes, including paper, wood, concrete, empty galvanized-steel barrels and drums, and cans were then disposed of in the pits until they reached capacity and were covered with soil. All burning/rubble pits were inactive by 1981, and all are covered except for the R-Area pit (131-1R), 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. Coal piles originally existed 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 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 mixing of the runoff and its seepage into the subsurface, thus preventing the entry of large surges of low pH runoff into surface streams. All of the basins are active including those in C and F Areas, which still collect runoff although 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 these assemblies to the basin water. 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. Sand filters are used to remove radioactive particulates from the disassembly basin water. The filtered basin water is circulated through deionizers to remove additional contaminants and is periodically purged through regenerated deionizers to the reactor seepage basins. The disassembly basin is then filled with clean water. Purging is carried out to reduce radiation exposure to operating personnel from the accumulation of tritium in the basin.

Reactor Seepage Basins

Since 1957, active 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 and small amounts of ^{90}Sr, ^{137}Cs, and ^{60}Co.

Before the use of mixed-bed deionizers and sand filters began in the 1960s, purge water was pumped directly from the disassembly basins to the seepage basins. From 1970 to 1978, the seepage basins for active reactors were bypassed, and the filtered, deionized purge water was discharged directly into site streams. In 1978, the seepage basins for active reactors were reactivated, and all but K-Area Reactor Seepage Basin are currently in use. In K Area, the reactor seepage basin was used in 1959 and 1960 only. After that time, when water has been purged from the K-Area Disassembly Basin to another basin, it has been discharged to the K-Area Retention Basin.

GROUNDWATER MONITORING RESULTS BY AREA

A AREA

A Area is located adjacent to M Area in the northwest portion of SRS (see Figure 6-1, Vol. II). 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 site 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. Plume definition wells installed to monitor the movement of organic compounds are discussed in the M-Area section of this report.

In 1989, groundwater was monitored at the following sites in A Area: the A-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 6-2 and 6-3, Vol. II). A summary of maximum groundwater monitoring results at these sites is given in Table 6-1 (Vol. II). The Hazardous Waste Management Facility and the background wells for A Area (well clusters MSB 29 and MSB 43) are described in the M-Area section of this report.

A-Area Burning/Rubble Pits

The A-Area Burning/Rubble Pits (731-A and 731-1A) are approximately 800 ft west of Road D and 1,000 ft north of the A-Area Metals Burning Pit (Figure 6-2, 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 previous section of this chapter for a discussion of SRS burning/rubble pits.

The pits are monitored by the four wells of the ARP series (Table 6-2, Vol. II). Horizontal groundwater flow is to the west toward the Savannah River Swamp. Relative to the pits, well ARP 3 is upgradient, and wells ARP 2 and 4 are sidegradient. Well ARP 1A, which is screened below the water table, is downgradient.

No radioactive constituents were detected above drinking water standards (DWS) in the ARP wells.

Trichloroethylene (up to 0.856 mg/L) was detected above the DWS in wells ARP 1A and 3. Tetrachloroethylene (up to 0.049 mg/L) was detected above the DWS in wells ARP 2 and 3. Mercury (at 0.0027 mg/L) was detected above the DWS in well ARP 4.

A-Area Coal Pile Runoff Containment Basin

A-Area Coal Pile Runoff Containment Basin (788-3A) is east of Road D (Figure 6-3, Vol. II) and approximately 535 ft southeast of the A-Area coal pile. See the previous section 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 6-3, Vol. II). The horizontal gradient at the site is low, making determination of horizontal flow directions difficult.

Gross alpha (up to 29.7 pCi/L) and total radium (up to 23 pCi/L) were detected above their respective DWS in wells ACB 3A and 4A. One anomalously high result for nonvolatile beta activity (132 pCi/L) was reported for well ACB 1A. This result is not consistent with the other results obtained during the year. No other radioactive constituents were detected above DWS in the ACB wells.

No chemical constituents were detected above DWS at this site. However, sulfate (up to 58.7 mg/L) and conductivity (up to 311 μmhos/cm) were 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 6-2, 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 and is part of the Resource Conservation and Recovery Act (RCRA) Facility Investigation (RFI) program.

The basin is monitored by seven wells of the ABP series, four of which were added to this series in 1989 (Table 6-4, Vol. II). These wells monitor the water table and lower zones. Wells ABP 1DD, 2DD, 4DD, 6D, and 7D are used as piezometers and were not sampled. Horizontal gradients are low, making interpretation of flow directions difficult. However, the direction of groundwater flow in the water table beneath the pit appears to be toward the west. Well ABP 3 appears to be upgradient, and the remainder of the wells are sidegradient. Wells ABP 1A, 2A, and 4 are screened below the water table.

Total radium (at 5.88 pCi/L) was detected above the DWS in well ABP 1A. No other radioactive constituents were detected above DWS at this site.

Trichloroethylene (up to 0.108 mg/L) was detected above the DWS in wells ABP 2A, 3, 3C, and 4. Tetrachloroethylene (up to 0.018 mg/L) was detected

A-Area Summary

A Area lies in the northwest portion of SRS and houses administrative, research, and support facilities. In 1989, groundwater from 73 wells at eight sites in A Area was analyzed to determine the quantities of certain radioactive and nonradioactive constituents that may be present.

Concentrations of trichloroethylene and tetrachloroethylene, organic solvents that do not occur naturally in groundwater, exceeded applicable standards in one or more wells at seven sites. The highest concentration of trichloroethylene was 3.76 mg/L at the Savannah River Laboratory Seepage Basins, and the highest concentration for tetrachloroethylene was 0.123 mg/L at the Motor Shop Oil Basin. Carbon tetrachloride (up to 0.021 mg/L) was above its standard in several wells at two sites. The presence of organics beneath A Area is partially a result of past operations in M Area, which is contiguous with A Area, and discussed in more detail in the M-Area description. Many M-Area plume definition wells are dispersed throughout A Area and thus delineate A-Area groundwater contamination and contamination transport.

Radioactive constituents were detected above applicable standards at four sites. Total radium activity (up to 23 pCi/L) exceeded its standard in one or more wells at the A-Area Coal Pile Runoff Containment Basin, the A-Area Metals Burning Pit, the Miscellaneous Chemical Basin, and the Silverton Road Waste Site. Gross alpha activity (up to 32 pCi/L) was elevated in two wells at the A-Area Coal Pile Runoff Containment Basin and in one well at the Miscellaneous Chemical Basin. Nonvolatile beta activity (up to 132 pCi/L) was elevated in one well at the A-Area Coal Pile Runoff Containment Basin and in two wells at the Miscellaneous Chemical Basin. Tritium activity (up to 50.8 pCi/mL) was above its standard in one well at the Miscellaneous Chemical Basin.

Lead was above its standard in one well each at the Metallurgical Laboratory Seepage Basin, the Miscellaneous Chemical Basin, and the Silverton Road Waste Site; and mercury and sulfate concentrations exceeded standards in one or more wells at the A-Area Burning/Rubble Pits and the A-Area Coal Pile Runoff Containment Basin, respectively. Conductivity exceeded its standard in one or more wells at six sites, pH at three sites, alkalinity at two sites, and total dissolved solids at one site. The maximum values for these four analytes were found in samples from wells at the Miscellaneous Chemical Basin.

above the DWS in wells ABP 2A and 3C. No other chemical constituents were detected above DWS.

Metallurgical Laboratory Seepage Basin

The Metallurgical Laboratory Seepage Basin (904-110G) at the east edge of A Area (Figure 6-3, 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. A closure plan and a RCRA Part B Post-Closure Plan have been submitted to the South Carolina Department for Health and Environmental control (SCDHEC) for review.

The basin is monitored by the 10 wells of the AMB series (Table 6-5, Vol. II). Five of these wells were added to the series in 1989 to monitor the Carolina bay adjacent to the Metallurgical Laboratory Seepage Basin. The water table in this area is flat, making determination of horizontal flow directions difficult.

No radioactive constituents were detected above DWS at this site.

Trichloroethylene (up to 0.3 mg/L) was detected above the DWS in wells AMB 4, 5, and 6. Tetrachloroethylene (up to 0.013 mg/L) and lead (at 0.103 mg/L) were detected above DWS in well AMB 5. No other chemical constituents were detected above DWS. However, conductivity (up to 278 μmhos/cm) was elevated in wells AMB 4, 7, 10D, and 10DD. Alkalinity (up to 137 meq/L) was elevated in well AMB 7.

Miscellaneous Chemical Basin

The Miscellaneous Chemical Basin (731-5A) is west of Road D near the A-Area Metals Burning Pit (Figure 6-2, 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. This site is currently inactive and is part of the RFI program.

The basin is monitored by seven MCB series wells, three of which were added to this series in 1989 (Table 6-6, Vol. II). Wells MCB 2, 4, 5, and 6 monitor the water table. The remaining wells (MCB 5C, 6C, and 7C) monitor between 155 ft and 170 ft msl. Wells MCB 8D and 9D are used as piezometers and were not sampled. The site is near the groundwater divide between Tims Branch and the Savannah River Swamp. Horizontal groundwater flow under the basin appears to be to the east-northeast toward Tims Branch. Wells MCB 4 and 5 are upgradient, and wells MCB 2, 6, 8D, and 9D are sidegradient. There is insufficient information to determine the horizontal flow directions in the lower zones.

Total radium (up to 9.6 pCi/L) was detected above the DWS in wells MCB 4, 5C, 6C, and 7C. Gross alpha (at 32 pCi/L) in well MCB 6C and tritium (at 50.8 pCi/mL) in well MCB 5C were detected above DWS. Nonvolatile beta activity (up to 72.6 pCi/L) was elevated in wells MCB 5C and 6C.

Trichloroethylene (up to 0.701 mg/L) and tetrachloroethylene (up to 0.102 mg/L) were detected above DWS in several wells. Carbon tetrachloride (up to 0.021 mg/L) was detected above the DWS in wells MCB 4 and 5. Lead (at 0.065 mg/L) was detected above the DWS in well MCB 5C. No other chemical constituents were detected above DWS. However, alkalinity (up to 1,290 meq/L), conductivity (up to 4,790 μmhos/cm), pH (up to 12.6), and total dissolved solids (TDS) (up to 635 mg/L) were elevated in wells MCB 5C, 6C, and 7C, suggesting that the water from these wells may be affected by the leaching of well grout. Elevated conductivity (at 106 μmhos/cm) was also detected in well MCB 2.

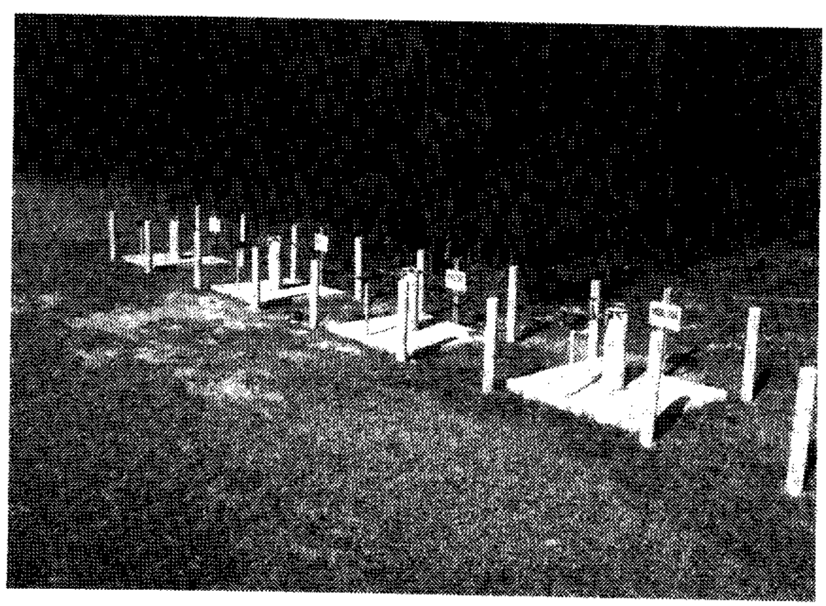
Motor Shop Oil Basin

The Motor Shop Oil Basin (904-101G) is at the south edge of A Area, by the 716-A Motor Shop (Figure 6-3, 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 before discharge to 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 three wells of the AOB series (Table 6-7, Vol. II). One of these wells (AOB 3) was added to this series during second quarter 1989. The basin is near the National Pollutant Discharge Elimination System (NPDES) Outfall A-14, a known source of halogenated organics. There is insufficient information to determine the horizontal groundwater gradient at this site.

No radioactive constituents were detected above DWS in the AOB wells.

The only chemical constituents detected above DWS were tetrachloroethylene (up to 0.123 mg/L) and



Groundwater well cluster located in A Area

trichloroethylene (up to 0.118 mg/L) in well AOB 1. Conductivity (at 108 μmhos/cm) was elevated in well AOB 3.

Savannah River Laboratory (SRL) Seepage Basins

Savannah River Laboratory (SRL) Seepage Basins (904-53G1, 904-53G2, 904-54G, and 904-55G) are east of Road 1-A across from SRL (Figure 6-3, 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 SRL 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 in 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. A Waste Site Assessment Report and a Groundwater Quality Assessment/Corrective Action Feasibility Plan have been submitted to SCDHEC for review.

The basins are monitored by eight wells of the ASB series (1A, 2A, 3A, 4, 5A, 6A, 6AA, and 7) (Table 6-8, Vol. II). Well ASB 6AA was monitored for the first time in 1989. The groundwater gradients in this area are relatively flat, and changes in flow direction have occurred. Wells ASB 2A and 3A appear to be upgradient, wells ASB 5A, 6A, and 7 are downgradient, and well ASB 4 is sidegradient of the basins.

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; well cluster ASB 9 is approximately 1,600 ft east of the seepage basins. Well clusters ASB 8 and ASB 9, including well ASB 9C added during first quarter 1989, are part of the M-Area Plume Definition program, and results for these wells are discussed in the M-Area Plume Definition section.

No radioactive constituents were detected above DWS in the ASB wells.

Trichloroethylene (up to 3.76 mg/L) was detected above the DWS in wells ASB 5A, 6AA, and 7. Tetrachloroethylene (up to 0.03 mg/L) was detected above the DWS in wells ASB 1A, 6AA, and 7. No other chemical constituents were detected above DWS. However, conductivity (up to 346 μmhos/cm) and pH (up to 10.8) were elevated in well ASB 6AA, suggesting that water from this well may be affected by the leaching of well grout.

Silverton Road Waste Site

The Silverton Road Waste Site (731-3A), southwest of Road C-1.1 (Figure 6-2, Vol. II), was used for disposal of metal shavings, construction debris, tires, drums, tanks, and miscellaneous items. The startup date is unknown, and no records of waste disposal activities have been kept. Operations at the site ceased 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 6-9, 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, well cluster SRW 2, and well SRW 3A upgradient of the site, well SRW 4 sidegradient to downgradient, and wells SRW 5 and 6 downgradient. During the year, well SRW 1 was either dry or could not be sampled. 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 (at 6.34 pCi/L) in well SRW 11 was the only radioactive constituent detected above DWS at this site.

Carbon tetrachloride (up to 0.012 mg/L) was detected above the DWS in wells SRW 6, 7, and 11. Trichloroethylene (up to 0.016 mg/L) was detected above the DWS in wells SRW 7, 11, and 14A. Lead (at 0.096 mg/L) was detected above the DWS in well SRW 7. Tetrachloroethylene concentrations (ranging up to 0.005 mg/L) were equal to the DWS in well SRW 11. No other chemical constituents were detected above DWS. However, conductivity (up to 103 μmhos/cm) was elevated in well SRW 16A; pH (at 3.9) was low in well SRW 2.

C AREA

C Area is located near the central part of SRS (see Figure 6-1 Vol. II). 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 site 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 1989, 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 the C-Area Reactor Seepage Basins (Figure 6-4, Vol. II). A summary of maximum groundwater monitoring results at these sites is given in Table 6-10 (Vol. II).

C-Area Burning/Rubble Pit

The C-Area Burning/RubblePit (131-C) is approximately 1,000 ft west of C Area (Figure 6-4, Vol. II) on a gentle, west-trending slope. See the previous section of this chapter for a discussion of SRS burning/rubble pits.

The site is monitored by the four wells of the CRP series (Table 6-11, Vol. II). Relative to the pit, CRP 1 is upgradient, well CRP 3 is downgradient, and wells CRP 2 and 4 are sidegradient.

Tritium (up to 380 pCi/mL) was detected above the drinking water standard (DWS) in all the CRP wells except CRP 4. No other radioactive constituents were detected above DWS.

Trichloroethylene (up to 14.4 mg/L) was detected above the DWS in all the CRP wells except CRP 2. Tetrachloroethylene (at 0.021 mg/L) was detected above its DWS in well CRP 1. Chromium (up to 0.184 mg/L) and lead (up to 0.56 mg/L) concentrations were above DWS in well CRP 3. No other chemical constituents were detected above DWS. However, pH (up to 12.1), alkalinity (up to 578 meq/L), TDS (at 471 mg/L), and conductivity (up to 3,100 μmhos/cm) were also elevated in well CRP 3, suggesting that from leaching of well grout may affect water in this well.

C-Area Coal Pile Runoff Containment Basin

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 6-4, Vol. II). See the previous section 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 6-12, Vol. II). Relative to the basin, CCB 2 is downgradient to sidegradient, CCB 4 is upgradient, and CCB 3 is sidegradient.

No radioactive or chemical constituents were detected above DWS in the CCB wells.

C-Area Disassembly Basin

The C-Area Disassembly Basin (105-C) is located in the C-Area reactor building (Figure 6-4, Vol. II). See the previous section of this chapter for a discussion of SRS disassembly basins.

Wells CDB 1 and 2 monitor the C-Area Disassembly Basin (Table 6-13, Vol. II). There is insufficient information to determine the horizontal groundwater gradient at this site.

Tritium (up to 395 pCi/mL) was detected above the DWS in wells CDB 1 and 2. No other radioactive constituents were detected above DWS at this site.

Lead concentrations (up to 0.128 mg/L) were above the DWS in both CDB wells. No other chemical constituents were detected above DWS.

C-Area Reactor Seepage Basins

The three C-Area Reactor Seepage Basins (Buildings 904-66G, 904-67G, and 904-68G) are currently active and periodically receive purge water when the C-Area reactor is operating. The basins are about 650 ft west of the reactor building (Figure 6-4, Vol. II).

The basins are connected in series, with water entering Basin 1 then moving to Basins 2 and 3. See the previous section of this chapter for a discussion of SRS reactor seepage basins.

The basins are monitored by the six wells of the CSB series (Table 6-14, Vol. II). Well CSB 1A is upgradient, well CSB 6A is sidegradient, and wells CSB 2A, 3A, 4A, and 5A are downgradient of the basins. Well CSB 1A was dry throughout the year.

Tritium (up to 42,700 pCi/mL) was detected above the DWS in all CSB wells except CSB 1A. No other

C-Area Summary

C Area is located in the west-central part of SRS and is the site of C Reactor, which was the last of the five SRS reactors to begin operations (in March 1955). During 1989, groundwater from 16 wells at four sites in C Area was monitored for certain radioactive and nonradioactive constituents that may be present.

Tritium was detected above its drinking water standard in 10 of the 12 wells at the C-Area Burning/Rubble Pit, the C-Area Disassembly Basin, and the C-Area Reactor Seepage Basins, with activity ranging up to 42,700 pCi/mL at the latter site. No other radioactive constituents were detected above applicable standards at C-Area sites.

Trichloroethylene (up to 14.4 mg/L) exceeded its standard in 7 of the 10 wells at the C-Area Burning/Rubble Pit and the C-Area Reactor Seepage Basins, tetrachloroethylene (up to 0.021 mg/L) was above its standard in one well at the C-Area Burning/Rubble Pit, and trans-1,2-dichloroethene (up to 0.53 mg/L) was above its standard in one well at the C-Area Reactor Seepage Basins.

Lead was above its standard in one or more wells at the C-Area Burning/Rubble Pit, the C-Area Disassembly Basin, and the C-Area Reactor Seepage Basins, and chromium was above its standard in one well at the C-Area Burning/Rubble Pit. Values for conductivity, pH, alkalinity, and total dissolved solids were above standards in several wells, with the maximum values for all four analytes found in the groundwater from one well at the C-Area Burning/Rubble Pit. None of the analytes in samples from the C-Area Coal Pile Runoff Containment Basin were above applicable standards.

radioactive constituents were detected above DWS at this site.

Trichloroethylene (up to 3.34 mg/L) was detected above the DWS in wells CSB 2A, 3A, 4A, and 5A. Lead concentrations (up to 0.133 mg/L) were above the DWS in wells CSB 2A, 3A, and 5A. The only other chemical constituent detected above DWS was trans-1,2-dichloroethene (at 0.53 mg/L) in well CSB 2A. However, conductivity (up to 320 μmhos/cm) was elevated in wells CSB 5A and 6A. Elevated pH (up to 11.8) was detected in well CSB 5A also, suggesting that water in this well may be affected by the leaching of well grout.

CENTRAL SHOPS AREA

Central Shops (CS) Area is located in the central part of SRS as shown in Figure 6-1 (Vol. II). Surface elevations 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 site boundary to CS Area is approximately 6.5 miles to the west-southwest. Four Mile Creek, Upper Three Runs Creek, and several other incised creeks are located between CS Area and the site boundary and they are areas of groundwater discharge.

In 1989, 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 6-5, Vol. II). A summary of maximum groundwater monitoring results for these sites is given in Table 6-15 (Vol. II).

Central Shops Burning/Rubble Pits

Central Shops Burning/Rubble Pits 631-1G and 631-5G are about 600 ft north of CS Area (Figure 6-5, Vol. II). Pit 631-6G is about 1 mile southeast of the area and is not monitored. The exact boundaries of the pits are unknown. See the previous section of this chapter for a discussion of SRS burning/rubble pits.

The site is monitored by the four wells of the CSR series (Table 6-16, Vol. II). Relative to the site, well CSR 2 appears to be upgradient and the remainder of the wells sidegradient to upgradient.

No radioactive or chemical constituents were detected above drinking water standards (DWS) 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 6-5, 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. After this time, the area was excavated and backfilled.

The site is monitored by the two wells of the CSO series (Table 6-17, Vol. II). Information from these wells is insufficient to determine horizontal flow directions.

Tritium (up to 23 pCi/mL) was detected above the DWS in well CSO 1. No other radioactive or chemical constituents were detected above DWS at this site.

Ford Building Seepage Basin

The Ford Building Seepage Basin (904-91G) (Figure 6-5, Vol. II) is approximately 100 ft east of the Ford Building (690-G). The basin received low-level radioactive wastewater from Ford Building operations (repairing heat exchangers) from 1964 to January 1984. The basin is currently inactive and is part of the RFI program.

The basin is monitored by the three wells of the HXB series (Table 6-18, Vol. II). These wells are screened below the water table, making interpretation of horizontal flow directions difficult.

Total radium (at 5.79 pCi/L) was detected above the DWS in well HXB 1. One anomalously high result for gross alpha (334 pCi/L) was detected above the DWS at well HXB 3. This result is not consistent with other results obtained during the year. No other radioactive or chemical constituents were detected above DWS at this site.

Hazardous Waste Storage Facility

Hazardous Waste Storage Facility (709-G, 709-2G, and 709-4G) is west of CS Area (Figure 6-5, Vol. II). Building 709-2G contains a mixture of low-level radioactive waste and hazardous waste. Since November 1983, wastes have been stored inside the buildings in drums placed on diked concrete floors designed to contain liquid spills. This facility, which is currently active, is inspected weekly for container leakage.

The site is monitored by the two wells of the HWS series (Table 6-19, Vol. II). Information from these wells is insufficient to determine horizontal flow directions.

Gross alpha (at 20.8 pCi/L) was detected above the DWS in well HWS 2. No other radioactive or chemical constituents were detected above DWS at this site.

Hydrofluoric Acid Spill Area

The Hydrofluoric Acid Spill Area (631-4G) is located at the south end of CS Area, just north of the rail line to C Area (Figure 6-5, 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 any material was released at this site.

This site is monitored by the four wells of the CSA series (Table 6-20, Vol. II). Horizontal gradients at the site are low, making interpretation of flow directions difficult. Well CSA 2 appears to be upgradient,

Central Shops Area Summary

Central Shops Area, located to the east of C Area near the center of SRS, includes supply, maintenance, and repair services and other support facilities. In 1989, 15 wells at five sites in the Central Shops Area were monitored to determine the levels of certain radioactive and nonradioactive constituents that may be present in the groundwater.

Radioactive constituents were above standards at four sites: gross alpha activity (up to 334 pCi/L) exceeded its standard at the Ford Building Seepage Basin and the Hazardous Waste Storage Facility; total radium activity (up to 6.93 pCi/L) exceeded its standard at the Ford Building Seepage Basin and the Hydrofluoric Acid Spill Area; and tritium activity (up to 23 pCi/mL) was above its standard at the Fire Department Training Facility. Elevated levels for each radioactive constituent occurred in samples from single wells.

Values of other radioactive analytes and for all nonradioactive analytes were not above standards at these sites. None of the analytes in samples from the Central Shops Burning/Rubble Pits were above applicable standards during the year.

wells CSA 1 and 3 sidegradient, and well CSA 4 downgradient of the site.

Total radium (at 6.93 pCi/L) was detected above the DWS in well CSA 4. No other radioactive or chemical constituents were detected above DWS at this site.

D AREA

D Area is located in the southwest part of SRS as shown in Figure 6-1 (Vol. II). Surface elevations across D Area range approximately from 100 to 150 ft msl, decreasing to the west-southwest toward the Savannah River. The nearest site boundary to D Area is the Savannah River, approximately 0.75 miles to the west. The water table discharges to the Savannah River and to the nearby swamp.

In 1989, 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 (Figure 6-6, Vol. II). A summary of the maximum groundwater monitoring results for these sites is presented in Table 6-21 (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 6-6, Vol. II). See the previous section of this chapter for a discussion of SRS burning/rubble pits.

This site is monitored by the four wells of the DBP series (Table 6-22, Vol. II). Three of the four wells are screened below the water table. However, well DBP 3 appears to be upgradient, wells DBP 1 and 4 sidegradient, and well DBP 2 downgradient of the pits.

No radioactive or chemical constituents were detected above drinking water standards (DWS) in the DBP wells. However, conductivity (up to 310 µmhos/cm) and sulfate (up to 97 mg/L) were elevated 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 6-6, Vol. II). See the previous section of this chapter for a discussion of SRS coal pile runoff containment basins. The D-Area Ash Basins (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 site 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 and Ash Basins are monitored by the 16 wells of the DCB series (Table 6-23, Vol. II). Horizontal groundwater flow under the site is toward the southwest. Relative to the site, wells DCB 2A, 3A, and 8 are upgradient, wells DCB 1A, 4A, 5A, and 10 are downgradient, and wells DCB 6, 7, and 9 are sidegradient. Wells DCB 1A, 6, 7, 9, 12, and 13 are downgradient of the coal pile. Well DCB 11 is located in the northern-most ash basin and is probably sampling water from within the basin. Wells DCB 12, 15, and 16 are downgradient of the coal pile, 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. Well DCB 14 is sidegradient to downgradient from the ash basins and may be downgradient from the coal pile.

Total radium (up to 35.8 pCi/L) was detected above the DWS in wells DCB 1A, 6, 7, and 10. Gross alpha (up to 82.8 pCi/L) was detected above the DWS in wells DCB 6, 10, and 14. Tritium (up to 292 pCi/mL) was detected above the DWS in wells DCB 12 and 14. Nonvolatile beta activity (up to 121 pCi/L) was elevated in well DCB 11.

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, 10, 12, and 13) 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 2.2) and high conductivity (up to 8,760 µmhos/cm), sulfate (up to 15,000 mg/L), and TDS (up to 10,000 mg/L) levels. Arsenic (up to 0.277 mg/L), chromium (up to 2.76 mg/L), fluoride (up to 10.1 mg/L), lead (up to 0.22 mg/L), trichloroethylene (up to 0.083 mg/L), and tetrachloroethylene (up to 0.01 mg/L) were detected above DWS in many of these same wells.

Also detected above the DWS were cadmium (up to 0.03 mg/L) in wells DCB 1A and 10, carbon tetrachloride (at 0.013 mg/L) in well DCB 16, mercury (at 0.003 mg/L) in well DCB 9, and selenium (at 0.014 mg/L) in well DCB 6. No other chemical constituents were detected above DWS. However, alkalinity (up to 349 meq/L) was elevated in wells DCB 13, 15, and 16.

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 6-6, 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 6-24, Vol. II). The horizontal gradient in this area is low, making determination of horizontal flow directions difficult. At least two major flow direction reversals have occurred since mid-1984.

No radioactive constituents were detected above DWS in the DOB wells.

D-Area Summary

D Area lies in the southwest portion of SRS and includes a large coal-fired power plant and the inactive heavy water facility. In 1989, groundwater from 24 wells at three sites in D Area was sampled to evaluate the levels of certain radioactive and nonradioactive constituents that may be present.

Radioactive constituents were above applicable standards at the D-Area Coal Pile Runoff Containment Basin and Ash Basins: total radium activity (up to 35.8 pCi/L) was elevated in four wells, gross alpha activity (up to 82.8 pCi/L) in three wells, tritium activity (up to 292 pCi/mL) in one well, and nonvolatile beta activity (up to 121 pCi/L) in one well.

Trichloroethylene (up to 0.37 mg/L) and tetrachloroethylene (up to 0.024 mg/L) concentrations were above standards at the D-Area Coal Pile Runoff Containment Basin and Ash Basins in eight and three wells, respectively, and in two wells each at the D-Area Oil Disposal Basin; carbon tetrachloride (at 0.013 mg/L) was above its standard in one well at the D-Area Coal Pile Runoff Containment Basin and Ash Basins.

Sulfate was above its standard in two wells at the D-Area Burning/Rubble Pits, in one well at the D-Area Oil Disposal Basin, and in 13 wells at the D-Area Coal Pile Runoff Containment Basin and Ash Basins, with the highest concentration at the latter site. Arsenic, cadmium, chromium, fluoride, mercury, lead, and selenium concentrations were above standards in one or more wells at the D-Area Coal Pile Runoff Containment Basin and Ash Basins. The maximum concentrations of sulfate and chromium in D Area were higher than those at any other site monitored at SRS in 1989, exceeding standards by 600 and 55 times, respectively. Conductivity was elevated in several wells at all three sites, with the highest levels at the D-Area Coal Pile Runoff Containment Basin and Ash Basins. Total dissolved solids exceeded its standard in 13 wells and pH in eight wells at the D-Area Coal Pile Runoff Containment Basin and Ash Basins.

Tetrachloroethylene (up to 0.024 mg/L) and trichloroethylene (up to 0.37 mg/L) were detected above DWS in wells DOB 1 and 2. No other chemical constituents were detected above DWS. However, conductivity (up to 138 μmhos/cm) was also elevated in wells DOB 1 and 2. Sulfate (up to 25.6 mg/L) was elevated in well DOB 1.

F AREA

F Area is located in the central part of SRS as shown in Figure 6-1 (Vol. II). 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 site 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 1989, groundwater was monitored at the following sites in F Area: the F-Area Acid/Caustic Basin, the F-Area A Line and F-Area Canyon Building, the F-Area Burning/Rubble Pits, the F-Area Coal Pile Runoff Containment Basin, the F-Area Effluent Treatment

Cooling Water Basin, the F-Area Seepage Basins, the F-Area Sludge Land Application Site, the F-Area Tank Farm, and the Old F-Area Seepage Basin (Figures 6-7 through 6-10, Vol. II). A summary of the maximum groundwater monitoring results for these sites is presented in Table 6-25 (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 6-8, Vol. II). See the previous section of this chapter for a discussion of SRS acid/caustic basins.

The site is monitored by the six wells of the FAC series (Table 6-26, Vol. II). The screen zone elevations in the wells at this site vary, and a clear pattern of water elevations in the wells does not exist, making interpretation of the horizontal flow directions difficult.

Total radium (up to 19.2 pCi/L) was detected above the drinking water standard (DWS) in wells FAC 4, 5, and 8. Gross alpha (up to 21.5 pCi/L) was detected above the DWS in well FAC 4. No other radioactive constituents were detected above DWS at this site.

No chemical constituents were detected above DWS. However, conductivity (up to 240 µmhos/cm) was elevated in all FAC wells except FAC 7. Sulfate (up to 61 mg/L) was elevated in wells FAC 3, 4, and 5. Elevated pH (up to 10.3) was detected in well FAC 3 also, suggesting that water in this well may be affected by the leaching of well grout.

F-Area A Line and F-Area Canyon Buildings

The F-Area Canyon Building (221-F) is in the center of F Area (Figure 6-8, Vol. II). The A-Line Uranium Recovery Facility (221-1F) is east of the south end of the Canyon Building (Figure 6-8, Vol. II). At the Canyon Building, material from the reactors is dissolved using nitric acid, and the desired radionuclides are separated from the other fission products. At the A-Line Building, uranium oxide is produced from uranyl nitrate.

The groundwater at the F-Area Canyon Building and the A-Line Uranium Recovery Facility is monitored by the two wells of the FAL series and seven wells of the FCA series (Table 6-27, Vol. II). Well FCA 19D was added in first quarter 1989. Wells FAL 1, FAL 2, and FCA 2D are between the southeast end of the canyon building and the A-Line building. These buildings are near the groundwater divide between Upper Three Runs Creek and Four Mile Creek. Horizontal groundwater flow under the northern part of the site is toward the east-northeast; horizontal flow under the southern portion of the site appears to be toward the east-southeast.

Five wells of the NBG series wells were installed between the Naval Fuel Material Facility (247-F), in the northern part of F Area, and the other facilities in F Area to determine the groundwater quality prior to startup of the Naval Fuel Material Facility (Table 6-27, Vol. II).

Horizontal groundwater flow appears to be toward the northeast in this area; however, gradient relationships between wells are unclear. The wells appear to be downgradient to sidegradient of the Canyon Building and upgradient to sidegradient of the Naval Fuel Material Facility.

Gross alpha (up to 96.4 pCi/L) was detected above the DWS in wells FCA 2D, 9D, and 16D. Total radium (up to 22.5 pCi/L) was detected above the DWS in wells FCA 9D, 10A, and 16D. Nonvolatile beta activity (up to 460 pCi/L) was elevated in wells FCA 2D and 9D. Tritium (up to 328 pCi/mL) was detected above the DWS in well FCA 16D. No other radioactive constituents were detected above DWS in the FCA and FAL wells.

Tritium (up to 2,100 pCi/mL) was detected above the DWS in wells NBG 1 and 2. Nonvolatile beta activity (up to 66.3 pCi/L) was elevated in well NBG 2. No other radioactive constituents were detected above DWS in the NBG wells.

Trichloroethylene (up to 0.245 mg/L) was detected above the DWS in wells FAL 1 and 2 and in wells FCA 2D, 16D, and 19D. Nitrate (up to 47 mg/L) was detected above the DWS in wells FCA 2D, 9D, and 16D. Lead concentrations (up to 0.797 mg/L) were above the DWS in wells FAL 2 and FCA 9D. No other chemical constituents were detected above DWS in FAL and FCA wells. However, conductivity (up to 420 µmhos/cm) was elevated in several FAL and FCA wells. TDS (up to 234 mg/L) and alkalinity (up to 169 meq/L) were elevated in well FCA 19D. Low pH (down to 3.7) was detected in well FCA 9D.

Trichloroethylene (up to 0.156 mg/L) was detected above the DWS in all five NBG wells. Nitrate concentrations (up to 94 mg/L) were above the DWS in wells

F-Area Summary

F Area, which contains one of the two chemical separations plants at SRS, is located near the center of SRS, west of H Area. In 1989, groundwater from 139 wells at nine sites in F Area was sampled to determine the quantities of certain radioactive and nonradioactive constituents that may be present. At the F-Area Seepage Basins, groundwater was analyzed from the water-table aquifer and three lower water zones.

Radioactive constituents were above applicable standards at all nine sites. Gross alpha activity was elevated in approximately 50 wells at five sites, including two of the water zones monitored beneath the F-Area Seepage Basin, with the highest concentration (3,500 pCi/L) in the water table beneath the F-Area Seepage Basins. Nonvolatile beta activity was elevated in over 50 wells at five sites, including three of the water zones beneath the F-Area Seepage Basins, with the highest activity (10,000 pCi/L) at the F-Area Tank Farm. Total radium activity was elevated in over 50 wells at eight sites, including three of the water zones beneath the F-Area Seepage Basins, with the highest activity (233 pCi/L) found in one of the lower zones beneath the F-Area Seepage Basins. And tritium activity was elevated in over 60 wells at five sites, including the four water zones monitored beneath the F-Area Seepage Basins, with the highest activity (38,800 pCi/mL) in the water table beneath the F-Area Seepage Basins. The maximum activities for gross alpha and total radium in F Area exceeded values obtained at all other sites monitored at SRS in 1989; these values were approximately 230 and 45 times applicable standards, respectively. Iodine-129, ^{226}Ra, ^{228}Ra, ^{89}Sr, ^{90}Sr, and ^{238}U activities were above standards in both the water table and one of the lower zones beneath the F-Area Seepage Basins; ^{241}Am and ^{235}U activities exceeded standards in the water table, and ^{63}Ni activity exceeded its standard in one of the lower water zones.

Organic compounds were above standards at four sites; the highest concentrations included 0.245 mg/L of trichloroethylene at the F-Area A Line and F-Area Canyon Buildings, 0.104 mg/L of tetrachloroethylene in one of the lower water zones beneath the F-Area Seepage Basins, and 0.007 mg/L of carbon tetrachloride at the F-Area Burning/Rubble Pits.

Nitrate was above its standard in over 40 wells at four sites, lead concentrations in 11 wells at three sites, and sulfate concentrations in eight wells at three sites. The maximum concentrations of nitrate and lead, found at the F-Area Seepage Basins, were higher than those at any other site monitored at SRS in 1989, exceeding standards by approximately 55 and 70 times, respectively. Arsenic, barium, cadmium, chromium, fluoride, mercury, and selenium concentrations were above standards at the F-Area Seepage Basins, and nitrite exceeded its standard at the F-Area Sludge Land Application Site. Alkalinity, conductivity, pH, and total dissolved solids exceeded standards in wells at three, eight, six, and three sites, respectively, including at least two of the water zones monitored beneath the F-Area Seepage Basins.

NBG 1 and 2. The only other chemical constituents detected above DWS at this site were lead (at 0.059 mg/L) in well NBG 1 and tetrachloroethylene (at 0.006 mg/L) in well NBG 2. However, conductivity (up to 840 µmhos/cm) was elevated in wells NBG 1, 2, and 3. TDS concentrations (at 635 mg/L) were also elevated in well NBG 2.

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, approximately 2,300 ft west of F Area (Figure 6-7, Vol. II). See the previous section of this chapter for a discussion of SRS burning/rubble pits.

The site is monitored by the four wells of the FBP series (Table 6-28, Vol. II). The tops of the screens in the FBP wells are below the water table, making interpretation of horizontal flow directions difficult.

Total radium (at 6.05 pCi/L) in well FBP 2A and nonvolatile beta activity (up to 72.6 pCi/L) in well FBP 1A were detected above DWS. No other radioactive constituents were detected above DWS at this site.

Trichloroethylene (up to 0.125 mg/L) was detected above the DWS in wells FBP 1A and 2A. Carbon tetrachloride (at 0.007 mg/L) was detected above the DWS in well FBP 2A; tetrachloroethylene (at 0.005

mg/L) was equal to the DWS in well FBP 3A. No other chemical constituents were detected above DWS. However, conductivity (up to 121 µmhos/cm) was elevated in well FBP 1A.

F-Area Coal Pile Runoff Containment Basin

The F-Area Coal Pile Runoff Containment Basin (289-F) is southeast of F Area (Figure 6-9, Vol. II). See the previous section of this chapter for a discussion of SRS coal pile runoff containment basins.

The basin is monitored by the six wells of the FCB series (Table 6-29, Vol. II). The screen zone elevations in the wells at this site vary and the horizontal gradients are low, making determination of horizontal groundwater flow directions difficult. Well FCB 7 was dry throughout the year.

Total radium (at 5.83 pCi/L) was detected above the DWS in well FCB 3. No other radioactive constituents were detected above DWS at this site.

No chemical constituents were detected above DWS. However, conductivity (up to 195 µmhos/cm) was elevated in wells FCB 3 and 6.

F-Area Effluent Treatment Cooling Water Basin

The F-Area Effluent Treatment Cooling Water Basin (241-97F) is located in the southwest portion of F Area (Figure 6-9, Vol. II). The basin will receive diverted cooling water from the separations processes, which may then be sent to the F/H Effluent Treatment Facility (ETF) if contaminated or to a permitted outfall if uncontaminated. The ETF was placed in service in 1988 to treat wastewater formerly sent to the F- and H-Area Seepage Basins.

The basin is monitored by the four wells of the FET series (Table 6-30, Vol. II). The horizontal flow gradient is low at this site, making interpretation of the horizontal flow directions difficult. In general, well FET 1D appears to be upgradient, and wells FET 2D, 3D, and 4D appear to be downgradient.

Total radium (at 5.77 pCi/L) was detected above the DWS in well FET 4D. No other radioactive constituents were detected above DWS in the FET wells.

Nitrate (at 207 mg/L) was detected above the DWS in well FET 4D. No other chemical constituents were detected above DWS at this site.

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 6-10, Vol. II). In 1955, the basin received wastewater from F Area containing low-level radioactivity and chemicals, including nitric acid, mercury, and sodium hydroxide. The basins operated under RCRA interim status from 1980 until they were taken out of service in the fourth quarter of 1988. Closure cap construction is underway.

The F-Area Seepage Basins were monitored by the F (11 wells) and FSB (59 wells) series wells in 1989 (Table 6-31, Vol. II). Forty-two RCRA POC and plume assessment wells, added during late 1987 and early 1988, are part of the FSB monitoring network. One FSB well (FSB 1TA) was installed during first quarter 1989 to produce water for closure cap construction. Wells in the FSB series without letters in their designators and those designated "D" wells are screened in the water table. Wells designated "C" are screened in the McBean member of the Santee Formation, wells designated "B" are screened in the upper Congaree Formation, and wells designated "A" are screened in the lower Congaree Formation.

Two water tables occur beneath the F-Area Seepage Basins: a perched groundwater table, 10 to 26 ft below the ground surface, and the normal water table, 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 northwest toward Upper Three Runs Creek.

Horizontal groundwater flow in the water table under the basins is toward the south in the direction of Four Mile Creek. Wells FSB 76, 99, 108D, and 109D are upgradient of the site; wells FSB 77, 78, 79, 92D, 93D, 94, 95, 104D, and 110D are downgradient; the remainder of the water-table wells are sidegradient. Wells F 2, 9, 14, 16, and 19 were either dry or could not be sampled during the year; wells FSB 87D and 94D were dry throughout the year.

At least one radioactive constituent was detected above DWS in all water-table wells except wells FSB 95D and 111D. Tritium (up to 38,800 pCi/mL), gross alpha (up to 3,500 pCi/L), total radium (up to 206 pCi/L), ^{90}Sr (up to 2,700 pCi/L), ^{238}U (up to 1,200 pCi/L), and nonvolatile beta (up to 6,210 pCi/L) activities were highest in the wells south of the basins. Other radioactive constituents detected above DWS in the water-table wells were ^{241}Am (up to 36 pCi/L), ^{129}I (up to 290 pCi/L), ^{226}Ra (up to 617 pCi/L), ^{228}Ra (up to 72 pCi/L), and ^{89}Sr (up to 340 pCi/L). Uranium-235 (up to 61 pCi/L) was detected above the DWS only in well FSB 78.

All the wells screened in the McBean Member of the Santee Formation had tritium activity (up to 27,000 pCi/mL) above the DWS except wells FSB 76C and 111C. Gross alpha (up to 780 pCi/L), total radium (up to 233 pCi/L), ^{89}Sr (up to 1,000 pCi/L), ^{90}Sr (up to 1,500 pCi/L), ^{129}I (up to 140 pCi/L), ^{228}Ra (up to 76 pCi/L), ^{226}Ra (up to 354 pCi/L), ^{238}U (up to 340 pCi/L), ^{63}Ni (at 53 pCi/L), and nonvolatile beta (up to 4,800 pCi/L) activities were detected above DWS in many of these same wells.

The only radioactive constituent detected above the DWS in the upper portion of the Congaree Formation was tritium (up to 220 pCi/mL) in wells FSB 78B and 87B. One anomalously high result for nonvolatile beta (76 pCi/L) was reported for well FSB 78B. This result is not consistent with other results obtained during the year.

In the lower portion of the Congaree Formation, tritium (up to 489 pCi/mL) was detected above the DWS in wells FSB 78A, 79A, 87A, 97A, 99A, and 100A. Total radium (up to 9.83 pCi/L) was detected above the DWS in well FSB 98A.

In the water-table wells, nitrate (up to 550 mg/L) was detected above the DWS in many wells. Cadmium (up to 0.052 mg/L) was detected above DWS in wells FSB 90D, 91D, 92D, 93D, 97D, 104D, and 105D. Lead concentrations (up to 3.66 mg/L) were above the DWS in wells FSB 76, 90D, 93D, 97D, 98D, and 105D. Also detected above DWS were barium (up to 2.74 mg/L) in wells FSB 90D, 97D, and 98D, fluoride (up to 6.1 mg/L) in wells FSB 90D, 91D, and 92D, tetrachloroethylene (up to 0.011 mg/L) in wells FSB 79, 108D, and 111D, and trichloroethylene (up to 0.025 mg/L) in wells FSB 79, 109D, and 111D. Other chemical constituents detected above DWS were mercury (up to 0.004 mg/L) in wells FSB 88D, 89D, and 107D, chromium (up to 0.051 mg/L) in wells FSB 93D and 98D, arsenic (up to 0.13 mg/L) in wells FSB 79 and 92D, and selenium (at 0.023 mg/L) in well FSB 110D. No other chemical constituents were detected above DWS. However, high conductivity (up to 4,400 µmhos/cm), TDS (2,810 mg/L), and low pH (down to 2.9) were detected in many wells. Sulfate (up to 50.9 mg/L) was elevated in wells FSB 78 and 110D.

Nitrate (up to 400 mg/L), conductivity (up to 2,700 µmhos/cm), and TDS (up to 3,090 mg/L) were elevated in most of the wells screened in the McBean Member of the Santee Formation. Chemical constituents detected above DWS include cadmium (up to 0.04 mg/L) in wells FSB 78C, 79C, 91C, 97C, 98C, 105C, and 106C, trichloroethylene (up to 0.016 mg/L) in wells FSB 91C, 95C, and 111C, and tetrachloroethylene (up to 0.014 mg/L) in wells FSB 88C, 89C, and 111C. Barium (up to 1.5 mg/L) in well FSB 97C and selenium (at 0.011 mg/L) in well FSB 98C were the only other chemical constituents detected above DWS. However, pH (up to 11.8) was elevated in wells 94C, 95C, and 110C. Alkalinity (up to 343 meq/L) was also elevated in wells FSB 94C and 95C. Low pH (down to 3.0) was detected in wells FSB 78C, 79C, 98C, 102C, and 105C.

No chemical constituents were detected above DWS in the upper part of the Congaree Formation. However, conductivity (up to 247 µmhos/cm) was elevated in wells FSB 76B, 78B, and 79B.

All wells in the lower Congaree Formation had high conductivity (up to 5,300 µmhos/cm). Alkalinity (up to 1,160 meq/L), TDS (up to 1,160 mg/L), and pH (up to 12.5) were elevated in wells FSB 96A, 98A, and 100A, suggesting that water in these wells may be influenced by well grout. Also elevated were pH (at 8.6) in well FSB 99A, TDS (up to 262 mg/L) in well FSB 97A, and sulfate (at 25.1 mg/L) in well FSB 100A. Tetrachloroethylene (up to 0.104 mg/L) was detected above the DWS in wells FSB 76A, 78A, and 101A. Trichloroethylene (up to 0.058 mg/L) was detected above DWS in wells FSB 78A, 87A, and 101A.

Other chemical constituents detected above DWS were chromium (up to 0.062 mg/L) in wells FSB 98A and 101A, barium (at 1.23 mg/L) in well FSB 98A, and nitrate (up to 16 mg/L) in well FSB 97A.

F-Area Sludge Land Application Site

The F-Area Sludge Land Application Site covers eight acres southeast of F Area, south of Road E (Figure 6-9, Vol. II). Sludge from SRS's sanitary wastewater treatment plants is currently disposed of at this site. Surface elevations at the site range from approximately 255 to 290 ft msl. See also the Sewage Sludge Application Sites section under General Areas.

The site is monitored by the four wells of the FSS series (Table 6-32, Vol. II). Horizontal groundwater flow is toward the southwest in the water table.

Tritium (up to 461 pCi/mL) was detected above the DWS in all the FSS wells except FSS 1D. No other radioactive constituents were detected above DWS.

Nitrite (up to 0.08 mg/L) was detected above the DWS in wells FSS 1D, 3D, and 4D. Lead concentrations (up to 0.068 mg/L) were above the DWS in wells FSS 1D and 3D. No other chemical constituents were detected above DWS. However, conductivity (up to 265 μmhos/cm) were elevated in wells FSS 1D and 2D. Alkalinity (up to 280 meq/L), pH (up to 9.5), and TDS (at 254 mg/L) were elevated in well FSS 1D, suggesting that water from this well may be affected by the leaching of well grout. Sulfate (at 47 mg/L) was elevated in well FSS 2D.

F-Area Tank Farm

The F-Area Tank Farm (241-F), at the southwest edge of F Area (Figure 6-9, 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, which forms the salt cake. In 1961, Tank 8 was overfilled, causing soil contamination and subsequent groundwater contamination in the area.

The site is monitored by the 27 wells of the FTF series (Table 6-33, 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. Horizontal gradients are low and variable from quarter to quarter. Water-table elevations indicate no clear trend in horizontal flow directions. Wells FTF 1, 2, 8, 9. 10, 11, 13, and 14 were either dry or could not be sampled during the year.

Gross alpha (up to 1,100 pCi/L), total radium (up to 91 pCi/L), and nonvolatile beta (up to 10,000 pCi/L) activities were detected above DWS in many of the FTF wells. Tritium (up to 44.9 pCi/mL) in wells FTF 5 and 27 was the only other radioactive constituent detected above DWS at this site.

No chemical constituents were detected above DWS in the FTF wells. However, pH (up to 12.4) and conductivity (up to 4,300 μmhos/cm) were elevated in wells FTF 12, 21, 24A, and 27, suggesting that water in wells FTF 12 and 21 may be affected by the leaching of well grout. Conductivity (up to 390 μmhos/cm) was also elevated in wells FTF 3, 4, 5, 6, 7, 25A, and 26.

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 6-8, 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 inactive basin contains some rainwater. Official waste-site closure has not been completed.

The basin is monitored by the four wells of the FNB series (Table 6-34, Vol. II). Horizontal groundwater flow under the basin is to the north-northeast toward Upper Three Runs Creek. Well FNB 4 is upgradient; well FNB 2 is downgradient; wells FNB 1 and 3 are sidegradient of the basin.

Tritium (up to 430 pCi/mL) was detected above the DWS in all the FNB wells except FNB 4. Gross alpha (up to 74 pCi/L) and total radium (up to 16.6 pCi/L) were detected above DWS in well FNB 2. Nonvolatile beta activity (up to 620 pCi/L) was elevated in wells FNB 2 and 3. No other radioactive constituents were detected above DWS at this site.

Trichloroethylene (up to 0.064 mg/L) was detected above the DWS in wells FNB 1 and 2. Nitrate (up to 27 mg/L) was detected above the DWS in well FNB 2. No other chemical constituents were detected above DWS. However, elevated conductivity (up to 290 µmhos/cm) and low pH (down to 3.4) were detected in well FNB 2.

GENERAL AREAS

The General Areas are those sections of SRS outside areas designated for specific purposes. In 1989, groundwater was monitored at the following sites in the General Areas: the Background Well Near Hawthorne Fire Tower; the Chemicals, Metals, and Pesticides (CMP) Pits; the Interim Waste Technology Site Characterization areas; the Par Pond Sludge Land Application Site; the Road A Chemical Basin (Baxley Road); the Sanitary Landfill; Sewage Sludge Application Sites; and the Separations Areas (Z and ZW wells). A summary of maximum groundwater monitoring results for these sites is presented in Table 6-35 (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 6-1, Vol. II). Well GBW 1 was installed at this site to provide background groundwater quality information (Table 6-36, Vol. II).

No radioactive or chemical constituents were detected above drinking water standards (DWS) in 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 6-11, 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 metals. In 1984, the pits were excavated, backfilled, and capped. During excavation, much of the liquid waste was recovered in the original burial drums.

The site is monitored by the 20 wells of the CMP series (Table 6-37, Vol. II). Wells CMP 8, 10, 11, 12, 13, 14C, and 15C monitor the water table. Water-table well CMP 16C was dry throughout 1989. The remaining wells monitor the lower zones. Groundwater flows away from the pits on three sides so that all wells are downgradient of the site except CMP 10, which is upgradient.

No radioactive constituents were detected above DWS at this site.

Tetrachloroethylene (up to 0.019 mg/L) and trichloroethylene (up to 0.01 mg/L) were detected above DWS in wells CMP 12 and 13. No other chemical constituents were detected above DWS. However, conductivity (up to 211 µmhos/cm) was elevated in many of the deeper CMP wells. These elevated conditions may be caused by naturally occurring carbonate rocks in this area. Elevated pH (up to 10.6) was also detected in wells CMP 9B and 15B.

Interim Waste Technology Site Characterization Wells

The Interim Waste Technology Site Characterization Wells are located on sites B, P, and Q, each covering approximately 300 acres. Site B is located in the north-central part of SRS, approximately 2 miles northeast of H Area. It lies south of Tinker Creek, west of Mill Creek, and east of McQueen Branch between two gently sloping ridges (Figure 6-12, Vol. II). Sites P and Q are adjacent to each other and are located south of the TC-1 Area and north of Highway 125. The sites occupy the eastward facing slope of a ridge separating the Savannah River floodplain from Upper Three Runs Creek (Figure 6-13, Vol. II).

The IDB, IDP, and IDQ well series were installed at Site B, Site P, and Site Q, respectively, during 1987-1988 and added to the Environmental Protection Department (EPD) monitoring program for sampling in 1989 (Table 6-38, Vol. II). These wells were installed by SRL to characterize potential sites for new waste management facilities. Wells IDB 3 and 4, IDP 3D and 10, and IDQ 5, 8, 9, and 10 were dry throughout 1989; well IDP 4 was either dry or could not be sampled.

Samples from the wells at these sites were not analyzed for radioactive or chemical constituents. However, alkalinity (up to 205 meq/L) was elevated in wells IDB 2B and IDQ 7. Conductivity (up to 943 µmhos/cm) was elevated in wells IDB 2B and 2C, IDP 3B and 3C, and IDQ 3B, 6, and 7. Elevated pH (up to 12.4) was detected in wells IDB 2B and 2C, IDP 3B and 3C, and IDQ 3B, 4, and 6, suggesting that water in many of the wells may be affected by the leaching of well grout.

Par Pond Sludge Land Application 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 is approximately 1.3 miles north-northeast of the intersection of SRS Roads B and F (Figure 6-14, Vol. II). Surface elevations at the site range approximately from 215 to 230 ft msl. In 1989, the site became part of the RFI program because of the presence of chlordane in the lagoon sludge applied to the site. See also the Sewage Sludge Application Sites section under General Areas.

The site is monitored by the three wells of the PSS series and well SSS 17 (Table 6-39, Vol. II). The data are insufficient to determine the exact direction of the horizontal groundwater flow at this site, but it appears to be toward the south-southeast.

Total radium (at 6.09 pCi/L) in well SSS 17 was the only radioactive constituent detected above DWS at this site.

Nitrite (at 0.03 mg/L) was detected above the DWS in well PSS 1D. No other chemical constituents were detected above DWS.

General Areas Summary

General Areas include the sites within SRS that are outside areas designated for specific purposes. These sites, located in various parts of SRS, are the Background Well Near Hawthorne Fire Tower; Chemicals, Metals, and Pesticides Pits; Interim Waste Technology Site Characterization Wells; Par Pond Sludge Land Application Site; Road A Chemical Basin; Sanitary Landfill; Sewage Sludge Application Sites; and Z and ZW Wells (wells scattered throughout the Separations Areas). In 1989, the groundwater at these sites was analyzed to determine the quantities of certain radioactive and nonradioactive constituents that may be present.

Radioactive constituents exceeded standards at four sites. Gross alpha activity was elevated in three wells at the Sanitary Landfill and in two of the Z and ZW Wells, with the highest activity (1,200 pCi/L) at the latter. Nonvolatile beta activity was elevated in two of the Z and ZW Wells (up to 1,200 pCi/L). Total radium activity was elevated in five wells at the Sanitary Landfill, in one well at the Par Pond Sludge Land Application Site, and in two wells at the Sewage Sludge Application Sites, with the highest activity (27.6 pCi/L) at the latter. And tritium activity was elevated in five wells at the Sanitary Landfill and in seven of the Z and ZW Wells, with the highest activity (166 pCi/mL) at the latter.

Trichloroethylene (up to 0.062 mg/L) was above its standard in two wells at the Chemicals, Metals, and Pesticides Pits and in five wells at the Sanitary Landfill. Tetrachloroethylene concentrations (up to 0.344 mg/L) were elevated in two wells each at the Chemicals, Metals, and Pesticides Pits and at the Sanitary Landfill. Benzene concentrations were elevated in one well and trans-1,2-dichloroethene concentrations in five wells at the latter site.

Lead was above its standard in one well at the Road A Chemical Basin, and nitrite concentrations were elevated in one well at the Par Pond Sludge Land Application Site. Sulfate and chromium concentrations exceeded standards in one well each at the Sanitary Landfill. Conductivity and pH exceeded standards in one or more wells at five sites each, and alkalinity was elevated at two sites. No analytes were above standards in the Background Well Near Hawthorne Tower.

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 6-15, Vol. II).

The basin is reported to have received miscellaneous radioactive and chemical aqueous waste, but no records of the materials disposed of at this site are available. The basin was closed and backfilled in 1973. It is currently part of the RFI program.

The basin is monitored by the five wells of the BRD series (Table 6-40, Vol. II). Well BRD 5D was added to the series during third quarter 1989. BRD 4 is screened below the water table, and BRD 3 was dry throughout 1989. Information from the remaining wells is insufficient to determine horizontal groundwater flow directions at the site.

No radioactive constituents were detected above DWS in the BRD wells.

Lead (at 0.051 mg/L) was detected above the DWS in well BRD 2. No other chemical constituents were detected above DWS at this site.

Sanitary Landfill

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 6-16, 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 15,000 to 20,000 tons of waste per year. In addition to the waste already listed, the landfill receives pesticide bags, empty cans, putrescible wastes, 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 6-41, Vol. II). Horizontal groundwater flow direction is to the southeast toward Upper Three Runs Creek. Relative to the site, wells LFW 29, 30, and 31 are upgradient; wells LFW 37, 38, 39, 40, and 41 are downgradient. The remainder of the wells are sidegradient or are within the landfill.

Total radium (up to 7.78 pCi/L) was detected above the DWS in wells LFW 6, 7, 18, and 21. Tritium (up to 153 pCi/mL) was detected above the DWS in wells LFW 7, 8, 10A, 18, and 21. Gross alpha (up to 35 pCi/L) was detected above the DWS in wells LFW 6, 7, and 21. No other radioactive constituents were detected above DWS at this site.

Trichloroethylene (up to 0.062 mg/L) was detected above the DWS in wells LFW 21, 22, 36, 37, and 38. Concentrations of trans-1,2-dichloroethene (up to 0.27 mg/L) were detected above the DWS in wells LFW 6, 7, 8, 36, and 37. Carbon tetrachloride (up to 0.024 mg/L) was detected above the DWS in wells LFW 10A, 21, 38, and 40.

Other chemical constituents detected above DWS were tetrachloroethylene (up to 0.344 mg/L) in wells LFW 21 and 39, chromium (at 0.316 mg/L) in well LFW 31, and benzene (at 0.008 mg/L) in well LFW 36. In addition, conductivity (up to 590 μmhos/cm) was above applicable standards in wells LFW 6, 7, 8, 17, 18, 21, and 36. Alkalinity (up to 264 meq/L) was elevated in wells LFW 6, 7, and 8. Sulfate (at 34 mg/L) was elevated in well LFW 21. Low pH (at 4.0) was recorded in well LFW 10A.

Sewage Sludge Application Sites

The Sewage Sludge Application Sites were originally 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 tenth permitted site, the F-Area Sludge Land Application Site. When this site becomes exhausted, sludge disposal will begin at the eleventh permitted site, the H-Area Sludge Land Application Site.

All Sewage Sludge Application Sites were monitored by 33 SSS series wells until 1988. New wells were installed in F, H, and K Areas and at the Par Pond site in 1988 and replaced 12 of the SSS wells. Descriptions of these new wells (FSS, HSS, KSS, and PSS) are provided under the F-Area, H-Area, K-Area, and General Areas sections, respectively. Other sewage sludge application sites are still monitored by the SSS series wells (Table 6-42, Vol. II).

Horizontal groundwater flow at the 40-Acre Hardwood Site (wells SSS 1, 2, and 3) appears to be toward the southwest (Figure 6-15, Vol. II). Horizontal groundwater flow at the Lower Kato Road Site (wells SSS 4, 5, and 6), the Kato Road Site (wells SSS 19, 20, and 21), and the Second Par Pond Borrow Pit (wells SSS 25, 26, and 27) appears to be toward the east (Figures 6-13 and 6-14, Vol. II). Horizontal flow at the Orangeburg Site (wells SSS 7, 8, and 9) is toward the southeast (Figure 6-16, Vol. II). There is insufficient information to determine the exact direction of the horizontal groundwater flow at the Lucy Site (wells SSS 10, 11, and 12) and at the Road F Site (wells SSS 22, 23, and 24), but it appears to be toward the south (Figure 6-17, Vol. II). Wells SSS 4, 6, 11, 12, 19, and 24 were dry throughout 1989.

Total radium (at 27.6 pCi/L) was detected above the DWS in well SSS 8 at the Orangeburg Site. Total radium (up to 9.04 pCi/L) was also detected above the DWS in well SSS 27 at the Second Par Pond Borrow Pit. No other radioactive constituents were detected above DWS at these sites.

No chemical constituents were detected above the DWS. However, elevated conductivity (up to 109 µmhos/cm) in well SSS 25 and low pH (down to 3.9) in well SSS 27 were detected at the Second Par Pond Borrow Pit. In addition, pH (down to 3.9) was low in wells SSS 7 and 8 at the Orangeburg site.

Z and ZW Wells

In 1951 and 1952, the Z and ZW wells were installed in the Separations Areas (Figures 6-7 through 6-10 and 6-18 through 6-19, Vol. II). These wells, which range from approximately 15 to 90 ft deep, measure water-table elevations. These wells also monitor for radioactive groundwater contamination that might exist within a large radius of F and H Areas. Monitoring results from these wells are presented in Table 6-43 (Vol. II), except for well ZW 6, which was dry throughout the year.

Gross alpha (up to 1,200 pCi/L) was detected above the DWS in wells Z 9 and ZW 3. Tritium (up to 166 pCi/mL) was detected above the DWS in wells Z 11 and 15 and in wells ZW 2, 5, 7, 9, and 10. Nonvolatile beta activity (up to 1,200 pCi/L) was elevated in wells Z 9 and ZW 5. No other radioactive constituents were detected above DWS.

Samples from these wells were not tested for chemical constituents. However, conductivity (up to 293 µmhos/cm) was elevated in wells Z 8 and 11 and in wells ZW 1A, 2, 4, 5, 7, 9, and 10. Elevated pH (up to 9.6) was also detected in wells Z 12, 13, and 15.

H AREA

H Area is located in the central part of SRS as shown in Figure 6-7 (Vol. II). Surface elevations across H Area range approximately from 270 to 315 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 site boundary to H Area is approximately 7.5 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 1989, 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 Cooling Water Basin, the H-Area Retention Basins, the H-Area Seepage Basins, the H-Area Sludge Land Application Site, and the H-Area Tank Farm (Figures 6-18 through 6-20, Vol. II). A summary of maximum groundwater monitoring results for these sites is given in Table 6-44 (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 (Figure 6-18, 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 previous section of this chapter for a discussion of SRS acid/caustic basins.

The basin is monitored by the four HAC series wells (Table 6-45, Vol. II). Relative to the basin, well HAC 4 is upgradient, well HAC 2 is downgradient, and wells HAC 1 and 3 are sidegradient. Horizontal groundwater flow beneath the basin is toward the northwest.

Tritium (up to 63 pCi/mL) was detected above the DWS in all the HAC wells. No other radioactive constituents were detected above DWS.

Mercury (at 0.0024 mg/L) was detected above the DWS in well HAC 2. No other chemical constituents were detected above DWS. However, conductivity (up to 667 µmhos/cm), sulfate (up to 275 mg/L), and TDS (up to 390 mg/L) were elevated in wells HAC 1, 2, and 3.

H-Area Summary

H Area, which houses one of the two chemical separations plants at SRS, lies near the center of SRS, directly south of S Area. In 1989, groundwater from 178 wells at nine sites in H Area was analyzed to determine the levels of certain radioactive and nonradioactive constituents that may be present. At one site, the H-Area Seepage Basins, groundwater was analyzed from the water-table aquifer and three lower water zones.

Radioactive constituents were above applicable standards at all nine sites. Tritium activity was elevated in over 135 wells at eight sites, including all four water zones monitored beneath the H-Area Seepage Basins, with the highest activity (160,000 pCi/mL) in the water table beneath the H-Area Seepage Basins. Gross alpha activity was elevated in over 40 wells at four sites, including three of the water zones beneath the H-Area Seepage Basins, with the highest activity (500 pCi/L) at the H-Area Tank Farm. Nonvolatile beta activity was elevated in over 60 wells at two sites, including three of the water zones beneath the H-Area Seepage Basins, with the highest activity (21,000 pCi/L) in the water table beneath the H-Area Seepage Basins. Total radium activity was elevated in over 30 wells at five sites, including three of the water zones beneath the H-Area Seepage Basins, with the highest activity (45.7 pCi/L) in the water table beneath the H-Area Seepage Basins. The maximum nonvolatile beta activity was higher than that at any other site monitored at SRS in 1989, exceeding its standard by 420 times. Radium-228, ^{89}Sr, and ^{90}Sr activities exceeded standards in the water table and in one of the lower zones beneath the H-Area Seepage Basins; ^{241}Am, ^{60}Co, ^{129}I, and ^{63}Ni activities exceeded standards in the former zone. Uranium-235 and ^{137}Cs activities were elevated in one well each at the H-Area Tank Farm.

Organic compounds were above standards at the H-Area Canyon Building and in three of the water zones monitored beneath the H-Area Seepage Basins; the highest concentrations included 0.11 mg/L of trichloroethylene in a lower water zone, 0.204 mg/L of tetrachloroethylene in a lower water zone, and 0.222 mg/L of benzene in the water table.

Cadmium exceeded its standard in 19 wells at three sites, chromium concentrations in 8 wells at three sites, lead concentrations in 15 wells at five sites, mercury concentrations in 14 wells at three sites, nitrate concentrations in 55 wells at two sites, and sulfate concentrations in seven wells at four sites. The maximum concentration of mercury, found in the water table beneath the H-Area Seepage Basins, was higher than that at any other site monitored at SRS in 1989, exceeding its standard by nine times. Alkalinity, conductivity, pH, and total dissolved solids exceeded standards in wells at two, seven, four, and four sites, respectively, including all water zones monitored beneath the H-Area Seepage Basins.

H-Area Auxiliary Pump Pit

The H-Area Auxiliary Pump Pit (241-49H) is at the east end of H Area (Figure 6-19, Vol. II). The facility will pump a high-level radioactive sludge and precipitate 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 two HAP series wells (Table 6-46, Vol. II). Horizontal groundwater flow appears to be toward the north. The wells appear to be downgradient of the pump pit and sidegradient of the coal pile runoff containment basin.

Tritium (up to 24.2 pCi/mL) was detected above the DWS in well HAP 1. No other radioactive constituents were detected above DWS at this site.

No chemical constituents were detected above DWS in the HAP wells. However, conductivity (up to 370 µmhos/cm) and alkalinity (up to 125 meq/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 (Figure 6-18, Vol. II). At the building, materials 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 6-47, Vol. II). The horizontal flow gradient at the site is low, making interpretation of groundwater flow directions difficult.

Tritium (up to 129 pCi/mL) was detected above the DWS in all four HCA wells. No other radioactive constituents were detected above DWS at this site.

Tetrachloroethylene (up to 0.031 mg/L) and trichloroethylene (up to 0.014 mg/L) were detected above DWS in wells HCA 2 and 4. Lead concentrations (up to 0.117 mg/L) were above the DWS in well HCA 4. No other chemical constituents were detected above DWS. However, sulfate (up to 43.0 mg/L) and conductivity (up to 210 µmhos/cm) were elevated in well HCA 2.

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 6-19, Vol. II). See the previous section 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 6-48, Vol. II). The horizontal groundwater flow direction under the basin appears to be toward the north. Wells HCB 2 and 3 appear to be upgradient of the basin; wells HCB 1 and 4 appear to be downgradient.

Tritium (up to 66.8 pCi/mL) was detected above the DWS in all four HCB wells. Gross alpha (up to 50.9 pCi/L) and total radium (up to 31.3 pCi/L) were detected above DWS in well HCB 2. No other radioactive constituents were detected above DWS at this site.

Cadmium (at 0.016 mg/L), chromium (at 0.113 mg/L), fluoride (at 4 mg/L), lead (at 0.15 mg/L), and selenium (up to 0.025 mg/L) were detected at levels equal to or above DWS in well HCB 2. No other chemical constituents were detected above DWS. However, conductivity (up to 2,920 µmhos/cm) and sulfate (up to 2,440 mg/L) were elevated in wells HCB 2 and 4. Low pH (down to 2.6) was detected in wells HCB 2 and 3; TDS (at 1,640 mg/L) was elevated in well HCB 2.

H-Area Effluent Treatment Cooling Water Basin

The H-Area Effluent Treatment Cooling Water Basin (241-103H) is southwest of H Area (Figure 6-18, Vol. II). The basin will receive diverted cooling water from the separations processes, which will be sent to the F/H Effluent Treatment Facility (ETF) if contaminated or to a permitted outfall if uncontaminated. The ETF was placed in service in 1988 to treat the wastewater formerly sent to the F- and H-Area Seepage Basins.

The basin is monitored by the four wells of the HET series (Table 6-49, Vol. II). These wells are screened below the water table, making the determination of horizontal flow directions difficult. However, well HET 1D appears to be upgradient, well HET 4D sidegradient, and wells HET 2D and 3D downgradient of the basin.

Tritium (up to 44.9 pCi/mL) was detected above the DWS in all four HET wells. No other radioactive or chemical constituents were detected above DWS at this site.

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 6-20, 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 for receipt of diverted cooling water or stormwater. 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 6-50, Vol. II). These wells are screened below the water table, making determination of horizontal flow directions difficult. However, wells HR3 11 and 13 appear to be upgradient of the basins, and well HR8 14 appears to be downgradient of basin 281-3H; wells HR8 11 and 14 appear to be sidegradient of basin 281-8H, and wells HR8 12 and 13 appear to be downgradient of basin 281-8H.

Tritium (up to 47.9 pCi/mL) was detected above the DWS in wells HR3 11 and 13 and in wells HR8 11, 12, and 13. Total radium (up to 16 pCi/L) and gross alpha (at 28.8 pCi/L) were detected above DWS in well HR8 14. No other radioactive constituents were detected above DWS at this site.

Nitrate (up to 35 mg/L) in well HR8 14 was the only chemical constituent detected above DWS at this site.

However, conductivity (up to 300 μmhos/cm) was elevated in wells HR3 13 and HR8 14. TDS (at 218 mg/L) was elevated in well HR8 14. Low pH (at 3.8) was detected in well HR3 11.

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 6-20, 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. Basins 1, 2, and 4 operated under RCRA interim status from 1980 until taken out of service in the fourth quarter of 1988. Closure cap construction is underway.

At the H-Area Seepage Basins, the water table is 28 to 60 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 a poorly confined aquifer within the McBean Formation and a semiconfined aquifer within the Congaree Formation.

There is a downward flow potential from the water table to the Congaree Formation as evidenced by the head relationships between the different zones. Contaminants in the water-table aquifer and the McBean Formation have moved horizontally at a much greater rate than vertically, indicating that the groundwater flow in these areas is more horizontal than vertical. The groundwater in the water-table aquifer and the McBean Formation flows south toward Four Mile Creek, whereas the groundwater in the upper part of the Congaree Formation flows toward Upper Three Runs Creek to the west.

The H-Area Seepage Basins were monitored by 16 wells of the H series, 102 wells of the HSB series, and well BG 10 in 1989 (Table 6-51, Vol. II). In fourth quarter 1987 and first quarter 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. One production well (HSB 1TB) was installed in 1989 to produce water for closure cap construction.

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. Screen zone elevations for these wells range from 200-235 ft msl. Wells HSB 65C, 86C, 111E, and 112E 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; screen zone elevations depend on the elevation of formations screened. Wells with a "B" after the well cluster number are screened at approximately 120-135 ft msl within the upper Congaree Formation. Wells with an "A" after the well cluster number are screened at approximately 160-180 ft msl within the lower Congaree Formation.

Water-table wells HSB 65 and 66 are upgradient of the basins. The other water-table wells are downgradient to sidegradient of the basins. Wells H 2 and 4 were dry throughout 1989; wells H 12, 15, and 19 were either dry or could not be sampled during the year.

Tritium (up to 160,000 pCi/mL) was detected above the DWS in all of the wells screened in the water table except in wells HSB 130D, 131D, and 132D. Observed tritium activities were highest in wells along the edges and downgradient of the seepage basins. Elevated gross alpha (up to 303 pCi/L), total radium (up to 45.7 pCi/L), and nonvolatile beta (up to 21,000 pCi/L) activities were also generally found downgradient of the basins. Other elevated radioactive constituents were ^{60}Co (up to 404 pCi/L), ^{129}I (up to 50 pCi/L), ^{63}Ni (up to 480 pCi/L), ^{226}Ra (up to 32 pCi/L), ^{228}Ra (up to 72 pCi/L), ^{89}Sr (up to 590 pCi/L), ^{90}Sr (up to 4,200 pCi/L), and ^{241}Am (up to 35 pCi/L).

At least one radioactive constituent was detected above DWS in all the wells screened in the Dry Branch and Santee Formations except wells HSB 83C, 100C, 125C, 130C, 132C, and 133C. Tritium (up to 27,100 pCi/mL), gross alpha (up to 33.7 pCi/L), total radium (up to 12 pCi/L), and nonvolatile beta (up to 260 pCi/L) activities were elevated generally in the same areas as the highest levels of radioactivity in the water table.

Tritium (up to 387 pCi/mL) in wells HSB 68B and 84B was the only radioactive constituent detected above DWS in wells screened in the upper portion of the Congaree Formation.

In wells screened in the lower portion of the Congaree Formation, tritium (up to 18,900 pCi/mL), gross alpha (at 20.8 pCi/L), ^{228}Ra (at 22 pCi/L), ^{89}Sr (at 160 pCi/L), ^{90}Sr (at 870 pCi/L), total radium (at 18.5 pCi/L), and nonvolatile beta (up to 4,370 pCi/L) activities were detected above DWS in well HSB 84A. The only other radioactive constituents detected above DWS were tritium (up to 158 pCi/mL) in wells HSB 83A and 119A and gross alpha (at 16 pCi/L) in well HSB 65A.

Of the water-table wells, samples from well BG 10 and the H well series were not tested for chemical constituents. In the HSB series wells, nitrate (up to 170 mg/L), mercury (up to 0.0184 mg/L), benzene (up to 0.22), and trichloroethylene (up to 0.028 mg/L) were detected above DWS in several wells. Other chemical constituents detected above DWS include cadmium (up to 0.022 mg/L) in wells HSB 84D and 86C, lead (up to 0.106 mg/L) in wells HSB 70 and 102D, and tetrachloroethylene (up to 0.008 mg/L) in wells HSB 101D and 106D. Arsenic (at 0.069 mg/L) in well HSB 101D and endrin (at 0.00277 mg/L) in well HSB 107D were the only other chemical constituents detected above DWS. However, elevated conductivity (up to 1,330 µmhos/cm), TDS (up to 1,880 mg/L), and low pH (down to 3.4) were detected in many HSB wells. In addition, pH (up to 9.1) and alkalinity (up to 104 meq/L) were elevated in well HSB 101D. Conductivity (up to 948 µmhos/cm) was also elevated in well BG 10 and in many H series wells.

In wells screened in the Dry Branch and Santee Formations, trichloroethylene (up to 0.11 mg/L), tetrachloroethylene (up to 0.204 mg/L), nitrate (up to 120 mg/L), and benzene (up to 0.19 mg/L) were detected above DWS in several wells. Endrin (at 0.00025 mg/L) was detected above the DWS in well HSB 133C. No other chemical constituents were detected above DWS. However, sulfate (at 36.2 mg/L) was elevated in well HSB 106C. Alkalinity (up to 148 meq/L) was elevated in wells HSB 70C and 133C. Conductivity (up to 950 µmhos/cm), TDS (up to 4,850 mg/L), and high pH (up to 11.5) were elevated in several wells.

Trichloroethylene (at 0.007 mg/L) in well HSB 65B was the only chemical constituent detected above DWS in wells screened in the upper portion of the Congaree Formation. However, conductivity (up to 280 µmhos/cm) was elevated in all the wells. Alkalinity (up to 108 meq/L) was elevated in wells HSB 68B and 86B. In addition, pH (up to 8.8) was high in well HSB 84B. TDS (at 203 mg/L) was elevated in well HSB 68B.

The only chemical constituents detected above DWS in wells screened in the lower portion of the Congaree Formation were chromium (at 0.061 mg/L) in well HSB 69A, benzene (up to 0.012 mg/L) in wells HSB 68A and 123A, and nitrate (up to 29.7 mg/L) in well HSB 84A. However, conductivity (up to 760 µmhos/cm) was elevated in all the wells. In addition, high pH (up to 11.5) was detected in wells HSB 119A, 120A, 123A, 124A, and 139A, suggesting that water in well HSB 124A may be affected by the leaching of well grout. TDS (up to 367 mg/L) was elevated in wells HSB 117A, 118A, 121A, 122A, 123A, and 124A. Alkalinity (up to 173 meq/L) was elevated in well HSB 124A.

H-Area Sludge Land Application Site

The H-Area Sludge Land Application Site covers 13 acres southeast of H Area, south of Road E (Figure 6-7, Vol. II). Surface elevations at the site range from approximately 300 to 305 ft msl. See also the Sewage Sludge Application Sites section under General Areas.

The site is monitored by the three wells of the HSS series (Table 6-52, Vol. II). Because the wells are almost in a line, the horizontal groundwater flow direction is difficult to interpret; however, it appears to be toward the southeast.

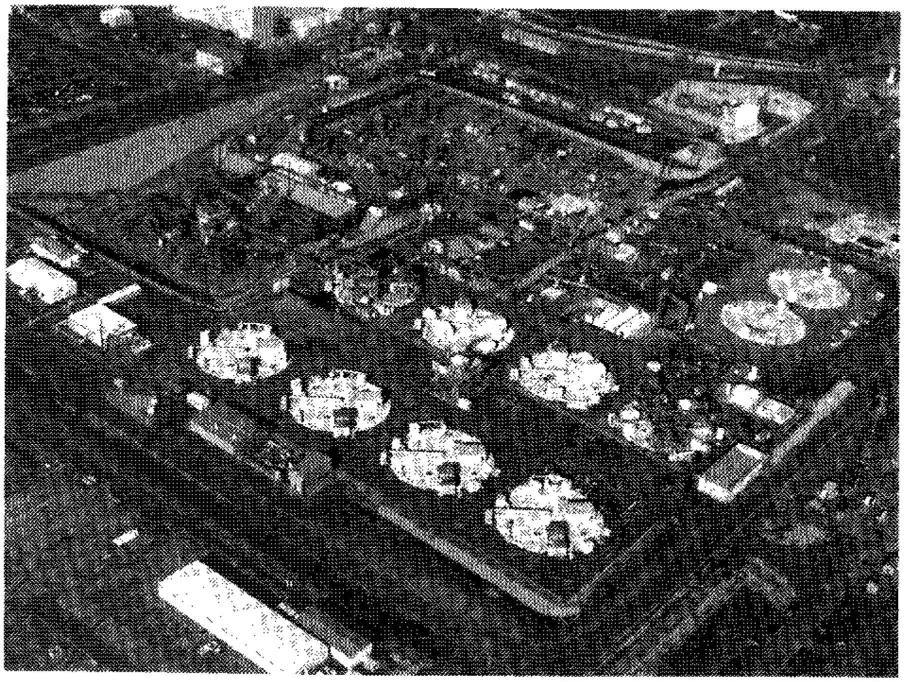
Total radium (at 7.49 pCi/L) in well HSS 3D was the only radioactive constituent detected above DWS at this site.

Lead (up to 0.13 pCi/L) was detected above the DWS in well HSS 3D. No other chemical constituents were detected above DWS.

H-Area Tank Farm

The H-Area Tank Farm (241-H), at the south end of H Area (Figure 6-18, 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.



Monitoring wells are installed around subsurface storage tanks to monitor for possible groundwater contamination

Tank 16 leaked prior to the removal of the waste from that tank in 1972. A spill occurred at Tank 13 in 1983.

In 1989, the site was monitored by the 32 wells of the HTF series (Table 6-53, Vol. II). The wells surround tank groups and monitor for leaks from the adjacent tanks. The site is on the groundwater divide between Upper Three Runs Creek and Four Mile Creek. Gradients at 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.

Gross alpha (up to 500 pCi/L) and nonvolatile beta (up to 750 pCi/L) activities were detected above DWS in many of the HTF wells, with the highest activities occurring around Tanks 13 through 16. Elevated radioactivity was also found east of Tanks 13 through 16 and in the northwestern part of the tank farm. Tritium (up to 199 pCi/mL) was detected above the DWS in several wells, with the highest activity occurring around Tanks 21 through 25. Total radium (up to 28 pCi/L) was detected above the DWS in wells HTF 6, 8, 16, 17, and 22. Uranium-235 (at 50 pCi/L) was detected above the DWS in well HTF 7 and ^{137}Cs (at 505 pCi/L was elevated in well HTF 6. No other radioactive constituents were detected above DWS at this site.

Cadmium (up to 0.141 mg/L), lead (up to 0.609 mg/L), and chromium (up to 0.312 mg/L) were detected above the DWS in many of the HTF wells. Mercury (at 0.0023 mg/L) was detected above the DWS in well HTF 12. No other chemical constituents were detected above DWS at this site. However, conductivity (up to 285 µmhos/cm) was also elevated in many of the HTF wells. Low pH (down to 3.9) was detected in wells HTF 6, 8, 20, and 27.

K AREA

K Area is located in the south-central part of SRS as shown in Figure 6-1 (Vol. II). The ground surface elevation near the central part of K Area is approximately 280 ft msl and slopes gently to the west toward Indian Grave Branch and to the east toward Pen Branch. The nearest site boundary to K Area is approximately 5 miles to the west. The dissection of Pen Branch and Indian Grave Branch creates a groundwater island in the Dry Branch and Santee Formations. Horizontal groundwater flow in the Congaree Formation is toward the Savannah River.

In 1989, 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 6-21, Vol. II). Maximum groundwater monitoring results for these sites are summarized in Table 6-54 (Vol. II).

K-Area Acid/Caustic Basin

The K-Area Acid/Caustic Basin (904-80G) is on the east side of K Area (Figure 6-21, Vol. II) near a tributary of Pen Branch. See the previous section of this chapter for a discussion of SRS acid/caustic basins.

The basin is monitored by the seven wells of the KAC series (Table 6-55, Vol. II). Relative to the basin, wells KAC 3, 5 and 6 are upgradient, wells KAC 4 and 7 are sidegradient, and well KAC 1 is downgradient.

Total radium (up to 25.6 pCi/L) was detected above the drinking water standard (DWS) in wells KAC 1 and 7. Gross alpha (up to 19.3 pCi/L) was detected above the DWS in well KAC 1. No other radioactive constituents were detected above DWS at this site.

Lead (at 0.082 mg/L) was detected above the DWS in well KAC 1. Selenium (at 0.042 mg/L) was detected above the DWS in well KAC 5. No other chemical constituents were detected above DWS. However, conductivity (up to 2,740 μmhos/cm) and sulfate (up to 1,220 mg/L) were elevated in all the wells except KAC 5. Also elevated were TDS (up to 1,860 mg/L) in wells KAC 1, 2, 3, and 7 and alkalinity (at 146 meq/L) in well KAC 3.

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 6-21, 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 6-56, Vol. II). Relative to the basin, well KAB 2 is upgradient, wells KAB 3 and 4 are downgradient, and well KAB 1 is sidegradient.

Total radium (up to 21 pCi/L) was detected above the DWS in all KAB wells except KAB 2. Gross alpha (up to 36.8 pCi/L) was detected above the DWS in wells KAB 1 and 4. No other radioactive constituents were detected above DWS at this site.

No chemical constituents were detected above DWS. However, conductivity (up to 750 μmhos/cm) and sulfate (up to 109 mg/L) were elevated in all four KAB wells. Alkalinity (up to 237 meq/L) and TDS (up to 426 mg/L) were elevated in wells KAB 2 and 4.

K-Area Burning/Rubble Pit

The K-Area Burning/Rubble Pit (Building 131-K) is approximately 900 ft northeast of K Area (Figure 6-21, Vol. II). See the previous section 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 6-57, Vol. II). The site is near the water-table divide between Indian Grave Branch and Pen Branch. Horizontal gradients at the site are low, making determination of flow directions difficult.

No radioactive constituents were detected above DWS in the KRP wells.

Tetrachloroethylene (up to 0.086 mg/L) and trichloroethylene (up to 0.027 mg/L) were detected above DWS in well KRP 4. Lead (at 0.062 mg/L) was detected above the DWS in well KRP 2. No other chemical constituents were detected above DWS at this site.

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 6-21, Vol. II). See the previous section 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 6-58, Vol. II). Relative to the basin, well KCB 1 is upgradient, well KCB 4 is sidegradient to upgradient, and wells KCB 2 and 3 are sidegradient to downgradient.

Total radium (up to 21.8 pCi/L) and tritium (up to 28.7 pCi/mL) were detected above DWS in wells KCB 2 and 3. Gross alpha (up to 31.4 pCi/L) was detected above the DWS in well KCB 3. No other radioactive constituents were detected above DWS at this site.

Benzene (at 0.007 mg/L) in well KCB 4 was the only chemical constituent detected above DWS. However, sulfate (up to 393 mg/L), conductivity (up to 698 μmhos/cm), and TDS (up to 505 mg/L) were elevated in all the KCB wells except KCB 2. Low pH (down to 3.5) was detected in well KCB 3.

K-Area Disassembly Basin

The K-Area Disassembly Basin (105-K) is located in the K-Area reactor building (Figure 6-21, Vol. II). See the previous section of this chapter for a discussion of SRS disassembly basins.

Wells KDB 1, 2, and 3 monitor the K-Area Disassembly Basin (Table 6-59, Vol. II). Relative to the basin, wells KDB 1 and 3 are sidegradient, and well KDB 2 is downgradient.

Tritium (up to 3,470 pCi/mL) was detected above the DWS in all three KDB wells. Total radium (at 6.3

pCi/L) was detected above the DWS in well KDB 1. No other radioactive constituents were detected above DWS at this site.

Trichloroethylene (up to 0.17 mg/L) was detected above the DWS in wells KDB 2 and 3. Tetrachloroethylene (up to 0.008 mg/L) was detected above the DWS in wells KDB 1 and 2. Lead concentrations (up to 0.081 mg/L) were above the DWS in well KDB 1. No other chemical constituents were detected above DWS. However, sulfate (at 29.6 mg/L), conductivity (up to 309 µmhos/cm), alkalinity (up to 106 meq/L), and TDS (at 206 mg/L) were elevated in well KDB 3.

K-Area Reactor Seepage Basin

The K-Area Reactor Seepage Basin (904-65G) is west of K Area (Figure 6-21, Vol. II). The basin was used 1959 through 1960. See the previous section of this chapter for discussion on reactor seepage basins.

The basin is monitored by the four wells of the KSB series (Table 6-60, Vol. II). Horizontal gradients at the site are low, making determination of flow directions difficult. Generally, well KSB 1 is upgradient, wells KSB 2 and 4A are sidegradient, and well KSB 3 is downgradient.

Tritium (up to 1,300 pCi/mL) was detected above the DWS in all the KSB wells. No other radioactive or chemical constituents were detected above DWS 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 6-21, 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 6-61, Vol. II). Relative to the basin, well KRB 8 is upgradient, well KRB 14 is downgradient, and wells KRB 1, 13, and 15 are sidegradient.

Tritium (up to 180,000 pCi/mL) was detected above the DWS in all the KRB wells. Total radium (at 6.5

K-Area Summary

K Area, located in the south-central part of SRS, is the site of K Reactor, which began operating in the fall of 1954. In 1989, groundwater from 34 wells at eight sites in K Area was analyzed to determine the quantities of certain radioactive and nonradioactive constituents that may be present.

Radioactive constituents were detected above applicable standards at seven of the sites: total radium activity (up to 34.7 pCi/L) was elevated in one or more wells at all sites except the K-Area Burning/Rubble Pit and the K-Area Reactor Seepage Basin; tritium (up to 180,000 pCi/mL) was above its standard in all but two wells monitored at the K-Area Coal Pile Runoff Containment Basin, the K-Area Disassembly Basin, the K-Area Reactor Seepage Basin, and the K-Area Retention Basin; gross alpha activity (up to 36.8 pCi/L) was elevated in one or more wells at the K-Area Acid/Caustic Basin, the K-Area Ash Basin, the K-Area Coal Pile Runoff Containment Basin, and the K-Area Retention Basin; and nonvolatile beta activity (up to 88.3 pCi/L) was elevated in one well at the K-Area Retention Basin.

Trichloroethylene (up to 0.17 mg/L) and tetrachloroethylene (up to 0.086 mg/L) concentrations exceeded standards in one or more wells at the K-Area Burning/Rubble Pit and the K-Area Disassembly Basin, and benzene (at 0.007 mg/L) was elevated in one well at the K-Area Coal Pile Runoff Containment Basin.

Sulfate exceeded its standard in most wells at four sites, with the highest concentration found at the K-Area Acid/Caustic Basin; lead concentrations likewise were elevated in one or more wells at four sites, with the highest concentration at the K-Area Retention Basin. Selenium and nitrite concentrations were above standards at the K-Area Acid Caustic Basin and the K-Area Sludge Land Application Site, respectively. Conductivity and total dissolved solids were above standards in one or more wells at five sites, alkalinity was elevated in one or more wells at three sites, and pH exceeded its standard in one well at the K-Area Coal Pile Runoff Containment Basin. Values for conductivity and total dissolved solids were highest at the K-Area Acid/Caustic Basin, and alkalinity was highest at the K-Area Ash Basin.

pCi/L) and nonvolatile beta (up to 88.3 pCi/L) activities were elevated above DWS in well KRB 15. Gross alpha (up to 18 pCi/L) was detected above the DWS in well KRB 14. No other radioactive constituents were detected above DWS in the KRB wells.

Lead (up to 0.897 mg/L) was the only chemical constituent detected above DWS in wells KRB 1, 8, and 13. However, TDS (at 248 mg/L) was elevated in well KRB 8.

K-Area Sludge Land Application 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 6-21, Vol. II). Surface elevations at the site range approximately from 180 to 220 ft msl. In 1989, the site was declared part of the RFI program because of the presence of chlordane in the lagoon sludge applied to the site. See also the Sewage Sludge Application Sites section under General Areas.

The site is monitored by the three wells of the KSS series (Table 6-62, Vol. II). Because the wells are almost in a line, the horizontal groundwater flow direction is difficult to interpret; however, it appears to be toward the southeast.

Total radium (up to 34.7 pCi/L) was detected above the DWS in well KSS 2D. No other radioactive constituents were detected above DWS at this site.

Nitrite (at 0.11 mg/L) in well KSS 1D was the only chemical constituent detected above DWS. However, conductivity (at 109 μmhos/cm) was also elevated in well KSS 1D.

L AREA

L Area is in the south-central part of SRS as shown in Figure 6-1 (Vol. II) (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 site 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 groundwater island in the Dry Branch Formation.

In 1989, 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 6-22, Vol. II). A summary of maximum groundwater monitoring results for these sites is given in Table 6-63 (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 6-22, Vol. II). See the previous section of this chapter for a discussion of SRS acid/caustic basins.

The basin is monitored by the four wells of the LAC series (Table 6-64, Vol. II). Horizontal gradients are low at this site, making interpretation of flow directions difficult.

No radioactive constituents were detected above drinking water standards (DWS) in the LAC wells.

Trichloroethylene (up to 0.039 mg/L) was detected above the DWS in all the LAC wells except LAC 1. Other chemical constituents detected above DWS were tetrachloroethylene (up to 0.036 mg/L) in well LAC 3 and lead (up to 0.078 mg/L) in well LAC 2. In addition, conductivity (up to 353 μmhos/cm) was elevated in wells LAC 3 and 4. Alkalinity (up to 149 meq/L) and pH (up to 9.6) were elevated in well LAC 3, suggesting that water in this well may be affected by the leaching of well grout. Sulfate (at 31.7 mg/L) was elevated in well LAC 4.

L-Area Burning/Rubble Pit

The L-Area Burning/Rubble Pit (131-L) is approximately 1,200 ft northwest of L Area, between Road 7-1 and the steam-line road (Figure 6-22, Vol. II). See the previous section of this chapter for a discussion of SRS burning/rubble pits.

The site is monitored by the four wells of the LRP series (Table 6-65, Vol. II). Relative to the pit, LRP 2 is upgradient, well LRP 1 is sidegradient, and wells LRP 3 and 4 are downgradient.

No radioactive constituents were detected above DWS in the LRP wells.

Lead concentrations (up to 0.101 mg/L) were above the DWS in well LRP 2. Tetrachloroethylene (at 0.009 mg/L) was detected above the DWS in well LRP 3. No other chemical constituents were detected above DWS at this site.

L-Area Disassembly Basin

The L-Area Disassembly Basin (105-L) is located in the L-Area reactor building (Figure 6-22, Vol. II). See the previous section of this chapter for a discussion of SRS disassembly basins.

The L-Area Disassembly Basin is monitored by wells LDB 1 and 2 (Table 6-66, Vol. II). Information is insufficient to determine horizontal groundwater flow directions at the site.

No radioactive constituents were detected above DWS in the LDB wells.

Tetrachloroethylene (up to 0.008 mg/L) in well LDB 1 was the only chemical constituent detected above DWS at this site. However, pH (at 3.9) was also low in well LDB 1.

L-Area Oil and Chemical Basin

The L-Area Oil and Chemical Basin (904-83G) is southeast of L Area (Figure 6-22, 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 site 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. This area is part of the RFI program.

The L-Area Oil and Chemical Basin is monitored by the four wells of the LCO series (Table 6-67, Vol. II). Relative to the basin, wells LCO 2 and 3 are upgradient, and wells LCO 1 and 4 are downgradient.

Tritium (up to 360 pCi/mL) was detected above the DWS in wells LCO 1 and 4. Nonvolatile beta activity (up to 180 pCi/L) was elevated in well LCO 1. No other radioactive constituents were detected above DWS at this site.

L-Area Summary

L Area lies in the south-central portion of SRS, east of K Area. This area houses L Reactor, which began operating in July 1954. In 1989, 18 wells at five sites in L Area were sampled to determine the quantities of certain radioactive and nonradioactive constituents that may be present in the groundwater.

Radioactive constituents were detected above applicable standards at two sites: tritium (up to 4,200 pCi/mL) was above its standard in two wells at the L-Area Oil and Chemical Basin and in three wells at the L-Area Reactor Seepage Basin; nonvolatile beta activity (up to 180 pCi/L) was elevated in one well in the L-Area Oil and Chemical Basin.

Tetrachloroethylene (up to 0.052 mg/L) was above its standard in one or more wells at the L-Area Burning/Rubble Pit, the L-Area Disassembly Basin, the L-Area Oil and Chemical Basin, and the L-Area Acid/Caustic Basin; trichloroethylene concentrations (up to 0.039 mg/L) were elevated in one or more wells at the latter two sites.

Sulfate and lead concentrations were above standards in one well each at two sites; the highest concentration of sulfate was found at the L-Area Oil and Chemical Basin, and the highest value of lead was at the L-Area Burning/Rubble Pit. Conductivity, alkalinity, and pH values were elevated in one or more wells at the L-Area Acid/Caustic Basin and the L-Area Oil and Chemical Basin, and total dissolved solids concentrations were elevated in two wells at the latter site. pH also exceeded its standard in two wells at the L-Area Reactor Seepage Basin and in one well at the L-Area Disassembly Basin.

Tetrachloroethylene (up to 0.052 mg/L) was detected above the drinking water standard in all LCO wells except LCO 1. Trichloroethylene (at 0.011 mg/L) was detected above DWS in well LCO 3. No other chemical constituents were detected above DWS. However, conductivity (up to 1,110 μmhos/cm) and TDS (up to 619 mg/L) were elevated in wells LCO 3 and 4. Alkalinity (up to 155 meq/L) and pH (up to 10.0) were also elevated in well LCO 3, suggesting that water in this well may be affected by the leaching of well grout. Sulfate (up to 449 mg/L) was elevated in well LCO 4.

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 6-22, Vol. II). The L-Area Reactor Seepage Basin was used from 1958 until 1969 and from 1985 to the present. See the previous section of this chapter for a discussion of SRS reactor seepage basins.

The basin is monitored by the four wells of the LSB series (Table 6-68, Vol. II). Horizontal groundwater flow direction under the site was toward the southeast during first quarter 1989 and more easterly for the remainder of the year. Well LSB 1 is downgradient, wells LSB 3 and 4 are upgradient to sidegradient, and well LSB 2 is sidegradient of the basin.

Tritium (up to 4,200 pCi/mL) was detected above the DWS in all the LSB wells except LSB 2. No other radioactive constituents were detected above DWS at this site.

No chemical constituents were detected above DWS at this site. However, pH (down to 3.8) was low in wells LSB 2 and 3.

M AREA

M Area is located in the northwest part of SRS as shown in Figure 6-1 (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 site 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 1989, groundwater in M Area was monitored at the M-Area Hazardous Waste Management Facility (HWMF) (Figure 6-3, Vol. II). A summary of the maximum results of this monitoring is presented in Table 6-69 (Vol. II).

Groundwater beneath A and M Areas is contaminated with halogenated organics as a result of past operations; in 1989, this plume of organics was monitored by approximately 200 plume definition wells (Figures 6-2 and 6-3, Vol. II). Since the discovery of the contamination in June 1981, progress has been made in assessing the extent of the contamination and in establishing a remediation program. As of December 1989, the inventory of organics in the groundwater is estimated to be approximately 380,000 lb with peak concentrations of 150 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 1989, 208,245 lb of organics have been removed from 871,746,850 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 6-3, 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. A closure cap was completed on the basin during 1989, and official RCRA closure is nearing completion. The basin will be the first SRS hazardous waste site to be closed under RCRA.

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, and 13C, and 22 (Table 6-70, Vol. II). Well clusters MSB 29 and 43 are the designated background wells for the site. Wells MSB 29DD and MSB 43DD are used as piezometers and were not sampled. Wells MSB 1A, 3A, and 4A were either dry or could not be sampled during the year. 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.

Total radium (up to 20 pCi/L) was detected above the drinking water standard (DWS) in wells MSB 2A, 8A, 22, and 29D. Gross alpha (up to 34.6 pCi/L) was detected above the DWS in wells MSB 22 and 29D. No other radioactive constituents were detected above DWS at this site.

Trichloroethylene (up to 34 mg/L), tetrachloroethylene (up to 128 mg/L), and nitrate (up to 84.6 mg/L) were detected above the DWS in many wells. Lead concentrations (up to 0.099 mg/L) were above the DWS in wells MSB 2A and 13B. The only other chemical constituents detected above DWS were silver (at 0.18 mg/L) in well MSB 7A, cadmium (at 0.023 mg/L) in well MSB 5A, chromium (up to 0.065 mg/L) in well MSB 13B, mercury (at 0.0085 mg/L) in well MSB 43A, and trans-1,2-dichloroethene (at 0.133 mg/L) in well MSB 22. In addition, conductivity (up to 645 μmhos/cm) was elevated in wells MSB 5A, 8A, 13C, and 22. TDS concentrations (up to 726 mg/L) were elevated in well MSB 13B. Low pH (down to 3.7) was detected in well MSB 2A.

Plume Definition Wells

Besides the waste-site groundwater monitoring conducted in A and M Areas, 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, the AC well series, and well ABW 1 (Table 6-71, Vol. II). Approximately 45 of the M-Area plume definition wells (MSB series) were installed in 1989, as was well ASB 9C (Figures 6-2 and 6-3, Vol. II). Wells MSB 12D, 17C, 23, 25, 35D, 38D, 41D, 42D, 45C, and 46C were either dry or the wells could not be sampled during the year.

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.

Total radium (up to 108 pCi/L) and gross alpha (up to 155 pCi/L) were detected above DWS in many plume definition wells. Tritium (at 24.9 pCi/mL) was elevated above the DWS in well ASB 8C, and gross alpha (at 30.1 pCi/L) was also elevated in well ASB 9. Nonvolatile beta activity (up to 80.4 pCi/L) was elevated in wells MSB 9C and 10A. Radium-226 (at

M-Area Summary

M Area is adjacent to A Area in the northwest part of SRS. M Area houses the fuel and target fabrication plant, which manufactures elements for irradiation in the reactors. In 1989, 9 background wells, 12 point-of-compliance wells for the M-Area Hazardous Waste Management Facility, and approximately 200 plume definition wells were sampled to determine the quantities of certain radioactive and nonradioactive constituents that may be present in the groundwater.

Trichloroethylene (up to 150 mg/L) exceeded its standard in over 100 wells and tetrachloroethylene (up to 196 mg/L) in over 70 wells. These maximum concentrations were higher than those at any other site monitored at SRS in 1989, exceeding applicable standards by at least 30,000 times. Other organics above standards in one or more wells were carbon tetrachloride, chloroform, chloroethene, benzene, and trans-1,2-dichloroethene. A groundwater remediation program has been underway since 1983 to remove the organic contaminants.

Radioactive constituents above standards were gross alpha (up to 155 pCi/L) in seven wells, including one background well; nonvolatile beta (up to 80.4 pCi/L) in two wells; total radium (up to 108 pCi/L) in 17 wells, including 1 background well; and tritium (up to 24.9 pCi/mL) and ^{226}Ra (at 146 pCi/L) in one well each. The highest values for all these constituents were found in the plume definition wells.

Nitrate and lead concentrations were above standards in 17 and three wells, respectively, with the highest values found in the point-of-compliance wells. Sulfate concentrations were elevated in three plume definition wells, silver concentrations in one point-of-compliance well, chromium and cadmium concentrations in one point-of-compliance well and one plume definition well each, and mercury concentrations in one background well and one plume definition well. Conductivity exceeded its standard in 44 wells, pH in 29 wells, alkalinity in six wells, and total dissolved solids in 4 wells.

146 pCi/L) was detected in well ASB 8. No other radioactive constituents were detected above DWS in the plume definition wells.

No chemical constituents were detected above DWS in the AC well series. However, in the MSB and ASB plume definition wells, nitrate (up to 35.1 mg/L) was detected above the DWS in wells near the M-Area Settling Basin. Trichloroethylene (up to 150 mg/L) and tetrachloroethylene (up to 196 mg/L) were also detected above DWS in many of the wells, with the highest concentrations also detected near the M-Area Settling Basin. Lead (at 0.069 mg/L) was detected above DWS in well MSB 36TA. Other chemical constituents detected above DWS were chloroform (at 1.39 mg/L) in well MSB 47C, carbon tetrachloride (at 0.006 mg/L) in well MSB 31C, cadmium (up to 0.026 mg/L) in well MSB 39A, chromium (at 0.051 mg/L) in well 36A, chloroethene (at 0.015 mg/L) in well MSB 10C, benzene (at 0.006 mg/L) in well MSB 9C, and mercury (up to 0.0093 mg/L) in well MSB 17A. Also detected above DWS were trichloroethylene (at 0.006 mg/L) in well ABW 1 and trans-1,2-dichloroethene (up to 1.78 mg/L) in wells MSB 9B, 11C, 28A, 47B, and 47C.

No other chemical constituents were detected above DWS. However, elevated conductivity (up to 2,130 μmhos/cm) and pH (up to 11.9) were detected in a number of wells, indicating that many wells may be affected by the leaching of well grout. Alkalinity (up to 558 meq/L) was elevated in wells MSB 16C, 37A, 44C, 48D, 69TA, and 71B. TDS (up to 260 mg/L) was detected in wells MSB 10C, 19B, and 31B. Sulfate (up to 171 mg/L) was elevated in wells MSB 11C, 17B, and 19C. Low pH (down to 3.6) was detected in wells MSB 9C, 11F, 12A, 19A, 24A, 27, 30B, 31B, 36A, 39C, 42B, and 73B.

P AREA

P Area is located in the south-central part of SRS (see Figure 6-1, Vol. II). Surface elevations across P Area range approximately from 310 to 330 ft msl.

The nearest site 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 1989, 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 6-23, Vol. II). A summary of the 1989 maximum groundwater monitoring results is presented in Table 6-72 (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 6-23, Vol. II). See the previous section of this chapter for a discussion of SRS acid/caustic basins.

The site is monitored by the six wells of the PAC series (Table 6-73, Vol. II). Relative to the basin, wells PAC 1 and 4 are upgradient, and wells PAC 2, 3, 5, and 6 are downgradient.

Total radium (up to 18.3 pCi/L) was detected above the drinking water standard (DWS) in wells PAC 5 and 6. Tritium (at 21.5 pCi/mL) was detected above the DWS in well PAC 5. No other radioactive constituents were detected above DWS at this site.

No chemical constituents were detected above DWS. However, sulfate (up to 424 mg/L) and conductivity (up to 891 μmhos/cm) were elevated in wells PAC 3, 4, 5, and 6. Also elevated were TDS (up to 664 mg/L) in wells PAC 3, 5, and 6 and alkalinity (up to 264 meq/L) in wells PAC 5 and 6.

P-Area Burning/Rubble Pit

The P-Area Burning/Rubble Pit (131-P) is approximately 1,200 ft west of P Area (Figure 6-23, Vol. II). See the previous section of this chapter for a discussion of SRS burning/rubble pits.

The site is monitored by the four wells of the PRP series (Table 6-74, Vol. II). Relative to the pit, well PRP 4 is upgradient, wells PRP 2 and 3 are sidegradient, and well PRP 1A is downgradient.

Tritium (up to 116 pCi/mL) in well PRP 1A was the only radioactive constituent detected above DWS at this site.

P-Area Summary

P Area is located in the east-central part of SRS, south of R Area. P Area is the site of P Reactor, which began operating in February 1954. In 1989, groundwater from 23 wells at five sites in P Area was analyzed to determine the quantities of certain radioactive and nonradioactive constituents that may be present.

Radioactive constituents above applicable standards were found at all five sites: tritium (up to approximately 219,000 pCi/mL) was above its standard in all wells monitored at the P-Area Disassembly Basin and the P-Area Reactor Seepage Basins and in one well each at the P-Area Acid/Caustic Basin and the P-Area Burning/Rubble Pit; total radium activity (up to 26.6 pCi/L) was elevated in two wells at the P-Area Acid/Caustic Basin and in one well at the P-Area Coal Pile Runoff Containment Basin.

Halogenated organic compounds exceeded standards in one well at the P-Area Burning/Rubble Pit, with carbon tetrachloride concentrations ranging up to 0.259 mg/L and both tetrachloroethylene and trichloroethylene concentrations ranging up to 0.056 mg/L.

Lead exceeded its standard in one or more wells at three sites, with the highest concentration at the P-Area Reactor Seepage Basins; sulfate concentrations were elevated in most of the wells monitored at the P-Area Acid/Caustic Basin and the P-Area Coal Pile Runoff Containment Basin, with the highest concentration at the latter site. Cadmium and selenium concentrations were elevated in one well at the P-Area Coal Pile Runoff Containment Basin, nitrate concentrations were elevated in one well at the P-Area Reactor Seepage Basins, and chromium concentrations were elevated in one well each at the P-Area Burning/Rubble Pit and the P-Area Coal Pile Runoff Containment Basin. Conductivity and total dissolved solids values were above standards in one or more wells each at three sites, and alkalinity and pH exceeded standards in several wells at one site each.

Carbon tetrachloride (at 0.259 mg/L), tetrachloroethylene (up to 0.056 mg/L), and trichloroethylene (up to 0.056 mg/L) were detected above DWS in well PRP 3. Chromium (at 0.066 mg/L) was detected above the DWS in well PRP 2. No other chemical constituents were detected above DWS. However, conductivity (up to 102 μmhos/cm) was elevated 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 6-23, Vol. II). See the previous section 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 6-75, Vol. II). Horizontal gradients near the basin are low, making interpretation of flow directions difficult.

Total radium (at 26.6 pCi/L) was detected above the DWS in well PCB 3A. No other radioactive constituents were detected above DWS at this site.

Cadmium (at 0.011 mg/L), chromium (up to 0.065 mg/L), lead (at 0.067 mg/L), and selenium (up to 0.016 mg/L) were elevated above DWS in well PCB 3A. No other chemical constituents were detected above DWS. However, low pH (down to 3.2) and elevated levels of sulfate (up to 12,600 mg/L) and conductivity (up to 1,579 μmhos/cm) were detected in wells PCB 1A, 3A, and 4A. TDS (at 2,100 mg/L) was also elevated in well PCB 3A.

P-Area Disassembly Basin

The P-Area Disassembly Basin (105-P) is located in the P-Area reactor building (Figure 6-23, Vol. II). See the previous section of this chapter for a discussion of SRS disassembly basins.

The basin is monitored by wells PDB 2 and 3 (Table 6-76, Vol. II). Both wells are screened below the water table, making interpretation of horizontal flow directions difficult.

Tritium (up to 330 pCi/mL) in wells PDB 2 and 3 was the only radioactive constituent detected above DWS at this site.

Lead (up to 0.062 mg/L) was detected above the DWS in wells PDB 2 and 3. No other chemical constituents were detected above DWS.

P-Area Reactor Seepage Basins

The P-Area Reactor Seepage Basins (904-61G, 904-62G, and 904-63G) are southwest of the reactor building (Figure 6-23, Vol. II). The basins are connected in series, with water entering Basin 1 then flowing to Basins 2 and 3. See the previous section of this chapter for a discussion of SRS reactor seepage basins.

The basins are monitored by the seven wells of the PSB series (Table 6-77, Vol. II). Horizontal groundwater flow is toward the west. Wells PSB 1A, 2A, 3A, and 4A are downgradient of the basins. Well PSB 5A is upgradient of Basin 3. Well PSB 7A is upgradient to sidegradient of Basin 1. Well PSB 6A is upgradient of Basin 2 and downgradient of Basin 1.

Tritium (up to 219,000 pCi/mL) in all seven PSB wells was the only radioactive constituent detected above DWS at this site.

Lead (up to 0.101 mg/L) was detected above the DWS in wells PSB 4A and 5A. Nitrate (up to 29 mg/L) was detected above the DWS in well PSB 2A. No other chemical constituents were detected above DWS. However, conductivity (up to 260 µmhos/cm) was elevated in well PSB 2A. TDS (at 566 mg/L) was also elevated in well PSB 5A.

RADIOACTIVE WASTE BURIAL GROUNDS

The Radioactive Waste Burial Grounds, located between F and H Areas (Figure 6-7, Vol. II), are used for storage of radioactive solid waste produced at the site and shipped from other U.S. Department of Energy facilities. The original area (643-G) began receiving waste in 1952 and was filled in 1972. Operations then shifted to an adjacent site, the 643-7G Burial Ground. The Mixed Waste Management Facility (MWMF; 643-28G), an area within 643-7G, was defined in 1986 (Figure 6-24, Vol. II). Closure of the 643-28G site is in progress. Sites 643-G and 643-7G are included in the RFI program.

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 engineered, low-level trenches and covered with at least 4 ft of soil.

Mixed wastes (low-level radioactive waste containing hazardous waste) stored within 643-G and 643-28G 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.

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 other hazardous wastes were discontinued. A plan was implemented to ensure that all other wastes were certified to be free of hazardous materials.

The Burial Grounds are monitored by wells HSB 85A, 85B, and 85C and the BG and BGO well series, except for well BG 10, which monitors the H-Area Seepage Basins. Twenty-one BGO series wells were added to the program in 1989. Thirty-eight of the BGO series wells at the perimeter of Burial Ground 643-7G are RCRA wells. BG and BGO series wells with a "D" or no letter after the well cluster number are screened in the water table. The lower portion of the water table, the Dry Branch Formation, and the Santee Formation lie between approximately 120 to 160 ft msl and are monitored by BGO wells with a "C" after the well cluster number. The Congaree Formation lies between approximately 0 to 120 ft msl and is monitored by BGO wells with an "A" after the well cluster number.

The MGA, MGC, MGE, MGG, and MGI series wells (grid wells) monitor the water table and perched

Radioactive Waste Burial Ground Summary

The Radioactive Waste Burial Grounds, which lie between F and H Areas, are used for storage of radioactive solid waste produced at SRS and shipped from other U.S. Department of Energy facilities. In 1989, 101 wells in and around Burial Ground 643-G (33 BG wells; 21 BGO wells; 47 MGA, MGC, MGE, MGG, and MGI wells) and 41 wells at Burial Ground 643-7G and the Mixed Waste Management Facility (wells HSB 85A, 85B, 85C; 38 BGO wells) were sampled to determine the levels of certain radioactive and nonradioactive constituents that may be present in the groundwater.

Tritium (up to 5,450,000 pCi/mL) was above its applicable standard in over 100 of the 142 wells; gross alpha activity (up to 1,200 pCi/L) and nonvolatile beta activity (up to 1,100 pCi/L) were elevated in over 10 wells each. The maximum tritium activity was higher than at any other site monitored at SRS in 1989, exceeding its standard by over 270,000 times. In addition, total radium (up to 20 pCi/L) and ^{241}Am (at 5.1 pCi/L) activities exceeded standards at Burial Ground 643-G.

Trichloroethylene (up to 0.43 mg/L), carbon tetrachloride (up to 0.095 mg/L), and tetrachloroethylene (up to 0.022 mg/L) concentrations were above standards in 23, 13, and 4 wells, respectively, at the burial grounds. Lead, endrin, conductivity, alkalinity, pH, and total dissolved solids levels also were elevated in one or more wells at the burial grounds. Nitrate, sulfate, trans-1,2-dichloroethene, and toxaphene concentrations exceeded standards at Burial Ground 643-G; and cadmium, chromium, benzene, and fluoride concentrations were elevated at Burial Ground 643-7G and the Mixed Waste Management Facility.

water zones in Burial Ground 643-G. The wells in these series are monitored by EHP and SRL as part of ongoing research projects.

The nearest site boundary to the Radioactive Waste Burial Grounds is approximately 6 miles to the west. The site is located on a water-table divide. Groundwater from the northeast parts of Burial Ground 643-7G and the MWMF (643-28G) flows toward the north-northwest, groundwater from the southwestern portions of Burial Ground 643-7G and the MWMF flows toward the west-southwest, groundwater under the northwestern parts of Burial Ground 643-7G and the MWMF flows toward the west, and groundwater under the eastern portions of Burial Ground 643-7G and the MWMF flows toward the east-southeast. Wells BGO 3D, 4D, 5D, 16, 18, 19D, 20D, and 21D are sidegradient, wells BGO 6D, 9D, 11D and 12 are downgradient, and wells BGO 1D and 2D are upgradient to sidegradient of Burial Ground 643-7G and the MWMF. BG series wells monitoring Burial Ground 643-G are sidegradient or downgradient of the site. Wells MGA 36, MGC 11 and 23, MGE 9, 21, and 34, and MGG 15, 19, 23, and 28 were either dry or could not be sampled during the year; wells BGO 10D and 14D were dry throughout 1989. A summary of the maximum groundwater monitoring results for the burial grounds is presented in Table 6-78 (Vol. II), and groundwater monitoring results for individual wells are in Table 6-79 (Vol. II).

At Burial Ground 643-G, tritium (up to 5,450,000 pCi/mL) was detected above the drinking water standard (DWS) in all the monitoring and SRL research wells except in wells BG 53 and BGO 26A, 26D, and 29A. Gross alpha (up to 1,200 pCi/L) was detected above the DWS in wells BG 52, 58, 60, and 62; BGO 26D, 27D, 31D, 32D, 36D, and 38D; MGC 19; and MGE 30. Nonvolatile beta activity (up to 1,100 pCi/L) was detected above the DWS in wells BG 52, 58 and 60, MGC 19, MGE 30, and in most of the SRL research wells. The only other radioactive constituents detected above DWS at Burial Ground 643-G were ^{241}Am (at 5.1 pCi/L) in well BGO 27C and total radium (up to 20 pCi/L) in wells BGO 26D and 32D.

Tritium (up to 8,800 pCi/mL) was detected above the DWS in many of the BGO wells at Burial Ground 643-7G and the MWMF. Gross alpha (up to 20 pCi/L) was detected above the DWS in wells BGO 5D and 8A. Nonvolatile beta activity (up to 82 pCi/L) was elevated in wells BGO 8A and 14A. No other radioactive constituents were detected above DWS at this site.

Samples taken from the BG, MGA, MGC, MGE, MGG, and MGI well series at Burial Ground 643-G were not analyzed for chemical constituents. Trichloroethylene (up to 0.43 mg/L) was detected above the DWS in wells BGO 26A, 27C, 27D, 30C, 30D, 31D, 32D, 33C, 35D, and 37C. Concentrations of trans-1,2-dichloroethene (up to 2.6 mg/L) were above the DWS in wells BGO 28D, 30D, 32D, 33C, and 37C. Tetrachloroethylene (up to 0.016 mg/L) was detected above the DWS in wells BGO 28D, 32D, and 37C.

Lead concentrations (up to 0.052 mg/L) were above the DWS in wells BGO 30D and 37D. Nitrate (up to 41 mg/L) was detected above the DWS in wells BGO 32D and 37C.

Also detected above DWS were carbon tetrachloride (up to 0.095 mg/L) in well BGO 37C, endrin (at 0.00025 mg/L) in well BGO 28D, and toxaphene (at 0.00906 mg/L) in well BGO 27D. No other chemical constituents were detected above DWS in the BGO wells. However, conductivity (up to 3,920 μmhos/cm) was elevated in many of the burial ground wells. In addition, pH (up to 12.3) was elevated in wells BGO 26A, 29A, and 35C, suggesting that water in well BGO 26A may be affected by the leaching of well grout. Alkalinity (up to 970 meq/L) in wells BGO 26A and 29A, TDS (up to 438 mg/L) in wells BGO 26A and 30C, and sulfate (up to 138 mg/L) in well BGO 30C were also elevated. Low pH (down to 3.9) was detected in wells BGO 38D and 39D.

Trichloroethylene (up to 0.14 mg/L) was detected above the DWS in many of the wells at Burial Ground 643-7G and the MWMF. Carbon tetrachloride (up to 0.041 mg/L) was detected above the DWS in wells BGO 1D, 2D, 3D, 4D, 5C, 5D, 8A, 8C, 8D, 10A, 10C, and 12A. Benzene concentrations (up to 0.046 mg/L) were above the DWS in wells BGO 1D, 3D, 5C, 8A, 8D, 10A, 10C, 12A, and 12D.

The only other chemical constituents elevated above DWS were lead (at 0.07 mg/L) in well BGO 11D, tetrachloroethylene (up to 0.022 mg/L) in well BGO 7D, cadmium (at 0.039 mg/L) in well BGO 11D, chromium (at 0.05 mg/L) in well BGO 5C, fluoride (at 15 mg/L) in well BGO 12C, and endrin (at 0.00037 mg/L) in well BGO 16D. In addition, conductivity (up to 5,600 μmhos/cm) was elevated in many of the BGO wells and wells HSB 85A and 85B. Alkalinity (up to 600 meq/L), pH (up to 12.3) and TDS (up to 6,860 mg/L) were elevated in many of the BGO series wells.

R AREA

R Area, located in the east-central part of SRS as shown in Figure 6-1 (Vol. II), is on a topographic divide where surface elevations range approximately from 280 to 330 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 site 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 R-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 1989, 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 6-25, Vol. II). A summary of the maximum groundwater monitoring results for these sites is given in Table 6-80 (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 6-25, Vol. II). See the previous section of this chapter for a discussion of SRS acid/caustic basins.

The site is monitored by the four wells of the RAC series (Table 6-81, Vol. II). The direction of horizontal groundwater flow under the basin was toward the southeast until fourth quarter 1989 when it shifted to the east. Well RAC 1 appears to be upgradient, well RAC 2 appears to be sidegradient, and wells RAC 3 and 4 appear to be downgradient to sidegradient of the basin.

Total radium (up to 9 pCi/L) was detected above the drinking water standard (DWS) in all the RAC wells except RAC 4. Gross alpha (up to 82.5 pCi/L) was detected above the DWS in wells RAC 2 and 3. No other radioactive constituents were detected above DWS at this site.

Lead (at 0.053 mg/L) was detected above the DWS in well RAC 2. No other chemical constituents were detected above DWS. However, conductivity (up to 172 μmhos/cm) and sulfate (at 35 mg/L) were elevated in well RAC 1.

R-Area Burning/Rubble Pits

The R-Area Burning/Rubble Pits (131-R and 131-1R) are approximately 900 ft southeast of R Area, southeast of Road G (Figure 6-25, Vol. II). See the previous section of this chapter for a discussion of SRS burning/rubble pits.

The site is monitored by the four wells of the RRP series (Table 6-82, Vol. II). Well RRP 1 appears to be upgradient, well RRP 2 appears to be sidegradient, and wells RRP 3 and 4 appear to be downgradient of the pits.

No radioactive or chemical constituents were detected above DWS 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 6-25, 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 directly 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 nonvolatile beta activity, including ^{90}Sr and ^{137}Cs. About half of the ^{90}Sr and ^{137}Cs has decayed since the accident. 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.

In 1989, the R-Area Reactor Seepage Basins were monitored by four wells of the RSA series, three wells of the RSB series, nine wells of the RSC series, 13 wells of the RSD series, 21 wells of the RSE series, and three wells of the RSF series (Table 6-83, Vol. II). Wells RSD 2B and RSE 4B and six were either dry or could not be sampled during the year. 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 northwest. South of Basin 1 and at the nearby abandoned sewer line, the water-table flow direction appears to be to the south.

Gross alpha (up to 74 pCi/L) was detected above the DWS in wells RSB 7, RSD 8, and RSE 8. Tritium (at

R-Area Summary

R Area, in the east-central portion of SRS, is the site of R Reactor and facilities. R Reactor was the first of the five SRS reactors to begin operations (in December 1953). In 1989, groundwater from 61 wells at three sites in R Area was monitored to determine the levels of certain radioactive and nonradioactive constituents that may be present.

Radioactive constituents exceeded applicable standards at two sites: nonvolatile beta activity (up to approximately 3,190 pCi/L) was elevated in 17 wells and tritium activity (up to 474 pCi/mL) in one well at the R-Area Reactor Seepage Basins; total radium activity (up to 9 pCi/L) was elevated in three wells at the R-Area Acid/Caustic Basin and gross alpha activity (up to 82.5 pCi/L) in two wells at the R-Area Acid/Caustic Basin and in three wells at the R-Area Reactor Seepage Basins.

Conductivity was above its standard in one well at the R-Area Acid/Caustic Basin and in several wells at the R-Area Reactor Seepage Basins; lead and sulfate concentrations exceeded standards at the former site and pH at the latter site. None of the analytes were above standards in samples taken from wells at the R-Area Burning/Rubble Pits.

474 pCi/mL) was detected above the DWS in well RSE 10. Nonvolatile beta activity (up to 3,190 pCi/L) was detected above the DWS in many of the wells. No other radioactive constituents were detected above DWS at this site.

No chemical constituents were detected above DWS. However, conductivity (up to 522 µmhos/cm) was elevated in wells RSC 3 and 5, RSD 9, and RSF 1. Elevated pH (up to 10.9) was also detected in well RSF 1, suggesting that water in this well may be affected by the leaching of well grout.

S AREA

S Area is located in the central part of SRS just north of H Area. 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 site boundary to S Area is approximately 6.5 miles to the north. Near-surface groundwater flows toward McQueen Branch, approximately 4,000 ft to the northeast.

In 1989, groundwater was monitored at the following sites in S Area: the S-Area Background Wells, the S-Area Low Point Pump Pit, and the S-Area Vitrification Building (Figure 6-19, Vol. II). A summary of the maximum groundwater results from S Area is presented in Table 6-84 (Vol. II).

S-Area Summary

S Area is located in the central part of SRS just north of H Area. This area houses the Defense Waste Processing Facility where radioactive waste will be incorporated into leach-resistant glass and stored in interim facilities. In 1989, 12 wells at three sites within S Area were sampled to determine quantities of certain radioactive and nonradioactive constituents that may be present in the groundwater.

Tritium activity was detected above its applicable standard in three of the S-Area background wells, and trichloroethylene concentrations were elevated in two of the background wells, with highest values of 24.2 pCi/mL and 0.094 mg/L, respectively.

Lead (at 0.062 mg/L), tetrachloroethylene (up to 0.006 mg/L), total radium (at 5.67 pCi/L), and total dissolved solids (at 546 mg/L) levels were above standards in single background wells. No analytes were above standards at the S-Area Low Point Pump Pit and the S-Area Vitrification Building.

S-Area Background Wells

The six SBG series wells were installed as background wells in S-Area and are screened below the water table (Table 6-85, Vol. II). The groundwater flow direction appears to be to the north toward Upper Three Runs Creek (Figure 6-19, Vol. II). Well SBG 5 appears to be upgradient, wells SBG 2 and 3 appear to be downgradient, and wells SBG 1, 4, and 6 appear to be sidegradient of the monitored area.

Tritium (up to 24.2 pCi/mL) was detected above the drinking water standard (DWS) in wells SBG 1, 3, and 4. Total radium (at 5.67 pCi/L) was detected above the DWS in SBG 3. No other radioactive constituents were detected above DWS.

Trichloroethylene (up to 0.094 mg/L) was detected above the DWS in wells SBG 4 and 5. Other chemical constituents detected above DWS were lead (at 0.062 mg/L) in well SBG 6 and tetrachloroethylene (up to 0.006 mg/L) in well SBG 4. No other chemical constituents were detected above DWS. However, TDS (at 546 mg/L) was elevated in well SBG 2.

S-Area Low Point Pump Pit

The S-Area Low Point Pump Pit (511-S) is at the south end of S Area (Figure 6-19, Vol. II). The facility will pump high-level radioactive sludge and precipitate 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 and precipitate 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 (Table 6-86, Vol. II). Horizontal groundwater flow direction under the pit appears to be toward the north. Well SLP 1 appears to be downgradient, and well SLP 2 appears to be sidegradient of the pit.

No radioactive or chemical constituents were detected above DWS in the SLP wells.

S-Area Vitrification Building

The S-Area Vitrification Building (221-S), also known as the S-Area Canyon Building, is located in the northern portion of S Area (Figure 6-19, Vol. II). The Vitrification Building will contain process and auxiliary equipment and personnel facilities to incorporate radioactive waste into leach-resistant glass. The glass will be cast in metal canisters and stored in an interim facility within S Area.

Four wells of the SCA series (SCA 1, 1A, 2, and 2A) monitored the S-Area Vitrification Building in 1989 (Table 6-87, Vol. II). Wells SCA 1A and 2A were dry throughout 1989. Because of insufficient water-level information, horizontal groundwater flow directions cannot be determined for this site.

No radioactive or chemical constituents were detected above DWS in the SCA wells.

TNX AREA

TNX Area is located in the southwest part of SRS as shown in Figure 6-1 (Vol. II). Surface elevations across TNX range approximately from 120 to 150 ft msl, decreasing to the west-southwest toward the Savannah River.

The nearest site boundary to TNX Area is the Savannah River, approximately 0.25 miles to the west. The water table discharges to the Savannah River and to the nearby swamp.

In 1989, 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 6-26, Vol. II). A summary of the maximum groundwater monitoring results for these sites is given in Table 6-88 (Vol. II).

New TNX Seepage Basin

The New TNX Seepage Basin (904-102T), located in the east section of the TNX facility, across River Road from the TNX process area (Figure 6-26, Vol. II), replaced the Old TNX Seepage Basin and operated from 1980 to 1988. A Waste Site Assessment Report and a Groundwater Quality Assessment/Corrective Action Feasibility Plan have been submitted to SCDHEC for review.

The basin is monitored by the four wells of the YSB series (Table 6-89, Vol. II). Horizontal groundwater flow beneath the basin is due west toward the Savannah River Swamp. Well YSB 2A is upgradient, well YSB 4A is downgradient, and wells YSB 1A and 3A are sidegradient.

No radioactive constituents were detected above drinking water standards (DWS) in the YSB wells.

No chemical constituents were detected above drinking water standard at this site. However, conductivity (up to 460 μmhos/cm) was elevated in wells YSB 3A and 4A. Elevated TDS (at 304 mg/L) was also detected in well YSB 3A.

Old TNX Seepage Basin

The Old TNX Seepage Basin (904-76T), in the southwest corner of the TNX facility (Figure 6-26, Vol. II), was in operation from 1958 to 1980 and received waste from pilot-scale tests conducted at TNX. In 1981, the basin wall was breached and the impounded water was drained into the adjacent wetlands. The basin was then backfilled with a sand and clay mixture and the top capped with clay.

The basin is monitored by the five XSB series wells (Table 6-90, Vol. II). Horizontal groundwater flow beneath the basin is toward the west in the direction of the Savannah River Swamp. Well XSB 3A is sidegradient, and wells XSB 1D, 2D, 4D, and 5A are downgradient.

Gross alpha (up to 16 pCi/L) was detected above DWS in well XSB 5A. The only other radioactive constituents detected above DWS were ^{228}Ra (at 25 pCi/L) in well XSB 4D, 90Sr (at 49 pCi/L) in well XSB 2D, and ^{226}Ra (up to 202 pCi/L) in wells XSB 2D and 5A.

Trichloroethylene (up to 0.993 mg/L) was detected above the DWS in all the XSB wells. Carbon tetrachloride (up to 0.2 mg/L) was detected above the DWS in all the XSB wells except XSB 3A. Other chemical constituents detected above DWS were tetrachloroethylene (up to 0.11 mg/L) in wells XSB 1D, 3A, and 5A, nitrate (up to 33.7 mg/L) in wells XSB 4D and 5A, and chloroform (at 0.221 mg/L) in well XSB 1D.

No other chemical constituents were detected above DWS. However, conductivity (up to 362 μmhos/cm) was elevated in all the XSB wells except XSB 1D. Also elevated were pH (at 9.0) in well XSB 2D and TDS (at 228 mg/L) in well XSB 5A.

TNX-Area Summary

TNX Area, located in the southwest part of SRS, is operated by the Savannah River Laboratory to test equipment prior to installation and to develop new designs. In 1989, 15 wells at three sites in TNX Area were monitored to determine the quantities of certain radioactive and nonradioactive constituents that may be present in the groundwater.

Radioactive constituents were above applicable standards at two sites: ^{226}Ra (up to 202 pCi/L)gross alpha (up to 69.9 pCi/L), ^{228}Ra (up to 27 pCi/L), and ^{90}Sr (up to 49 pCi/L) were above standards in 5, 4, 3, and 2 wells, respectively, of the 11 wells at the Old TNX Seepage Basin and the TNX Burying Ground; nonvolatile beta (up to 55 pCi/L), , and total radium (up to 39 pCi/L) were above standards in several wells at the TNX Burying Ground. Radium-226 (at 202 pCi/L) was detected at the Old Seepage Basin.

Carbon tetrachloride (up to 0.75 mg/L), tetrachloroethylene (up to 0.11 mg/L), and trichloroethylene (up to 4 mg/L) concentrations were above standards at the Old TNX Seepage Basin and the TNX Burying Ground. Carbon tetrachloride concentrations were elevated in 9 wells, trichloroethylene in 10 wells, and tetrachloroethylene in five wells at these two sites. Chloroform and trans-1,2-dichloroethene exceeded standards in one well each at the Old TNX Seepage Basin and the TNX Burying Ground, respectively.

Nitrate exceeded its standard in two or more wells at two sites, while mercury concentrations were elevated in one well at the area. Conductivity and total dissolved solids exceeded standards in one or more wells at all three sites, with maximum values of both detected in the TNX Burying Ground wells; and pH exceeded its standard in one well each at two sites.

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 6-26, Vol. II). The buried material included contaminated conduit, tin, drums, structural steel, and depleted uranium. Most of the buried material was excavated and sent to the 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 6-91, Vol. II). Horizontal groundwater flow under the burying ground is toward the west in the direction of the Savannah River Swamp. Well TBG 7 is upgradient, well TBG 1 is downgradient, and the remainder of the wells are sidegradient or within the site.

Total radium (up to 39 pCi/L) and ^{226}Ra (up to 30 pCi/L) were detected above DWS in wells TBG 3, 4, and 6. Gross alpha (up to 69.9 pCi/L) was detected above the DWS in wells TBG 3, 4, and 7. Radium-228 (up to 27 pCi/L) was detected above the DWS in wells TBG 3 and 4. The only other radioactive constituents detected above DWS were ^{90}Sr (at 23 pCi/L) in well TBG 3 and nonvolatile beta activity (at 55 pCi/L) in well TBG 4.

Carbon tetrachloride (up to 0.75 mg/L) and trichloroethylene (up to 4 mg/L) were detected above DWS in all the TBG wells except TBG 2. Nitrate (up to 54 mg/L) was detected above the DWS in wells TBG 3, 4, and 6. Tetrachloroethylene (up to 0.048 mg/L) and trans-1,2-dichloroethene (up to 0.25 mg/L) were detected above DWS in wells TBG 3 and 4. Mercury (up to 0.0044 mg/L) was detected above the DWS in well TBG 4. Benzene (at 0.097 mg/L) was detected above the DWS in well TBG 7. No other chemical constituents were detected above DWS at this site. However, conductivity (up to 475 µmhos/cm) was elevated in all the TBG wells except TBG 2. TDS (up to 329 mg/L) was also elevated in wells TBG 1, 3, 4, and 5. Low pH (at 3.9) was detected in well TBG 4.

Z AREA

Z Area, located north of the intersection of Road F and Road 4 (Figure 6-1, Vol. II), is being developed for the disposal of saltstone. The saltstone will be made by mixing low-level radioactive supernate from the Separations Areas Tank Farms with fly ash, cement, and pulverized blast furnace slag.

In 1989, groundwater was monitored at the following Z-Area sites: the Z-Area Background Wells and the Z-Area Low Point Drain Tank (Figure 6-19, Vol. II). A summary of the maximum groundwater monitoring results is presented in Table 6-92 (Vol. II).

Z-Area Summary

Z Area, located north of the intersection of Road F and Road 4 near the center of SRS, is being developed for the disposal of low-level radioactive material in the form of saltstone.

In 1989, groundwater from five wells (three Z-Area background wells and two wells monitoring the Z-Area Low Point Drain Tank) was analyzed to determine the quantities of certain radioactive and nonradioactive constituents that may be present.

Tritium activity was detected above drinking water standards in the two wells monitoring the Z-Area Low Point Drain Tank, with the highest activity at 30.9 pCi/mL. No other analytes were found above applicable standards at either site during the year.

Z-Area Background Wells

The three ZBG wells were installed as background wells in Z Area (Figure 6-19, and Table 6-93, Vol. II). Two of the wells (ZBG 1 and 2) monitor the water table, and the third well (ZBG 1A) monitors a perched water zone between 276 ft and 281 ft msl. Well ZBG 1 is upgradient of the site, and well ZBG 2 is within the site.

No radioactive or chemical constituents were detected above drinking water standards (DWS) in the ZBG wells.

Z-Area Low Point Drain Tank

The Z-Area Low Point Drain Tank (551-Z) is southeast of S Area (Figure 6-19, Vol. II). The facility will receive low-level radioactive salt solution from the H-Area Tank Farm and pump it to the Z-Area Salt Solution Holding Tank (201-Z). When the H-Area pump is shut down, the low point drain tank has sufficient capacity to collect the solution still remaining in the lines via gravity flow.

The site is monitored by the two ZDT series wells (Table 6-94, Vol. II). Well ZDT 1 is downgradient, and well ZDT 2 is sidegradient of the tank.

Tritium (up to 30.9 pCi/mL) was detected above the DWS in both ZDT wells. No other radioactive or chemical constituents were detected above DWS at this site.

1989 HIGHLIGHTS

- The K-Area and Par Pond Sludge Land Application Sites were added to the RFI program in 1989. These areas are monitored by the KSS and PSS monitoring wells.
- The number of radionuclide-specific analyses increased during 1989, especially in F and H Areas to better characterize the radioactive contaminants in the groundwater.
- The maximum activity for total radium was measured in one of the lower zones beneath the F-Area seepage basins.
- In 1989, all monitoring wells were analyzed for a comprehensive list of 32 radioactive and nonradioactive constituents to track the concentrations of contaminants and to identify any new contaminants that may be present.
- Although trichloroethylene and tetrachloroethylene were detected in groundwater samples collected from M Area, a groundwater remediation program is underway to remove the organic contaminants.

7 Food and Drinking Water Monitoring Programs

SUMMARY—Radiological and nonradiological monitoring protocols and 1989 results are reported for milk, food products, and drinking water along with applicable standards. Milk samples, collected at five dairies within a 25-mile radius of SRS, are analyzed for tritium, gamma-emitting radionuclides, and ^{90}Sr, while farm products including vegetables, fruit, grain, poultry, meat, and eggs are analyzed for gamma-emitting radionuclides, tritium, ^{90}Sr, uranium/plutonium (non-specific), ^{238}Pu, and ^{239}Pu.

Concentrations of ^{137}Cs and ^{90}Sr in milk were within ranges reported by the EPA for the southeastern United States [EPA82, EPA83] and are attributed to worldwide fallout. On the other hand, tritium in milk is attributed to releases from SRS. In 1989, the concentrations of radionuclides measured in foods were near or below levels measured in the control sample from Columbia, SC.

For drinking water analyses, EMS collected samples from 35 onsite facilities and 16 surrounding towns, as well as from two water treatment plants downriver from SRS, and from a water treatment plant upriver of SRS which serves as a control. All samples were analyzed for gross alpha, nonvolatile beta, and tritium each time they were collected, while ^{90}Sr analyses were done annually for samples collected onsite. Tritium was occasionally detected in onsite drinking water samples collected in operating areas, and was the only radionuclide measured at downriver water treatment plants.

In the nonradiological monitoring program this year, 27 onsite drinking water systems, disinfected with chlorine, sodium hydroxide, and polyphosphates, were monitored routinely for residual chlorine and total coliform. No confirmed positive concentrations of tetrachloroethylene, trichloroethylene, or 1,1,1-trichloroethane were detected in monthly analyses of drinking water at six domestic water wells in the A-Administration/M Areas.

INTRODUCTION

Radioactive materials can be transported to man through consumption of food, milk, and drinking water. For this reason, the Environmental Monitoring Section (EMS) analyzes samples from these media to determine the contributions of radioactivity from SRS operations and worldwide fallout.

To ensure the consumption of drinking water is safe, additional drinking water samples are collected at both on- and offsite locations and analyzed to determine concentrations of nonradioactive materials.

A complete discussion of sample collection and analytical procedures for these media is found in Chapter 1 of this report.

RADIOLOGICAL MONITORING PROGRAM

Milk

Description of Monitoring Program

Milk samples are collected every two weeks at five dairies within a 25-mile radius of SRS and from locally produced inventories of a major local distributor. Sampling locations are shown in Figure 7-1.

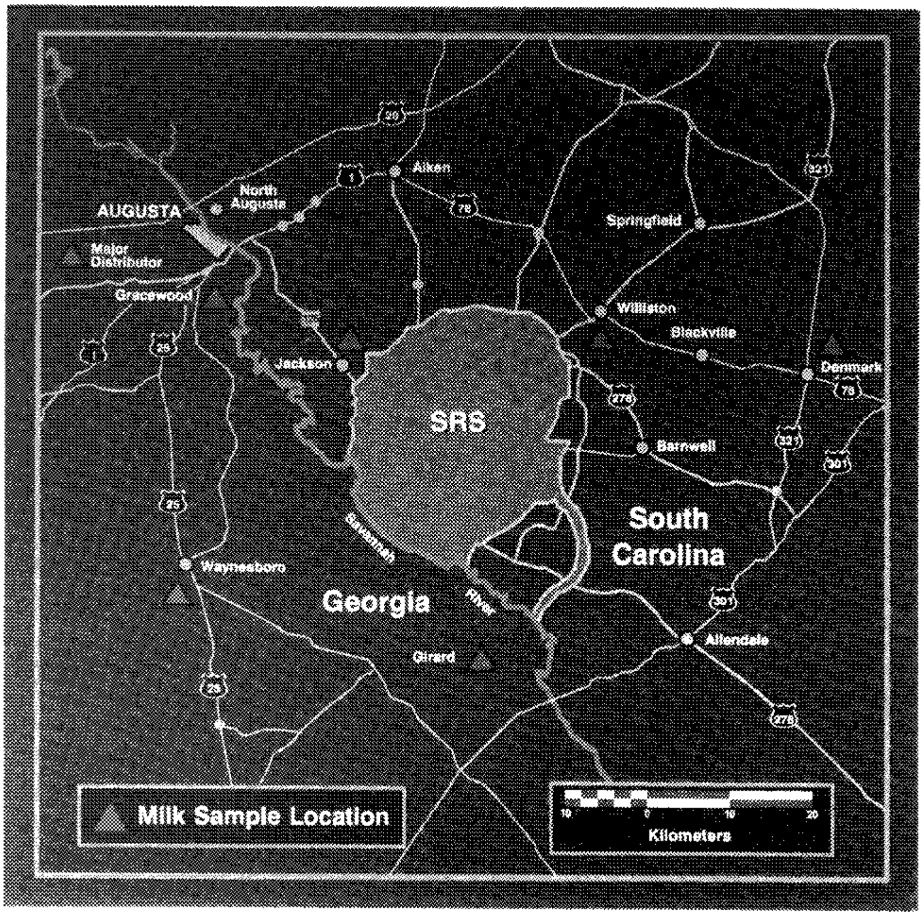


Figure 7-1. Milk sample locations

Milk samples are analyzed for tritium and gamma-emitting radionuclides, primarily ^{137}Cs and ^{131}I. Additional milk samples are collected quarterly and analyzed for ^{90}Sr.

Program Changes in 1989
The dairy in Williston, SC that had been supplying milk for the monitoring program, closed in August 1989. Another dairy, in Denmark, SC, was added to the monitoring program as a replacement.

Applicable Standards
The Department of Energy has established a Revised Interim Radiation Dose Limit of 100 mrem committed effective dose equivalent (committed dose) for individual members of the public. This limit applies to all individual members of the public and includes the dose a person receives as a consequence of DOE operations, through all pathways. One such pathway is the consumption of milk that contains radioactivity.

Monitoring Results
A comparison of radionuclide concentrations in milk over the past three years is presented below in Table 7-1. Concentrations of radionuclides have remained fairly constant. Comprehensive monitoring data for 1989 are presented in Table 7-1, Vol. II.

Gamma-Emitting Radionuclides
Cesium-137 concentrations in milk ranged from less than the lower limit of detection (LLD) to 5.1 pCi/L. The average concentration of 1.6 pCi/L is similar to concentrations from previous years. Concentrations of ^{137}Cs in milk in the surrounding area of SRS 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.

Concentrations of ^{131}I were not detected in any milk samples in 1989. 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

Table 7-1
Monitoring Data for Milk

Analysis	1987 Max	1987 Avg	1988 Max	1988 Avg	1989 Max	1989 Avg
Tritium, pCi/mL	4.0	0.6	4.0	0.5	1.67	0.3
Strontium-90, pCi/L	11.0	7.0	9.1	3.6	8.0	3.2
Cesium-137, pCi/L	8.1	2.1	7.5	1.7	5.1	1.6

no announced atmospheric nuclear weapons tests or other major nuclear incidents in 1989.

Strontium-90

Concentrations of ^{90}Sr in milk ranged from 0.45 to 8.0 pCi/L with an average concentration of 3.7 pCi/L. These concentrations are within ranges observed in previous years and are attributed to worldwide fallout.

Tritium

Tritium in milk is attributed to releases from SRS. Since 1987, the concentrations of tritium in milk have remained fairly constant, with averages ranging from 0.3 pCi/mL in 1988 to 0.6 pCi/mL in 1987. Maximum and average tritium concentrations in milk since 1987 are compared in Table 7-1.

Perspective

The tritium concentrations in milk that are attributed to SRS releases do not correspond to large radiation doses when compared to dose limits. For example, the 50-year committed dose from drinking 0.5 L of milk per day for a year, containing 1.7 pCi/mL tritium concentration is approximately 0.02 mrem (0.0002 mSv). This dose is 0.02% of the DOE annual limit.

Food

Description of Monitoring Program

Farm products including vegetables, fruit, grain, poultry, and meat are collected annually from 14 locations within the six counties surrounding SRS. Eggs are collected quarterly. Six locations are near the site perimeter and eight locations are approximately 25 miles from SRS. Additionally, collards are collected annually from Columbia, SC as a control sample. Food sample locations are shown in Figure 7-1, Vol. II.

Food samples are analyzed for gamma-emitting radionuclides, tritium, ^{90}Sr, uranium and plutonium (non-specific), ^{238}Pu, and ^{239}Pu.

Applicable Standards

The DOE limit for doses to members of the public, 100 mrem committed dose per year from DOE operations, was previously discussed. Another pathway of exposure to which this limit applies is the consumption of food that contains radioactivity.

Monitoring Results

Radioactivity in food monitoring data are presented in Table 7-2, Vol. II. In 1989, the concentrations of radionuclides measured in foods were near or below levels measured in the control sample (collards) from Columbia, SC and are thus attributed to worldwide fallout.

Gamma-Emitting Radionuclides

Concentrations of naturally occurring ^{40}K varied from less than the lower limit of detection (LLD) to 5.9 pCi/g. The results of ^{40}K analyses were within ranges normally observed in food and vegetation. Concentrations of other gamma-emitting radionuclides in foods were generally near or less than the LLD (see Table 1-5, Vol. II for LLD values for food samples). The maximum ^{137}Cs concentration, 0.03 pCi/g, was measured in both eggs and collards.

Strontium

Strontium-90 concentrations were within the ranges observed in past years and were similar to concentrations measured in the control sample collected from Columbia, South Carolina. The maximum ^{90}Sr concentration in 1989 was 0.29 pCi/g in collards, the control sample, compared to a maximum in 1988 of 1.0 pCi/g in corn. Strontium-90 concentrations in food are attributed to accumulation of the radionuclide in the soil from worldwide fallout.

Uranium and Plutonium

Uranium and plutonium (U/Pu) maximum concentrations ranged from 0.003 pCi/g in samples of chicken, pork, and beef, to 0.007 pCi/g in a grain sample. The maximum U/Pu concentration measured in the control sample in 1989 was 0.005 pCi/g. These maximums are lower than the 1988 U/Pu maximum concentration of 0.38 pCi/g.

Maximum concentrations of ^{238}Pu in food ranged from 0.02 to 0.84 fCi/g. This maximum was measured in the control sample. Maximum ^{239}Pu concentrations in food ranged from 0.02 to 0.17 fCi/g, and the control sample contained a maximum of 0.10 fCi/g of ^{239}Pu. Worldwide fallout that has accumulated in the soil accounts for the concentrations of plutonium measured in food.

Tritium

Maximum tritium concentrations in free water obtained from freeze-drying the food ranged from 0.63 to 3.9 pCi/mL. The maximum concentration was measured in collards, the control sample. This maximum tritium concentration was lower than both the 1988 maximum of 7.1 pCi/mL and the 1987 maximum of 4.3 pCi/mL.

Perspective
The radiation dose from eating foods containing tritium, attributable to SRS operations, is a small fraction of the annual DOE dose limit. If a person consumed collards at a maximum consumption rate of 64 kg/year (140 lb/yr), the 50-year committed dose 0.003 mrem (0.00003 mSv) for tritium (average 0.76 pCi/g), which is 0.00003% of the 100 mrem DOE annual dose, and 0.4% of the average CSRA individual's annual dose from naturally occurring radioactivity.

Drinking Water

Description of Monitoring Program
The Environmental Monitoring Section collects drinking water samples from 35 onsite facilities and from 16 surrounding towns. The frequency of sample collection varies depending on the use of the drinking water system. Most onsite systems are sampled either monthly or quarterly. Samples from surrounding towns are collected semiannually. The offsite public drinking water locations are shown below in Figure 7-2.

Samples are also collected and analyzed at two water treatment plants downriver from SRS that supply treated Savannah River water to consumers in Beaufort and Jasper Counties, SC, and Port Wentworth, GA. 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. This treatment plant serves 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 living in Beaufort and Jasper counties.

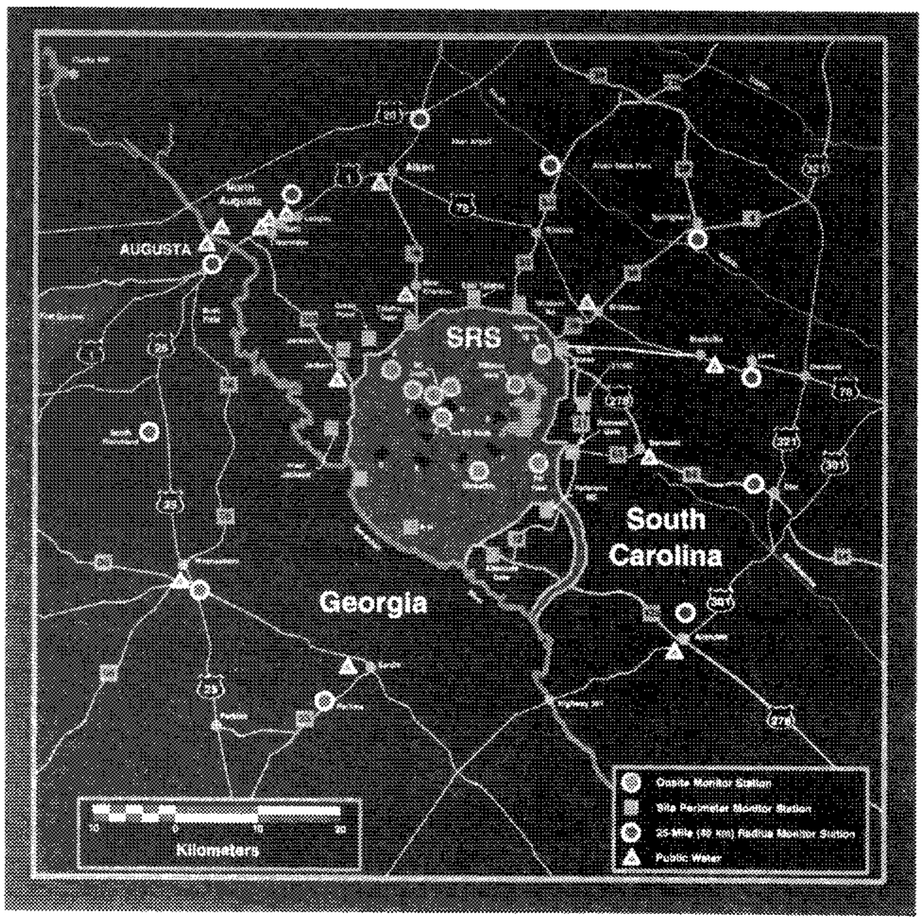


Figure 7-2. Locations for offsite public drinking water samples

Samples from a water treatment plant in North Augusta, SC are also collected for analysis. The North Augusta Water Treatment Plant is upriver from SRS and is unaffected by SRS operations. Therfore, this location provides a control for comparison of results from the other treatment plants. Raw and finished water samples from these three plants are collected daily by treatment plant personnel and composited for monthly analysis by SRS.

All drinking water samples are analyzed for concentrations of gross alpha, nonvolatile beta, and tritium each time they are collected. Strontium-90 analyses are performed annually for samples collected onsite.

Program Changes in 1989

- Two new offsite drinking water locations, in the Talatha community and at the Operations Recreational Association (ORA) Site, were added to the radiological monitoring program during 1989.

- The collection and analysis frequencies of drinking water samples from 400-D Area were changed from quarterly to monthly.

Applicable Standards

SRS drinking water systems are required to meet the water quality criteria in the South Carolina Primary Drinking Water regulations (R61-58). Included in these regulations are compliance requirements for radionuclides based on EPA drinking water standards. The drinking water standards are based on an annual whole body dose of 4 mrem from the consumption of 2 L of water per day [EPA75, EPA87], and are given as maximum contaminant levels (MCL). Although SRS is not required to meet these MCLs for radioactivity, it is the policy of SRS to comply with these standards to ensure consumption of SRS drinking water is safe. Table 7-2 (below) lists the MCLs for radionuclides analyzed in the monitoring program.

These EPA drinking water standards also apply to offsite public drinking water systems.

Monitoring Results

Radioactivity monitoring data for drinking water are presented in Table 7-3, Vol. II.

Table 7-2
EPA Maximum Contaminant Levels for Radionuclides in Drinking Water[a]

Gross alpha[b]	15 pCi/L
Nonvolatile beta[c]	50 pCi/L
Tritium	20 pCi/mL
Strontium-89	20 pCi/L
Strontium-90	8 pCi/L

[a] These limits are based on annual average concentrations that would produce a total body or organ dose equivalent of 4 mrem/yr, assuming an intake of 2 L of water per day.
[b] Including radium-226 and excluding radon and uranium.
[c] If the nonvolatile beta analysis result exceeds 8 pCi/L, a ^{90}Sr analysis must be performed.

Gross Alpha and Nonvolatile Beta

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 concentrations of naturally occurring radionuclides indicated radium concentrations over 20 pCi/L in some locations [Mi80].

Gross alpha and nonvolatile beta results for finished water samples collected from the Beaufort-Jasper and Port Wentworth water treatment plants were comparable to concentrations observed at the water treatment plant in North Augusta, SC used as a control location. These results are summarized below in Table 7-3.

Table 7-3
Average Alpha and Beta in Drinking Water from Offsite Water Treatment Plants

Location	Alpha (pCi/L)	Beta (pCi/L)
Beaufort-Jasper	0.05	2.0
Port Wentworth	0.09	2.2
North Augusta	0.04	1.6

Tritium

Small but measurable concentrations of tritium were occasionally detected in onsite drinking water samples collected in operating areas. The maximum onsite tritium concentration was 3.6 pCi/mL, which is 18% of the EPA drinking water standard of 20 pCi/mL. In 1987, SRL conducted special study to determine whether tritium was present in the Tuscaloosa aquifer. The study indicated that trace levels of tritium detected in onsite drinking water samples are introduced after sample collection (during chemical treatment or through exposure to atmospheric tritium) and do not reflect contamination in the aquifer.

The maximum tritium concentration in drinking water supplies from surrounding towns was 0.60 pCi/mL, or 3% of the EPA drinking water standard.

Increased concentrations of tritium are the only measurable SRS impact on drinking water at downriver water treatment plants. Tritium, when present in water supplies using Savannah River water, is attributed to SRS releases. The measurable tritium concentrations in surface water result from direct liquid releases to SRS streams and from the exchange of tritium from SRS atmospheric releases

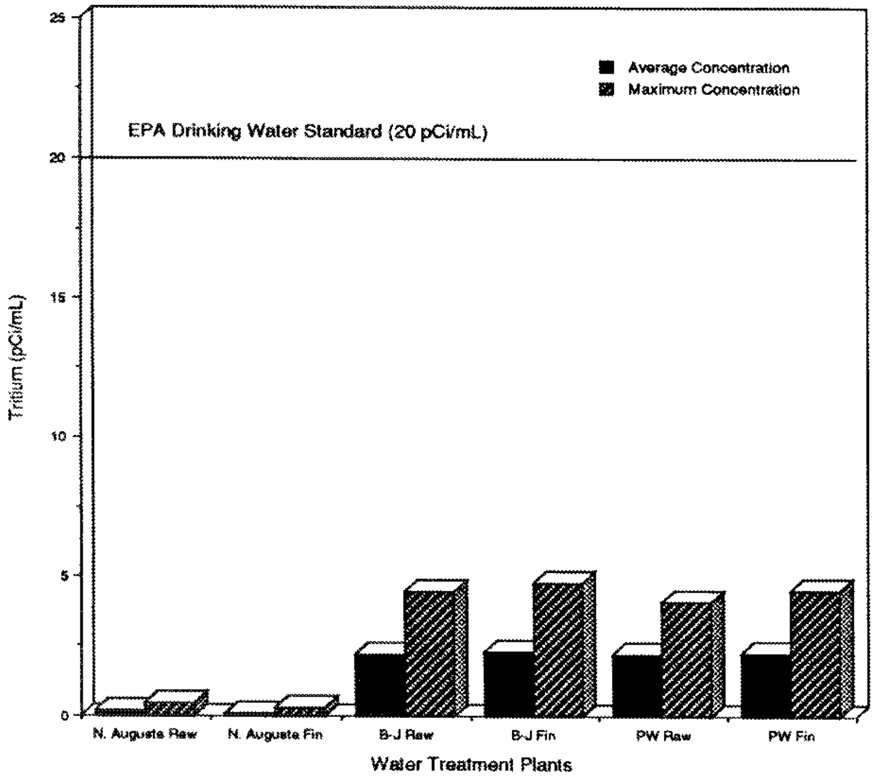


Figure 7-3. Tritium concentrations at water treatment plants

with hydrogen in rainwater and surface water. Above, Figure 7-3 summarizes and compares the maximum and average tritium concentrations in samples collected from the water treatment plants.

Strontium

Onsite drinking water samples are also analyzed for $^{89,90}Sr$. The maximum strontium concentration, 1.02 pCi/L, was measured in K Area. Since there is no drinking water standard for $^{89,90}Sr$, this concentration can only be compared to the drinking water standard for ^{89}Sr, which is 8 pCi/L and that for ^{90}Sr, which is 20 pCi/L.

NONRADIOLOGICAL MONITORING

Drinking Water

Description of Monitoring Program

The 27 separate onsite drinking water systems are operated and monitored by the SRS Power Operations Department. Most of the larger systems draw water from wells installed in the Black Creek-Middendorf formations (also known as the Tuscaloosa aquifer). The smaller systems utilize more shallow wells that draw water from the Congaree or McBean formations.

The drinking water is disinfected with chlorine to ensure that bacteriological concentrations are maintained below state and federal limits. Sodium hydroxide or soda ash is added to water in larger systems to maintain a pH within acceptable limits. Polyphosphates are also added to three systems for iron and corrosion control. The concentrations of chemicals added to the water are monitored daily at all 27 systems.

The domestic water system in D Area is supplied with treated surface water from the Savannah River. The D-Area laboratory performs turbidity and total coliform analyses daily.

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 of the water supply.

In addition, the primary supplies are analyzed for a comprehensive list of chemicals and other water quality parameters on a 12 to 16 month basis. Because comprehensive analyses were performed in November 1988, no samples were collected in 1989 for this comprehensive analysis. Samples from the 27 drinking water systems will be collected in early 1990.

Chlorocarbons are monitored monthly in drinking water at six domestic water wells and at two process water wells located in the A-Administration Area of the site. Well locations are shown in Figure 7-2, Vol. II. In 1981, groundwater in the vicinity of M Area was found to be contaminated with metal degreasing solvents. Follow-up sampling indicated that trichloroethylene and tetrachloroethylene (chlorocarbons) were present in Wells 20A and 53A in the A-Administration Area. These wells were removed from service and well 82A replaced these two wells to supply drinking water. Water from wells 20A and 53A are now restricted to process water applications. Chlorocarbons are also measured at other onsite locations on a semiannual basis.

Table 7-4
Drinking Water Standards for Nonradiological Contaminants[a,b]

Analyte	Standard
total trihalomethanes	<100 µg/L
tetrachloroethylene	<5 µg/L[c]
trichloroethlyene	<5 µg/L
1,1,1-trichloroethane	<200 µg/L
total coliform	either monthly average ≤ 1 colony/100 mL or ≤ 4 colonies/100 mL in more than one sample

[a] SCDHEC-recommended guidelines call for a minimum of 0.2 mg/L (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" [EPA75] apply. See Appendix E.
[c] EPA standard.

1989 Program Changes
In 1989, a special sampling program began as required under the Safe Drinking Water Act (SDWA) of 1986. The SDWA requires each drinking water supplier to determine the concentrations of 51 unregulated volatile organics once per quarter for four consecutive quarters. The results will be used to provide guidance for determining future drinking water regulations. In 1989, four consecutive quarters of results were obtained for samples collected in the 700-A Administration Area. Sample collection and analysis continues at other operating areas onsite and will be completed in 1990.

Applicable Standards
SCDHEC implements drinking water standards for South Carolina that are at least as stringent as the federal standards. Many of these regulations apply only to community drinking water systems, and SRS is a noncommunity drinking water system. However, SRS uses SCDHEC maximum contaminant levels (MCL) and recommended guidelines to ensure safe drinking water at SRS. Standards used at SRS are summarized in Table 7-4 (above).

Monitoring Results
Monitoring data show that residual chlorine concentrations were above the minimum level of 0.2 mg/L in 1989. Elevated total coliform counts were detected in a few domestic water samples collected in 1989. Because sufficient concentrations of chlorine were present to kill the coliform bacteria, the eleveated results are attributed to sampling or procedure error. Analytical results are presented in Table 7-4, Vol. II.

No confirmed positive concentrations of tetrachloroethylene, trichloroethylene, or 1,1,1-trichloroethane were detected in monthly analyses of drinking water from the domestic water wells in A/M Areas during 1989.

Process water wells 20A and 53A continued to show elevated chlorocarbon concentrations. In 1989, the maximum concentration in these process wells was 317 µg/L trichloroethylene, measured in well 20A.

For samples collected semiannually, four samples contained detectable quantities of 1,1,1-trichloroethane. The maximum concentration of 5.87 µg/L measured at the River 1G pump station is below the EPA drinking water standard of 200 µg/L. Monitoring results for chlorocarbons in SRS drinking water are presented in Tables 7-5, and 7-6, Vol. II.

Table 7-7, Vol. II summarizes the maximum concentrations of volatile organics measured in SRS drinking water for samples collected and analyzed during 1989 as part of the special sampling program required by the SDWA.

1989 HIGHLIGHTS

- Concentrations of ^{137}Cs in milk ranged from less than the LLD to 5.1 pCi/L, with the average concentration of 1.6 pCi/L being similar to data from previous years.
- Iodine-131 was not detected in any of the milk samples collected in 1989.
- The tritium concentrations in milk that are attributed to SRS releases correspond to a 50-year committed dose from drinking 0.5 L of milk per day for a year of 0.01 mrem (0.0001 mSv), which is 0.01% of the DOE Revised Interim Radiation Dose Limit of 100 mrem for annual exposure.
- Two new offsite drinking water locations, in the Talatha community and at the Operations Recreational Association (ORA) Site, were added to the radiological monitoring program during 1989.
- 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.
- In 1989, a special sampling program, required under the Safe Drinking Water Act of 1986, began at SRS. The program requires drinking water suppliers to determine concentrations of 51 unregulated volatile organics each quarter for four consecutive quarters.

8 Wildlife Monitoring Program

SUMMARY—This chapter describes the radiological and nonradiological monitoring program for measuring the effects of SRS operations on the wildlife population. Concentrations of ^{137}Cs, gross alpha, and nonvolatile beta activity were measured in fish caught in the Savannah River, in onsite streams and ponds, Thurmond Lake (control lake), and in seafood caught near the mouth of the Savannah River. The 50-year committed dose from eating fish caught downriver from SRS for a year, having a maximum ^{137}Cs concentration of 1.2 pCi/g, would be 0.7 mrem (0.007 mSv), 0.7% of the DOE Revised Interim Radiation Dose Limit for an annual exposure of 100 mrem. Cesium-137 was not detected in either crabs or oysters.

Over 700 deer and 170 hogs were analyzed for ^{137}Cs during the annual hunts at SRS, and samples of bone, thyroids, and muscle were removed from 5 to 10% of the deer and analyzed for ^{90}Sr, and ^{137}Cs. In deer muscle, the maximum concentration of ^{137}Cs was 25 pCi/g, which would give a 50-year committed dose of 0.28 mrem (0.0028 mSv) to an individual who consumed one 8 oz. steak of deer meat. This dose is 0.28% of the DOE annual dose limit. In addition, monitoring results are reported for furbearers, turkeys, and turtles trapped onsite.

In the nonradiological monitoring program, over 250 fish from onsite streams and ponds, the Savannah River, and Thurmond Lake, were collected and analyzed for mercury, and the results are reported. Finally, the muscle and liver of 97 deer were analyzed for cadmium, chromium, lead, and mercury. Low concentration of metals were detected in a few deer although most were below minimum detectable levels.

INTRODUCTION

The protected boundary of the Savannah River Site (SRS) provides refuge for an abundance of wildlife. One objective of the site's environmental monitoring program is to collect and analyze a thorough representation of wildlife on and in the vicinity of the site and to determine the effects of SRS operations on the wildlife population.

RADIOLOGICAL MONITORING PROGRAM

The DOE has established a Revised Interim Radiation Dose Limit for individual members of the public. The limit is 100 mrem committed effective dose equivalent (committed dose) per year. The limit applies to all individual members of the public, and includes doses a person receives as a consequence of routine DOE operations, through all exposure pathways. Pathways that relate to wildlife monitoring include the consumption of fish and seafood, primarily from the Savannah River, and consumption of deer and hogs obtained on SRS property.

Fish and Seafood

Description of Monitoring Program

Savannah River fish are trapped upriver from, adjacent to, and downriver from SRS throughout the year. Additional fish are caught in the mouth of the Savannah River (river miles 0-8) and in site streams and ponds. Fish caught from Thurmond Lake are used as control samples because of the lake's location upriver from SRS. Fish samples are analyzed for gross alpha, nonvolatile beta, and gamma-emitting radionuclides.

Seafoods (crabs and oysters) are collected annually from the mouth of the Savannah River near Savannah, GA, and analyzed for gross alpha, nonvolatile beta, and gamma-emitting radionuclides. The flesh of the crabs was composited into one sample; oyster meat was also composited into four 500-mL samples.

Fish sampling locations on the Savannah River are shown in Figure 8-1, Vol. II.

Monitoring Results

Table 8-1 (below) summarizes the maximum concentrations of ^{137}Cs, gross alpha, and nonvolatile beta activity measured in fish caught in the Savannah River, in onsite streams and ponds, and in Thurmond Lake, and in seafood caught near the mouth of the Savannah River.

Figure 8-1 (facing page) compares concentrations of gross alpha and nonvolatile beta over a four-year period in SRS streams and the Savannah River.

Monitoring data for fish caught in the Savannah River, in SRS streams and ponds, and from Thurmond Lake, the control location, are presented in Table 8-1, Vol. II. Comparisons of ^{137}Cs data to data results from previous years are presented in Table 8-2, Vol. II.

In the following monitoring results discussion, uncertainty values are provided because most mesurements are at or near the lower limits of detection.

Savannah River

A total of 22 river fish from three locations were analyzed for gross alpha and nonvolatile beta to screen for radioactivity. Five fish contained measurable concentrations of gross alpha, and all fish contained measurable concentrations of nonvolatile beta. These concentrations were within ranges seen in previous years.

Gross alpha concentrations ranged from -0.47 ± 0.72 pCi/g to 0.82 ± 0.66 pCi/g. This maximum concentration of gross alpha was detected in a catfish caught upriver from the site. Nonvolatile beta concentrations ranged from 0.42 ± 1.2 pCi/g to 7.1 ± 2.1 pCi/g. The maximum concentration of nonvolatile beta was detected in a bream caught upriver from the site. In fish from Thurmond Lake, the maximum concentrations of gross alpha (0.12 ± 0.34 pCi/g) and nonvolatile beta (3.6 ± 2.0 pCi/g) were detected in a bass.

Gross alpha was not detected in the composited sample of crabmeat. The maximum concentration of gross alpha in the oyster composites was 0.91 ± 0.73 pCi/g. Both the crab and oyster composites contained measurable concentrations of nonvolatile beta. The nonvolatile beta concentration in the crab composite was 1.5 ± 1.4 pCi/g. The maximum nonvolatile beta concentration in the oysters was 0.9 ± 1.3 pCi/g.

Table 8-1
Radioactivity in Fish and Seafood Caught On and Near SRS

	Maximum Concentration (pCi/g)[a]		
Location	**Alpha**	**Beta**	**Cesium-137**
Savannah River fish[b]	0.82 (22)	7.1 (22)	1.2[c] (225)
Crab and oysters	0.91 (5)	1.5 (5)	<LLD (5)
SRS fish (streams, ponds, swamps)	1.4 (138)	408 (138)	255[d] (388)
Thurmond Lake	0.12 (6)	3.6 (6)	2.9 (12)

[a] The numbers in parentheses indicate the number of samples analyzed.
[b] Caught in the Savannah River upriver from, adjacent to, and downriver from SRS.
[c] The maximum was detected in a catfish in the Savannah River downriver from SRS at the River-10 sampling location.
[d] The maximum was detected in a bass from Pond B. Pond B is isolated from public access.

In 1989, a total of 225 individual fish from the Savannah River and Thurmond Lake were analyzed for gamma-emitting radionuclides (see Figure 8-2 page 172) for fish sample locations on the Savannah River). Cesium-137 was the only man-made gamma-emitting radionuclide detected. Fifty-one of the 225 fish analyzed contained measurable levels of ^{137}Cs; however, concentrations of ^{137}Cs were less than 1 pCi/g in all but four fish. Two of those

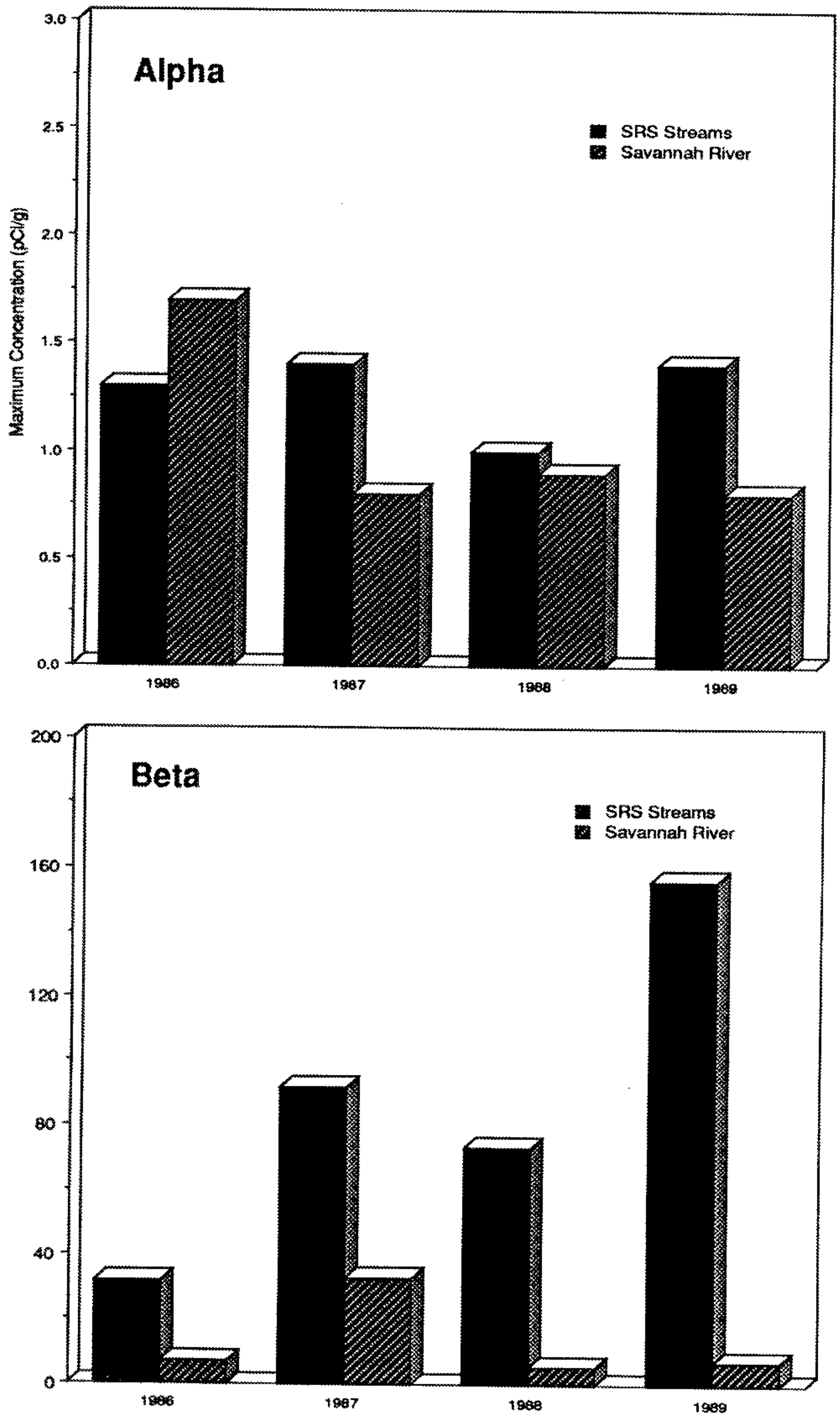


Figure 8-1. Alpha and beta concentrations in fish caught from SRS streams and the Savannah River over a four-year period

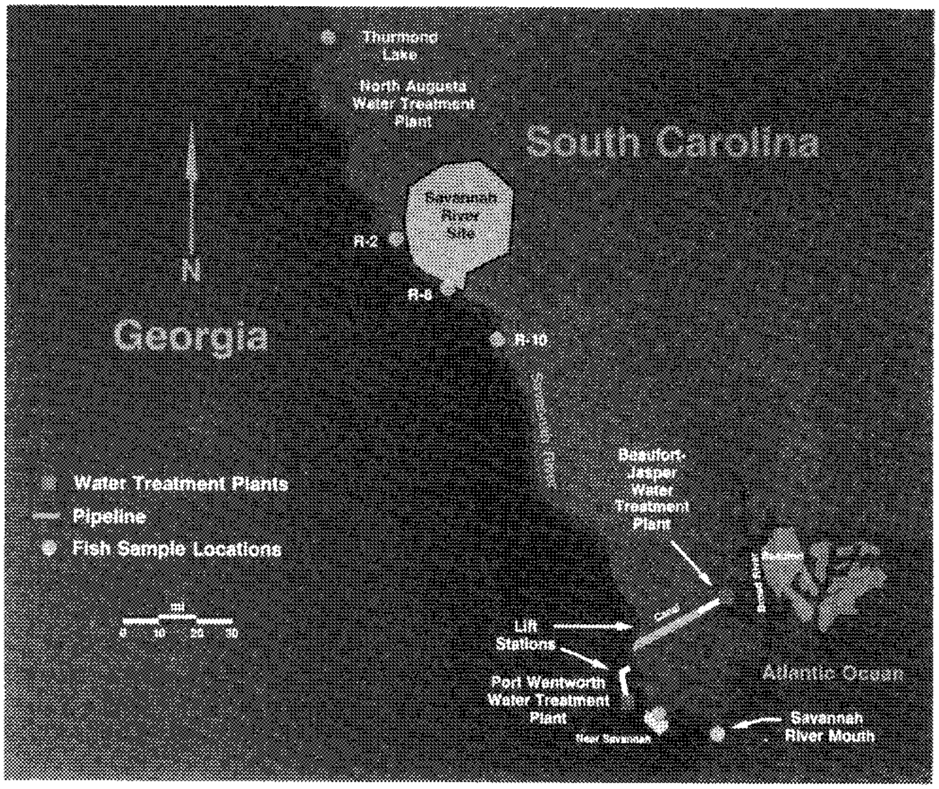


Figure 8-2. Fish sample locations along the Savannah River

fish were caught in Thurmond Lake. The maximum concentration of ^{137}Cs measured in fish downriver from SRS was 1.2 ± 0.43 pCi/g in a catfish caught at River-10. Average ^{137}Cs concentrations in fish caught upriver, adjacent to, and downriver from SRS from 1981 through 1989 are compared in Figure 8-3.

Crabs and oysters caught at the mouth of the Savannah River were analyzed for gamma-emitting radionuclides. Cesium-137 was not detected in either the crab or in the oyster composites.

Onsite Surface Waters

Gross alpha and nonvolatile beta analyses were performed on 138 fish caught in SRS streams and ponds. Gross alpha concentrations ranged from -0.44 ± 0.63 pCi/g to a maximum of 1.4 ± 1.7 pCi/g. The maximum gross alpha concentration was detected in a bream from Upper Three Runs Creek. Nonvolatile beta concentrations ranged from -0.16 ± 1.0 pCi/g to 410 ± 42 pCi/g, with the maximum detected in a bass from Pond B.

Cesium-137 was the only man-made gamma-emitting radionuclide detected in the fish caught on SRS. The maximum ^{137}Cs concentration in a fish from an SRS stream was 11 ± 1.0 pCi/g, measured in a bream from Four Mile Creek.

The highest ^{137}Cs concentration in fish caught in SRS ponds was 255 ± 13 pCi/g, detected in a bass from Pond B. The average ^{137}Cs concentration in fish from Pond B was 86 pCi/g. Fish from Pond B contain higher concentrations of ^{137}Cs than fish from other onsite locations because it is part of the effluent release pathway from R Area to Par Pond. R-Reactor effluents were discharged through this canal from the late 1950s until R-Reactor operation was permanently discontinued in 1964. During that time, R Area released approximately 170 Ci of ^{137}Cs.

The maximum ^{137}Cs concentration in Par Pond fish was slightly lower than the 1988 maximum concentration of 11 ± 0.3 pCi/g. In 1989, the maximum ^{137}Cs concentration was 9.2 ± 0.5 pCi/g, measured in a crappie. Currently, Par Pond receives reactor heat exchanger cooling water from P Area. However, current releases of radioactivity from this source consist only of small amounts of tritium. No measurable ^{137}Cs is released through 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.

Concentrations of ^{137}Cs in fish generally decreased from site streams and ponds between 1971 and 1979. Since 1979, concentrations of ^{137}Cs in fish from site streams and ponds have remained fairly constant.

Perspective

Although consumption of fish is not a primary source of radiation dose to the public downriver from SRS (1% in 1989), doses are routinely calculated for consumption of fish containing ^{137}Cs. The 50-year committed dose from eating fish caught downriver from SRS for a year with an average consumption of 11.3 kg/year having a ^{137}Cs concentration of 1.2 pCi/g would be 0.7 mrem (0.007 mSv). This dose is 0.7% of the DOE dose limit of 100 mrem per year. This dose is also a small percentage (0.24%) of the average Central Savannah River Area (CSRA) individual's annual dose from naturally occurring radioactivity (295 mrem).

A higher committed dose would result from eating fish caught in SRS streams and ponds than would result from eating river fish. However, access to SRS streams and ponds is restricted; therefore, using fish for food is not allowed. If a person were to illegally consume fish caught within SRS boundaries which contained 255 pCi/g of ^{137}Cs (maximum at Pond B) at an average consumption of 11.3 kg/year, that person would receive a committed dose of 144 mrem, which is above the DOE annual dose limit, and 49% of the average Central Savannah River Area (CSRA) individual's annual dose from naturally occurring radioactivity.

Deer and Hogs

Description of Monitoring Program

Annual hunts are conducted at SRS to control the site's deer and hog populations and to reduce animal-vehicle accidents. The Environmental Monitoring Section (EMS) performs field analysis for ^{137}Cs on the deer and hogs at the hunt site using a portable 2 × 2 in. sodium iodide [NaI(Tl)] 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 bone, thyroid, and muscle are removed from 5 to 10% of the animals and analyzed for ^{90}Sr and ^{137}Cs. The 1989 hunts yielded 712 deer and 178 hogs, compared to 855 deer and 146 hogs in 1988.

During the SRS annual hunts in 1988, 52 of the 855 deer were sampled for ^{90}Sr and tritium analyses. Tritium analyses were performed on deer muscle and ^{90}Sr analyses were performed on deer bone and muscle. Because these results were not available for the *Savannah River Site Environmental Report for 1988*, they are included in this report.

In addition to the controlled hunts, EMS collects deer samples each year from an 18,000-acre controlled hunting camp located on the South Carolina Coastal Plain (SCCP) about 65 miles east of SRS in Beaufort county. Deer samples from this location are consid-

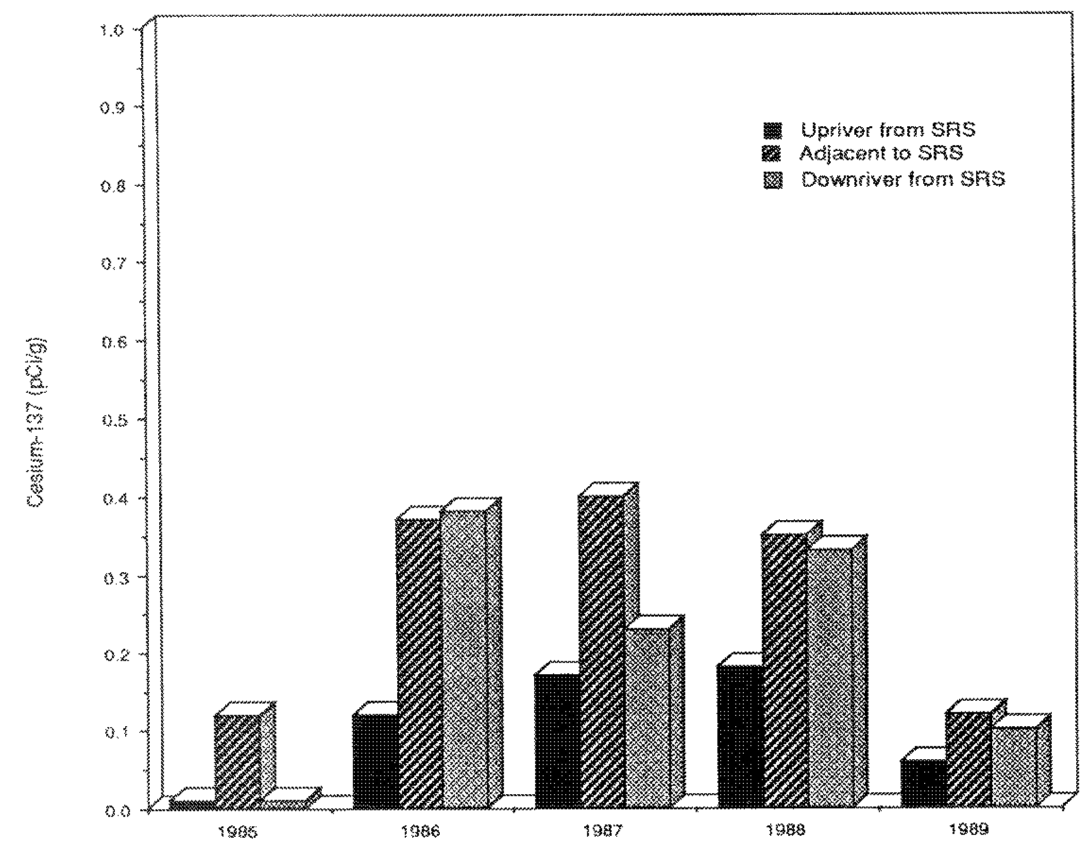


Figure 8-3. Comparison of ^{137}Cs in fish upriver, adjacent to, and downriver from SRS

ered as control samples, not influenced by SRS operations, and analyzed for gamma-emitting radionuclides. During 1989, EMS collected 22 deer from the controlled camp on the SCCP.

In 1989, EMS initiated a special survey to study the ^{137}Cs levels in deer collected onsite and in deer collected in the southeastern United States. The study is focusing on the following objectives:

- to gain a greater perspective on the contributions of site operations versus the contributions of worldwide fallout, to levels of ^{137}Cs in deer

- to investigate the typical consumption, by onsite hunters and the public, of SRS deer (considering that more than one deer can be consumed by an individual in one year)

These studies were not complete at the end of 1989. Therefore, the results are not included in this report, but will be published when the study is complete.

Deer Hunts at SRS

For six weeks of each year, annual controlled deer hunts are conducted over the 300-square-mile Savannah River Site. These hunts help control the deer population and reduce animal-vehicle accidents.

The hunts are normally conducted on Wednesday and Saturday of each week beginning in November and lasting until mid-December. Members of the public who wish to participate in the hunts submit applications to the WSRC Security Department Deer Hunt Office. A random drawing determines the hunt participants. Each hunt may consist of 100 to 300 hunters, depending upon the size of the hunting area.

The SRS is divided into 50 hunting areas called compartments. Figure 8-1 in Vol. II shows the general area of each compartment. Different compartments are hunted each day. A typical hunt day begins at 4 a.m. and lasts until about 8 p.m. Before a hunter is allowed to leave the meeting point, he must receive an identification badge and a safety orientation. The hunters are transported to a hunting compartment and positioned at a specific location (still hunting), where they hunt until noon.

The hunters are then taken to a second compartment to hunt for the remainder of the day (around 5 p.m.). Environmental Monitoring personnel measure the ^{137}Cs levels in the deer with a portable detector, then distribute the deer to the hunters.

In 1989, a total of 712 deer were killed in the annual deer hunts.

Monitoring Results

Table 8-2 presents maximum concentrations of ^{137}Cs and ^{90}Sr found in deer and hogs taken in hunts on the SRS in 1989. Laboratory and field measurements of ^{137}Cs in deer are presented in Table 8-3, Vol. II. Comparisons of ^{137}Cs in deer from SRS and SCCP are given in Table 8-4, Vol. II. Tables 8-5 and 8-6 in Volume II summarize tritium and ^{90}Sr measurements in deer sampled during the 1988. The 1989 measurements of ^{90}Sr in deer bone and muscle are presented in Table 8-7, Vol. II. In the following monitoring results discussion, uncertainty values are provided because most mesurements are at or near the lower limits of detection.

Gamma-Emitting Radionuclides

In deer, the 1989 maximum ^{137}Cs field measurement in muscle tissue was 25 pCi/g, with an average concentration of 7.3 pCi/g. Measurements in hogs were somewhat lower with a maximum ^{137}Cs concentration of 14 pCi/g and an average of 2.7 pCi/g. The 1988 maximum and average ^{137}Cs concentrations in deer were 60 pCi/g and 10.2 pCi/g, respectively. In hogs, the 1988 maximum and average field measurements were 16 pCi/g and 6.1 pCi/g, respectively.

From the 22 deer collected at the SCCP, the average laboratory measurement of ^{137}Cs was 6.8 ± 7.0 pCi/g, while the deer collected on SRS had an average field measurement of 7.3 ± 8.5 pCi/g. The maximum concentration of 25 pCi/g measured in the deer from SRS was higher than the 11 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 contributed by SRS operations, or it may reflect differences in the diets of the deer. A compari-

Table 8-2
Radioactivity in Deer and Hogs on SRS[a]

	Maximum Concentration (pCi/g) ^{137}Cs	^{129}I[b]	^{90}Sr[c]
Deer	30[d] (96)	2,100[e] (40)	12 (12)
	25[f] (712)		
Hogs	14[g] (178)	-	-

[a] Number in parentheses indicate number of species analyzed.
[b] Thyroid.
[c] Bone.
[d] Laboratory analysis.
[e] Measured in a deer collected from C Area.
[f] Field measurement – Consumption of the meat of this deer would lead to a 50-year committed dose of 30 mrem (0.3 mSv) from ^{137}Cs.
[g] Field measurement.
– No analysis.

son of ^{137}Cs concentrations in SRS and SCCP deer since 1968 has shown year-to-year variations in both maximum and average concentrations, as shown in Table 8-4, Vol. II. These comparisons indicate that much of the ^{137}Cs concentration in deer can be attributed to worldwide fallout.

Muscle samples were collected from 96 deer and analyzed in the laboratory 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. Table 8-3, Vol. II compares field and laboratory ^{137}Cs measurements in deer. Laboratory measurements showed ^{137}Cs in the muscle samples from 1.6 ± 0.2 pCi/g to 29.5 ± 1.3 pCi/g. The 1989 maximum concentration was lower than the 1988 maximum concentration of 64.0 ± 1.0 pCi/g. The 1989 average concentration of ^{137}Cs in deer, as measured in the laboratory, was 8.9 pCi/g compared to 9.8 pCi/g in 1988. Figure 8-4 (below) compares concentrations of ^{137}Cs in deer from 1981 to 1989.

Tritium
Tritium analyses of muscle from deer sampled in 1988 indicated small concentrations of tritium ranging from less than 1 pCi/g to 9.1 pCi/g. Tritium concentrations in deer sampled during 1988 are presented in Table 8-5, Vol. II.

Strontium
As expected, concentrations of ^{90}Sr were higher in the bone of the deer than in the muscle. Higher concentrations in bone occur because ^{90}Sr is chemically similar to calcium; therefore, like calcium, ^{90}Sr concentrates in the bone. For bone samples analyzed in 1989, ^{90}Sr ranged from 3.0 ± 1.73 to 12 ± 2.62 pCi/g. In 1988, concentrations ranged from 2.4 to 38 pCi/g. These data are presented in Table 8-6 and Table 8-7, Vol. II. Strontium-90 was not detected in muscle samples from deer collected in 1988. In 1989, the maximum concentration in muscle was 0.79 ± 0.85 pCi/g.

Comparative Analyses by University of Tennessee
Muscle and thyroid samples were collected from SRS deer and sent to the Department of Physiology and

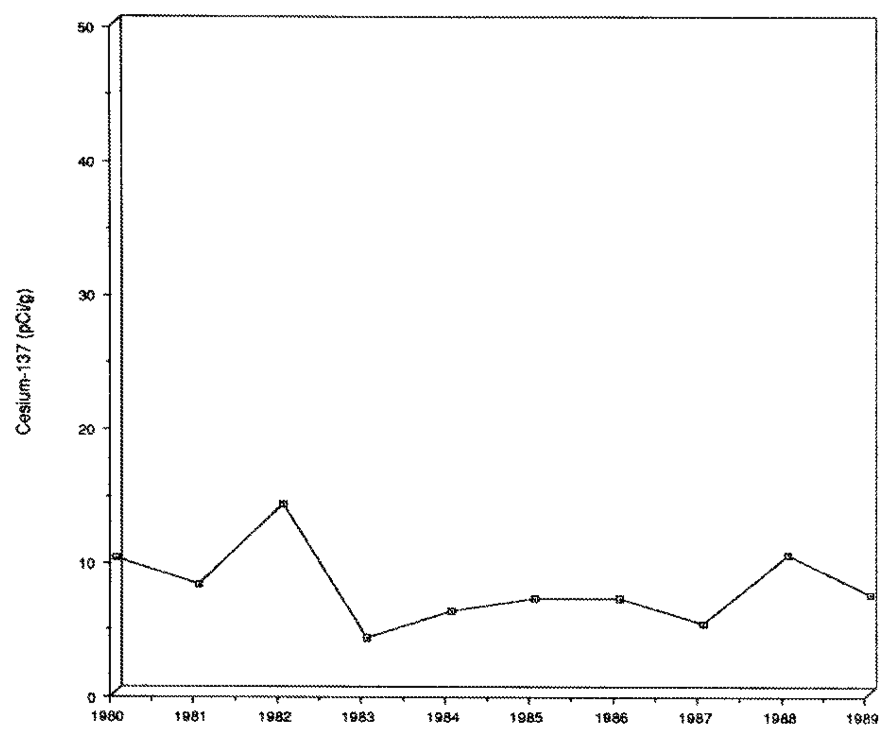


Figure 8-4. Average ^{137}Cs in SRS deer

Biophysics, University of Tennessee, Memphis, for analysis. The muscle samples were analyzed for ^{137}Cs, and the thyroids were analyzed for both ^{129}I and ^{137}Cs. The EMS did not analyze the thyroids of the deer for ^{129}I. The University of Tennessee reported concentrations of ^{137}Cs in the muscle samples from less than 1 pCi/g to 20.3 pCi/g. The analyses for ^{137}Cs in muscle were consistent with EMS measurements.

Iodine-129 concentrations in the thyroids ranged from 0.27 pCi/g to 2,145 pCi/g. The maximum ^{129}I concentration was measured in a male deer collected from C Area. Concentrations of ^{137}Cs in the thyroids ranged from 0.1 to 21 pCi/g. These data are presented in Table 8-8, Vol. II.

Perspective

It is important to measure ^{137}Cs in deer due to the prevalence of cesium from worldwide fallout and SRS operations. Since cesium can be deposited in deer tissue, enough of the radionuclide can be consumed by people to result in a significant radiation dose.

The committed dose to an individual who consumed one 8 oz steak of deer meat with 25 pCi/g of ^{137}Cs would be 0.28 mrem (0.0008 mSv). This dose is 0.08% of the 100 mrem DOE annual dose limit. It should be noted that the dose received from consuming food with concentrations of radionuclides 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 25 pCi/g ^{137}Cs every day for one year, he would receive a committed dose of 104 mrem (0.3 mSv). This dose is above the DOE annual dose limit and 35% of the average CSRA resident's average annual dose from naturally occurring radioactivity.

The deer with the highest ^{137}Cs concentration, 25 pCi/g, had edible meat which weighed approximately 70 kg. An adult consuming all of this meat would receive a committed dose of 88 mrem (0.88 mSv), or 88% of the DOE annual dose limit.

Consuming one 8 oz deer steak every day for a year, from the deer having the highest concentration of tritium (5.7 pCi/g), would result in a committed dose of 0.03 mrem (0.0003 mSv). This dose is 0.03% of the 100 mrem DOE dose limit for annual exposure.

Furbearers

Description of Monitoring Program

SRS is closed to outside hunters except for the controlled hunts of deer and hogs. Therefore, furbearers on SRS are not a likely food source for the surrounding population. Furbearing animals such as foxes, raccoons, opossums, and rabbits are trapped and analyzed for gamma-emitting radionuclides in the laboratory.

The U.S. Forest Service administers a contract for trapping beavers in selected areas within the SRS perimeter. The purpose of trapping is to reduce the beaver population in specific areas of SRS and thereby minimize 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 1989, no beavers were trapped.

Monitoring Results

EMS trapped 29 furbearers along 10 transects across SRS and in the Savannah River swamp near Creek Plantation during 1989. Fourteen animals analyzed for gamma-emitting radionuclides indicated low levels of ^{137}Cs. The maximum concentration of ^{137}Cs was 16 pCi/g in a raccoon trapped near Pond B. Monitoring results for furbearers are shown in Table 8-9, Vol. II.

Turtles

Description of Monitoring Program

The Savannah River Ecology Laboratory (SREL) traps turtles both onsite and offsite as part of an ongoing study to learn about the animal's migratory behavior. Trapped turtles are surveyed for radioactivity with a G-M detector (Thyac), aged, and sexed.

Turtles collected from sites where no turtles had been collected previously, and those turtles having field radiation measurements above levels previously detected in turtles from the same locations are submitted for laboratory analysis. No on- or offsite turtles were submitted for laboratory analysis in 1989.

Monitoring Results

A total of 476 turtles, mainly pondsliders and eastern mud turtles, were trapped in 1989. Eighteen of the turtles trapped onsite had radioactivity levels above the background reading of 150 counts/min. All of these 18 turtles were pondsliders captured onsite at the H-Area seepage basins.

Radioactivity was not detected in any of the turtles trapped offsite. The SREL trapped turtles offsite in locations adjacent to Lower Three Runs Creek.

Ducks

The SREL and EMS trap ducks at Par Pond and Pond B. The trapped ducks are counted whole for gamma-emitting radionuclides. Because of low water levels in Par Pond and Pond B, no ducks were trapped at SRS during 1989.

Turkeys

Wild turkeys are trapped onsite and used to repopulate South Carolina game areas. All turkeys are monitored with a portable NaI(Tl) detector before leaving SRS. The EMS monitored 30 turkeys in 1989. Monitoring results ranged from 2 to 10 pCi/g.

NONRADIOLOGICAL MONITORING PROGRAM

Fish

Description of Monitoring Program

The EMS analyzes the flesh of fish caught from onsite streams and ponds, the Savannah River, and Thurmond Lake to determine concentrations of mercury in the fish. The fish analyzed represent the most common edible species of fish for the Central Savannah River Area. Fish collected from Thurmond Lake are used as controls.

Mercury has been detected in fish from the river and streams since the analyses began in 1971. These analyses are performed to assess the uptake of mercury that is assumed to come principally from industrial releases upriver from SRS. Much of the mercury detected in onsite fish reflects mercury previously present in Savannah River water, which is used as cooling water in site facilities and subsequently pumped into SRS streams and lakes.

Applicable Standards

Other than occupational exposure, the greatest source of mercury intake in people is consumption of food, particularly fish. The Food and Drug Administration (FDA) has established a guideline of 0.5 µg Hg/g, which is a recommended maximum concentration of mercury in fish for consumption by humans. Because SRS streams are not open for public fishing, SRS uses the FDA level as a guide to gauge concentrations of mercury in onsite streams.

Monitoring Results

In 1989, a total of 254 fish from SRS streams, ponds, the Savannah River, and offsite lakes were collected and analyzed for mercury. Mercury in fish monitoring data are presented in Table 8-10, Vol. II.

Savannah River

Several individual fish contained concentrations of mercury above the FDA guide. However, the average concentration of mercury in fish from the Savannah River was 0.24 µg Hg/g downriver from SRS and 0.44 µg Hg/g upriver from SRS. These concentrations are higher than the average mercury concentration (0.17 µg Hg/g) measured in fish from Thurmond Lake, the control location. The average offsite mercury concentrations at all locations were below the 0.5 µg Hg/g FDA guideline.

Onsite Surface Waters

Mercury was also detected in fish from onsite surface waters above the 0.5 µg Hg/g guide. The mercury concentrations in fish analyzed from onsite surface waters ranged from 0.05 µg Hg/g to 2.4 µg Hg/g. The maxi-

Fish are collected from SRS streams and analyzed for mercury

mum concentration was measured in a bass from Four Mile Creek. The average mercury concentration in fish from onsite surface waters was 0.51 μg Hg/g. The highest average mercury concentration from a specific location was 0.78 μg Hg/g from Steel Creek.

Deer

In 1988, special samples from 97 deer were collected to determine the concentrations of heavy metals in deer muscle and liver. This was the first year that measurements of this type were made. These samples were analyzed for cadmium, chromium, lead, and mercury.

Although most analyses were below minimum detectable levels, low concentrations of metals were detected in a few deer. No conclusions were made following these analyses because of the limited amount of data. Table 8-11, Vol. II presents the analytical results for these analyses.

1989 HIGHLIGHTS

- Five of 22 river fish that were analyzed contained measurable quantities of gross alpha, and all fish contained measurable quantities of nonvolatile beta, but the concentrations were within ranges seen in previous years.
- The highest ^{137}Cs concentration in fish from SRS ponds was found in a fish from Pond B at 255 pCi/g. The average ^{137}Cs concentration in Pond B fish was 86 pCi/g. Pond B is part of the effluent release pathway from R Area to Par Pond, and contains fish with higher concentrations than other onsite locations.
- The maximum concentration of 25 pCi/g ^{137}Cs measured in a deer from SRS was higher than the 11 pCi/g maximum detected in deer from the SCCP control group. The higher SRS value reflects either some uptake of ^{137}Cs from SRS operations, or differences in diets of the deer.
- Eighteen of 476 turtles trapped in 1989 had onsite measured radioactivity levels above the background reading. All eighteen turtles were captured at the H-Area seepage basins.
- The average mercury concentrations measured in fish offsite was 0.33 μg Hg/g, and onsite was 0.51 μg Hg/g, compared to the FDA guideline of 0.5 μg Hg/g.

9
Monitoring of Rainwater, Soil, Vegetation, and Sediment

SUMMARY—This chapter describes the sampling protocols and results of the radiological monitoring of rainwater, soil, vegetation, and Savannah River and stream sediments. SRS maintains a network of rainwater sampling stations at the H-Area onsite station, the Darkhorse and Barnwell gate site perimeter stations, a 25-mile-radius station, and four 100-mile-radius stations. Rainwater samples, which are passed through an ion column to concentrate the radionuclides, are analyzed for gross alpha, nonvolatile beta, gamma-emitting radionuclides, ^{238}Pu, and ^{239}Pu. Rainwater that passes through the column and collects in a sample bottle is analyzed for tritium. The maximum and average concentrations of these radionuclides were essentially the same at each of these locations during 1989.

Both soil and sediment samples, collected annually on and around SRS, are analyzed for gamma-emitting radionuclides, ^{90}Sr, and ^{238}Pu, and ^{239}Pu. Plutonium concentrations in soil samples around the separations areas were somewhat greater in 1989 than those detected at the site perimeter, reflecting F- and H-Area releases. In Savannah River sediment samples, concentrations of radioactivity were within ranges detected from worldwide fallout, while stream sediment results reflect contributions of radioactivity from SRS liquid releases. In 1989, higher concentrations of radionuclides were measured in sediment samples from Beaver Pond than any other location, and results for the past three years are compared.

For vegetation monitoring, samples were collected at onsite, site perimeter, 25-mile-radius, and 100-mile-radius locations, as well as at seepage and retention basins located near the reactor and separations areas, and inside the Radioactive Waste Burial Ground (RWBG). Gross alpha and nonvolatile beta concentrations in onsite vegetation were similar to those at 25 and 100 miles, except for the H-Area seepage basin, and locations within the RWBG.

INTRODUCTION

Monitoring rainwater, soil, vegetation, and sediment for radioactivity is an essential element of the SRS environmental monitoring program. Collection and analysis of these environmental samples are crucial in quantifying the deposition of radioactive materials from routine and nonroutine atmospheric and surface water releases from SRS, as well as from 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.

RADIOLOGICAL MONITORING PROGRAM

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.

After incidents such as the Chernobyl incident or other releases of 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 a reltively small number of 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 necessary for representative monitoring.

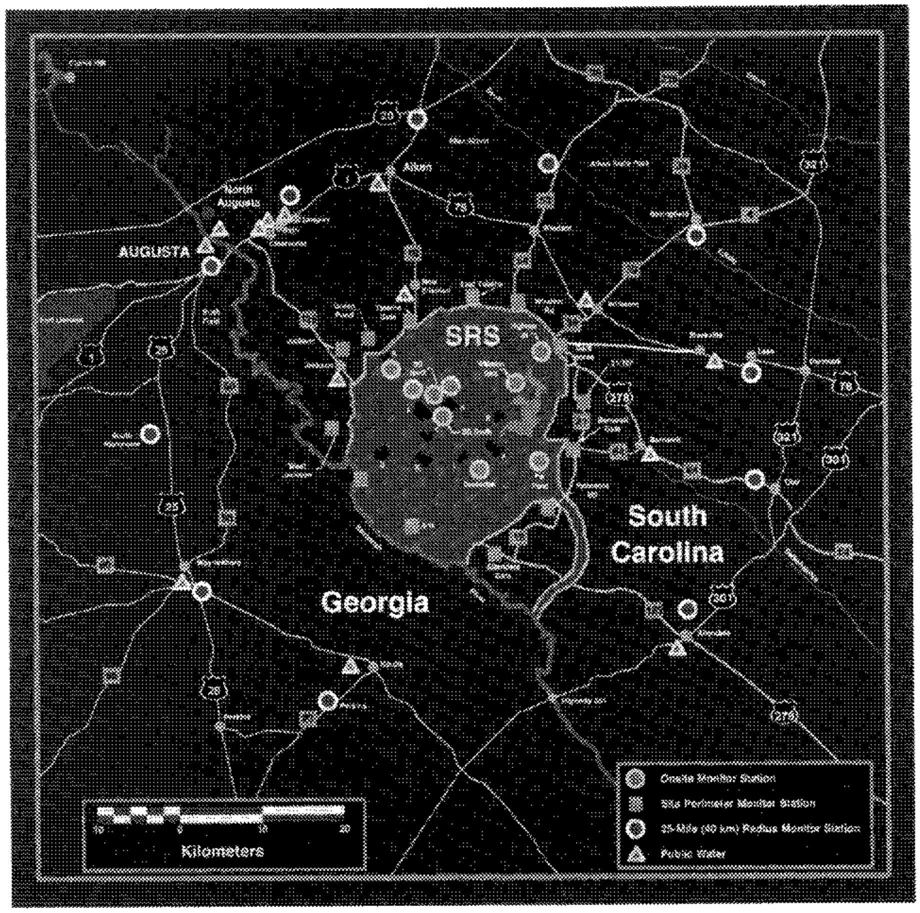


Figure 9-1. Rainwater collection pans are located on top of selected air monitoring stations on- and offsite

SRS maintains a network of rainwater sampling stations as a part of the monitoring program for worldwide fallout and emissions from the site. Samples are collected monthly from the H-Area onsite station, the Darkhorse and Barnwell gate site perimeter stations, and at the Olar, South Carolina 25-mile-radius station (see Figure 9-1, above). Quarterly samples are also collected from the four 100-mile-radius stations (at Columbia and Greenville, SC; and Macon and Savannah, GA). These samples are analyzed for gross alpha, nonvolatile beta, tritium, gamma-emitting radionuclides, ^{89,90}Sr, ^{238}Pu, and ^{239}Pu.

Additional rainwater samples from eight other locations are collected and retained until analyses from the primary locations are completed and reviewed.

Monitoring Results

Rainwater depositions for 100-mile-radius locations are difficult to compare with the other locations monitored because of differences in sampling frequency. Samples at the 100-mile-radius locations are collected quarterly, whereas samples are collected monthly from onsite, site perimeter, and 25-mile-radius locations.

The method for collecting rainwater involves passing the water through an ion column, concentrating the radionuclides. After the water has passed through the ion column, it collects in a bottle beneath the column so that concentrations of tritium can be determined. The ion columns and the water in the bottle are then collected and analyzed to determine the concentration of radionuclides (see Chapter 1 for analytical method).

More activity will collect on the ion column and be measured in the sample the longer the ion column remains at the monitoring station. levels of radioactivity are higher at the 100-mile-radius locations compared to the onsite, site perimeter, and 25-mile radius locations because of the longer collection time. Table 9-1, Vol. II presents deposition of radioactivity in rainwater results for 1989.

Gross Alpha and Nonvolatile Beta
In 1989, maximum gross alpha depositions onsite, at the site perimeter, and at 25-mile-radius stations ranged from 17 pCi/m^2 to 48 pCi/m^2. The maximum nonvolatile beta depositions in rainwater at the same locations ranged from 316 pCi/m^2 to 441 pCi/m^2. The maximum nonvolatile beta deposition was measured in H Area. Table 9-1 (right) indicates that the maximum concentrations of these radionuclides were essentially the same at each of these locations during 1989.

Table 9-1
Comparison of Gross Alpha and Nonvolatile Beta in Rainwater

	Maximum (pCi/m^2)	
Location	**Alpha**	**Beta**
Onsite	17	441
Site perimeter	48	316
25-mile radius	21	430

The maximum alpha deposition at the 100-mile-radius station was 64 pCi/m^2, measured at the Greenville, SC monitoring station. The maximum 100-mile-radius nonvolatile beta deposition was 730 pCi/m^2, observed in Greenville, SC. Because of the location of these monitoring stations relative to SRS, these depositions are attributed to worldwide fallout, not to releases from SRS.

Gamma-Emitting Radionuclides
Cesium-137 and ^{7}Be were the only gamma-emitting radionuclides detected in rainwater during 1989. The deposition of ^{137}Cs in rainwater onsite, site perimeter, and 25-mile radius ranged from below the lower limit of detection (LLD) to 250 pCi/m^2. The maximum ^{137}Cs deposition was at the Darkhorse monitoring station. Maximum concentrations of ^{7}Be, a naturally occurring radionuclide, ranged from 1,500 to 42,000 pCi/m^2.

The only gamma-emitting radionuclide detected at the 100-mile-radius stations was naturally occurring ^{7}Be. The maximum depositions ranged from 3,000 to 13,000 pCi/m^2.

Tritium
Because tritium is not collected on the ion column, tritium deposistions are not calculated. However, the concentration of tritium is measured in samples collected at the site perimeter and the 100-mile radius. Tritium concentrations in rainwater averaged 1.3 pCi/mL at the site perimeter and 0.09 pCi/mL at the 100-mile radius.

The maximum concentration of tritium in rainwater at the site perimeter was 12 pCi/mL, measured at the Darkhorse monitoring station, compared to the maximum concentration at the 100-mile radius of 0.39 pCi/mL. These higher tritium concentrations in rainwater at the site perimeter may be attributed to atmospheric tritium releases from SRS.

Strontium
Maximum deposition of ^{89,90}Sr in rainwater at all monitoring stations ranged from 21 pCi/m^2 at the site perimeter to 70 pCi/m^2 at the H-Area monitoring station. The maximum concentration at the 25-mile radius station was 60 pCi/m^2. These depositions are attributed to worldwide fallout.

Plutonium
The maximum depositions of ^{238}Pu in rainwater ranged from 0.08 to 2.4 pCi/m^2. Maximum deposition of ^{239}Pu ranged from 0.14 to 1.9 pCi/m^2. The maximum depositions of ^{238}Pu and ^{239}Pu were measured in samples from the H-Area monitoring station.

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, at the site perimeter, and at 25-mile-radius locations. 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 local concentrations of radionuclides in soils are often spatially nonuniform. In addition, 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. An average concentration of multiple samples provides a better measure of soil radionuclide concentrations.

Program Changes in 1989

Two new onsite sampling locations, S and Z Area, were added to the monitoring program in 1989. The Saltstone Facility is located in Z Area and the DWPF is located in S Area.Four samples will be collected annually at each of the quadrants around S and Z Areas to determine the concentration of radionuclides in the soil that may be contributed by these facilities.

Monitoring Results

Measurements of radioactive concentrations in soil for 1989 are presented in Table 9-2, Vol. II.

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. The deposition of radioactivity in soil, calculated in mCi/km^2 from the sample concentrations in Table 9-2, Vol. II, is presented in Table 9-3, Vol. II. A yearly summary of deposition values since 1973 is shown in Table 9-4, Vol. II.

Strontium

The maximum concentrations of ^{90}Sr in soil were 0.71 pCi/g around F, H, S, and Z Areas, 0.02 pCi/g at the site boundary, and 0.10 pCi/g at the 100-mile radius locations. The ^{90}Sr concentrations measured in the soils are similar to concentrations observed over the last several years and result primarily from worldwide fallout from nuclear weapons tests.

Collection of soil samples at the site boundary

Table 9-2
Average Cesium-137 Deposition in Soil

Location	Avg Deposition(mCi/km^2) 1989	1988
F Area	65	100
H Area	89	73
Site perimeter	68	75
100-Mile radius	46	33

Strontium-90 deposition averaged 30 mCi/km^2 in F Area and 11 mCi/km^2 in H Area. Average depositions at the site perimeter and at the 100-mile-radius were 0.6 and 2.4 mCi/km^2, respectively. The depositions of ^{90}Sr have ranged from 3 to 30 mCi/km^2 in F Area and from 4 to 25 mCi/km^2 in H Area since 1973. Table 9-4 in Vol. II provides a summary of depositions is soil since 1973 for each of the sampling groups.

Cesium-137

Cesium-137 concentrations ranged from 0.05 pCi/g around S Area to 0.96 pCi/g around F Area, somewhat lower than the range of 0.14 to 1.1 pCi/g measured onsite during 1988. Concentrations of ^{137}Cs at the site perimeter and at the 100-mile radius ranged from 0.29 to 0.79 pCi/g. Offsite data are consistent with previous years and are within the concentrations observed from worldwide fallout.

The calculated deposition results for 1989 at all locations were similar to the results reported during 1988. Table 9-2 (above) summarizes and compares the 1989 depositions of ^{137}Cs in soil with those from 1988.

Plutonium

In 1989, plutonium concentrations in soil samples around F and H Areas were somewhat greater than those detected at S and Z Area and at the site perimeter, reflecting F- and H-Area releases. Cumulative atmospheric plutonium releases from the separations areas, since 1955, total 0.7 Ci ^{238}Pu and 3.0 Ci ^{239}Pu through 1989. The majority of these releases occurred in earlier years of SRS operation. Releases for 1989 were 0.86 mCi of ^{238}Pu and 1.3 mCi of ^{239}Pu. Most concentrations of ^{238}Pu and ^{239}Pu measured in soil at the SRS boundary and at the 100-mile-radius sampling locations during 1989 were near or below the lower limit of detection, and all concentrations at those locations were within the ranges observed in previous years.

Deposition results in 1989 for ^{238}Pu and ^{239}Pu were similar at all locations except F Area. The maximum ^{238}Pu and ^{239}Pu depositions in the 1989 F-Area results were 7.9 and 15 mCi/km^2, respectively. These depositions are lower than the 1988 depositions of 34 and 28 mCi/km^2, respectively.

Sediment

Description of Monitoring Program

Sediment samples have been collected annually at six locations on the Savannah River upriver from, adjacent to, and downriver from SRS since 1975 and at nine site 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 and most radionuclides will be concentrated. As a result, the samples are not representative of the entire stream bed. Sediment is analyzed for gamma-emitting radionuclides, ^{90}Sr, and ^{238}Pu and ^{239}Pu.

Monitoring Results

The analytical results for 1989 and a summary of results from 1975 to 1989 for both river and stream sediment samples are presented in Table 9-5, Vol. II. Concentrations of radionuclides 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, and thus contaminants, may also cause variations in concentrations.

Concentrations of radioactivity in river sediment were within the ranges detected from worldwide fallout. Onsite stream sediment results reflect current and previous contributions of radioactivity from SRS liquid releases. In 1989, higher concentrations of radionuclides were measured in samples from Four Mile Creek A-7A (a beaver pond) than were measured in previous years. Table 9-3 compares 1989 concentrations in sediment from Beaver Pond with those measured during 1987 and 1988.

<u>Gamma-Emitting Radionuclides</u>

Potassium-40, a naturally occurring radionuclide, and ^{137}Cs were the only gamma-emitting radionuclides routinely detected in river sediment. The maximum 1989 ^{137}Cs concentration detected in the river sediment was 0.94 pCi/g; the 1988 maximum was 0.74 pCi/g. Concentrations of naturally occurring ^{40}K were within ranges observed in previous years, with a maximum of 23 pCi/g.

Higher concentrations of ^{137}Cs were measured in stream sediments than in the river sediments in 1989. A maximum ^{137}Cs concentration of 410 pCi/g was measured at Four Mile Creek A-7A. The concentration of ^{137}Cs has increased significantly over the past two years at this location and is attributed to liquid releases from SRS.

<u>Strontium</u>

The maximum ^{90}Sr concentration in river sediment downriver from SRS in 1989 was 0.07 pCi/g, compared to a maximum of 0.25 pCi/g in 1988. The maximum concentration in river sediment was measured below Four Mile Creek and below Little Hell Landing.

The maximum ^{90}Sr concentration in stream sediment, measured at Four Mile Creek A-7A, was 2.5 pCi/g (see Table 9-3 below). Concentrations of ^{90}Sr in sediment at this location have not changed significantly from previous years (Table 9-5, Vol. II).

<u>Plutonium</u>

The concentrations of ^{239}Pu in river sediment during 1989 ranged from 0.002 to 0.006 pCi/g. Plutonium-238 in river sediment ranged from 0.010 to 0.089 pCi/g. The maximum concentrations of ^{238}Pu and ^{239}Pu were measured in a sediment sample taken in the Savannah River below Four Mile Creek. Concentrations of these radionuclides in river sediment are similar to those reported in 1988.

Table 9-3
Comparison of Radionuclides in Sediment at Four Mile Creek A-7A from 1987 to 1989

	(pCi/g)		
Radionuclide	**1987**	**1988**	**1989**
Cesium-137	32	262	410
Cobalt-60	0.77	6.3	2.1
Potassium-40	-	4.2	4.7
Strontium-90	0.98	3.0	2.5
Plutonium-238	0.66	2.49	5.7
Plutonium-239	0.23	0.76	1.1

- Not detected

Increasing ^{238}Pu concentrations have been observed in Beaver Pond over the past two years. The ^{238}Pu concentration in the Four Mile Creek A-7A sediment sample was 5.7 pCi/g in 1989 and 2.49 pCi/g in 1988, compared to 0.66 pCi/g in 1987. As shown in Table 9-3, concentrations of ^{239}Pu at Four Mile Creek A-7A were also higher during 1989 than concentrations measured in previous years.

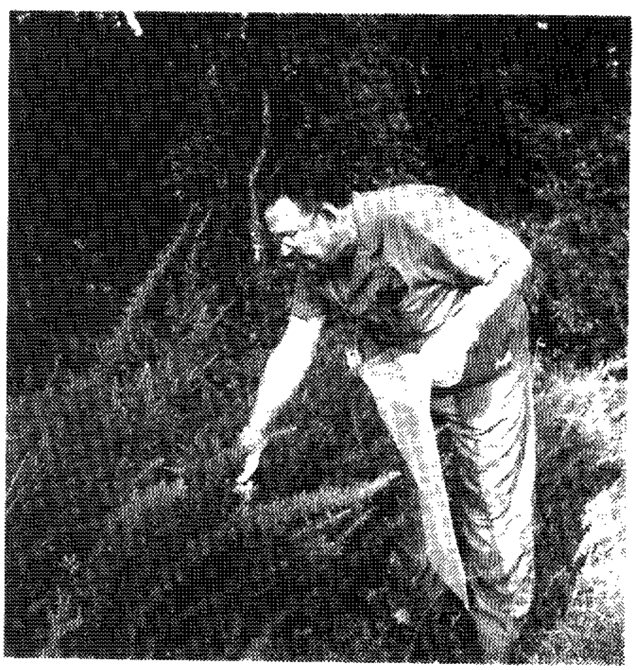
Vegetation

Description of Monitoring Program

Radioactive contamination of growing plants may result from transfer of radioactive materials from the soil or from radioactivity deposited from the atmosphere.

Vegetation samples are collected at onsite, site perimeter, 25-mile radius, and 100-mile-radius locations. Onsite samples are collected around seepage and retention basins, in and around the Radioactive Waste Burial Ground (RWBG), around the Defense Waste Processing Facility (DWPF) in S Area, and around the Saltstone Facility in Z Area.

Grass is analyzed routinely for radioactivity; Bermuda grass is used, if available, because of its importance as a pasture grass for dairy herds and its 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.



Collection of onsite vegetation samples

Monitoring Results

Measurements of the radioactivity in vegetation, based on dry weight, are presented in Table 9-6, Vol. II.

Gross Alpha and Nonvolatile Beta

The maximum concentration of gross alpha detected in onsite vegetation was 1.3 pCi/g in a vegetation sample from H Area. The maximum concentrations of gross alpha measured offsite were 2.0 pCi/g at the site perimeter (Highway 21/167); 2.7 pCi/g at the 25-mile-radius station in Springfield, SC; and 3.3 pCi/g at the 100-mile-radius location in Columbia, SC.

Maximum nonvolatile beta concentrations ranged from 13 to 31 pCi/g at the F- and H-Area locations, from 12 to 37 pCi/g at the site perimeter, from 19 to 40 pCi/g at the 25-mile-radius locations, and from 17 to 48 pCi/g at the 100-mile-radius locations. The differences in nonvolatile beta concentrations in the soil are attributed to variations in worldwide fallout patterns.

Gamma-Emitting Radionuclides

Naturally occurring ^{7}Be and ^{40}K were the major contributors to the beta-gamma activities in vegetation, although ^{137}Cs was measured in some vegetation samples. The concentrations measured in samples from onsite, site perimeter, 25-mile radius, and 100-mile-radius locations were similar in all samples. The maximum concentrations of ^{137}Cs measured in these samples were 0.62 pCi/g onsite, 0.33 pCi/g at the site perimeter, 0.50 pCi/g at the 25-mile radius, and 0.20 pCi/g at the 100-mile radius.

Tritium

Tritium concentrations in vegetation represent the concentration in free water which has been extracted from the sample by freeze drying. Tritium concentrations were significantly different between vegetation samples collected at the F- and H-Area, site perimeter, 25-mile, and 100-mile-radius locations. On the facing page, Figure 9-2 compares the maximum and average concentrations measured onsite, site perimeter, 25-mile radius, and 100-mile radius.

In 1989, tritium concentrations decreased with increasing distance from the site. The average tritium concentration at onsite sample locations in F and H Areas was 18 pCi/mL, compared to 2.7 pCi/mL at the site perimeter stations, 1.0 pCi/mL at 25-mile-radius stations and 0.09 pCi/mL at 100-mile-radius stations. Maximum tritium concentrations ranged from 81 pCi/mL in F Area, 14 pCi/mL at a site

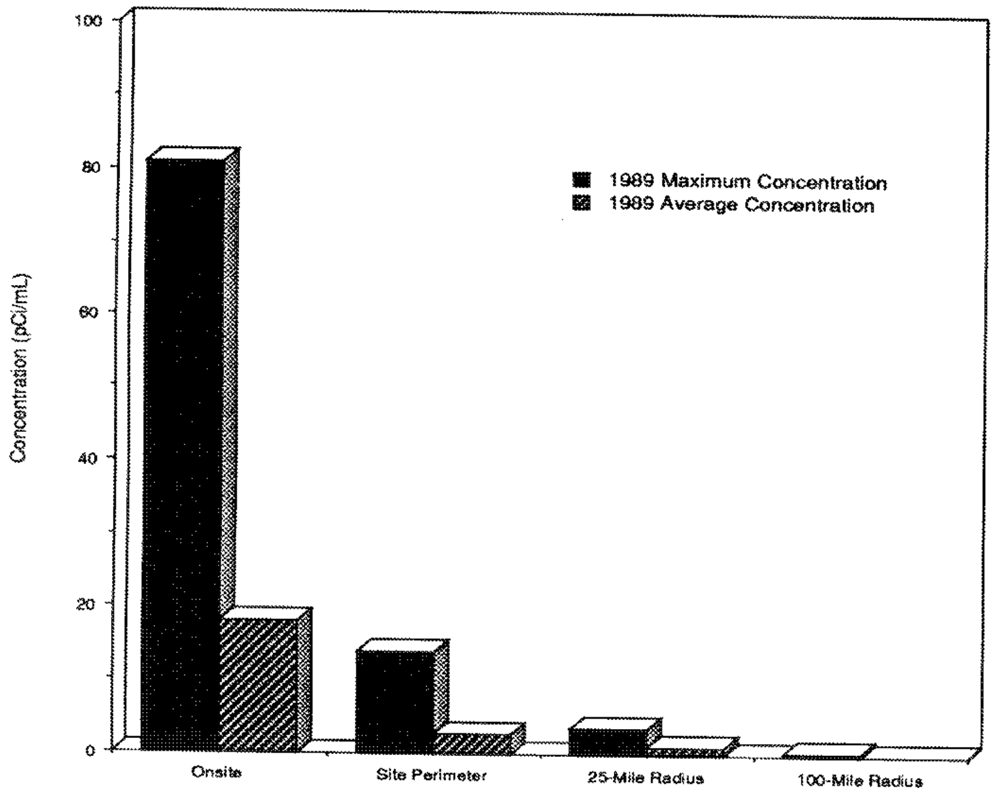


Figure 9-2. Comparison of tritium concentrations in vegetation in 1989

perimeter location, 3.5 pCi/mL at a 25-mile-radius location, and 0.44 pCi/mL at the Greenville, SC, 100-mile-radius sample location. These higher concentrations around the site are attributed to releases from SRS. Maximum and average concentrations for 1989 are similar to those measured in 1988.

Strontium

Concentrations of $^{89,90}Sr$ in vegetation also demonstrated decreasing concentration with increasing distance from the site, with averages of 1.7 pCi/g onsite, 1.3 pCi/g at the site perimeter, 0.79 pCi/g at the 25-mile radius, and 0.14 pCi/g at the 100-mile radius. The 1989 maximum $^{89,90}Sr$ concentration was 2.9 pCi/g in F Area. These measured concentrations are near the LLD for strontium determination in soil.

Seepage and Retention Basins

In addition to the onsite, site perimeter, 25-mile, and 100-mile-radius 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 gross alpha, nonvolatile beta, and $^{89,90}Sr$ concentrations.

The gross alpha concentrations were near the levels observed offsite with a maximum of 1.9 pCi/g. Concentrations of nonvolatile beta were also near the levels observed offsite, with the exception of the H-Area seepage basin. The H-Area seepage basin sample was analyzed three times because the results obtained after each analysis varied significantly. The result that was reported, 90 pCi/g, is the average of the three analyses results. The maximum concentration of $^{89,90}Sr$ was 7.6 pCi/g at the 100-R Area seepage basin.

Seepage and retention basin vegetation monitoring results are presented in Table 9-7, Vol. II.

Radioactive Waste Burial Ground

Vegetation samples were also collected inside the RWBG to determine whether uptake of radioactivity by vegetation from buried waste has occurred. Vegetation is collected annually from a relatively large area at 51 locations inside the RWBG. This collection method provides coverage of a large part of the facility, yet keeps the number of samples to a minimum. The RWBG samples were analyzed for gross alpha, nonvolatile beta, and gamma-emitting radionuclides. Sample locations are shown in Figure 9-1, Vol. II; data are presented in Table 9-8, Vol. II.

In 1989, location 4 was the only location within the RWBG that showed higher levels of radioactivity than in 1988. The concentration of nonvolatile beta at location 4 was 140 pCi/g, compared to 15 pCi/g in 1988. The concentration of ^{137}Cs at this location was 0.18 pCi/g, which is lower than the 1988 concentration of 0.39 pCi/g.

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 was cleared of vegetation and treated with herbicide several times. Since the application of the herbicide, concentrations of nonvolatile beta at these locations have continued to decrease.

In 1989, the most noticeable decrease occurred in concentrations of nonvolatile beta. It is unclear whether the herbicide restricted the plant roots from penetrating the contaminated soil or if it prevented vegetation from growing in the areas of contamination. Table 9-4 (left) compares 1989 concentrations of radionuclides measured in vegetation at locations 9, 9A, and 10 with those measured in 1988.

Table 9-4
Radionuclide Concentrations Measured in Vegetation inside the Radioactive Waste Burial Ground

	1988 (pCi/g)	1989 (pCi/g)
Location 9		
Gross alpha	0.04	1.3
Nonvolatile beta	41	43
Cesium-137	0.45	0.79
Location 9A		
Gross alpha	0.13	0.23
Nonvolatile beta	328	16
Cesium-137	4.5	0.27
Location 10		
Gross alpha	0.13	0.18
Nonvolatile beta	99	24
Cesium-137	1.9	2.5

Vegetation samples were also collected quarterly outside of RWBG fences. Vegetation sampling locations outside the RWBG are shown in Figure 9-2, Vol. II. Monitoring data are shown in Table 9-9, Vol. II.

The average alpha and nonvolatile beta concentrations in vegetation outside the RWBG fence were 1.2 and 17 pCi/g, respectively. These concentrations are similar to those reported in 1988 (0.40 pCi/g, gross alpha and 16 pCi/g, nonvolatile beta), but higher than those observed before 1988. The higher average alpha concentrations are attributed to analysis correction for self-absorption of the sample.

Cesium-137 was the only man-made radionuclide detected in vegetation outside of RWBG. A maximum ^{137}Cs concentration of 2.1 pCi/g was detected at the Burial Ground 12 sampling location.

These surveys indicate control practices at the RWBG have been generally effective in preventing the spread of contamination from the facility.

1988 HIGHLIGHTS

- In 1989, maximum gross alpha depositions in rainwater onsite, at the site perimeter, and at 25-mile-radius stations ranged from 21 to 48 pCi/m^2, compared to 64 pCi/m^2, measured at the 100-mile-radius station. Higher levels of radioactivity are expected at the 100-mile-radius locations because of less frequent collection of the ion columns.
- Cesium-137 and ^{7}Be were the only gamma-emitting radionuclides detected in rainwater during 1989.
- Maximum ^{90}Sr concentrations in soil were 0.71 pCi/g around F,H, S, and Z Areas, 0.02 pCi/g at the site boundary, and 0.10 pCi/g at the 100-mile radius locations, and result primarily from worldwide fallout.
- Cumulative atmospheric plutonium releases from the separations areas since 1955, total 0.7 Ci ^{238}Pu and 3.0 Ci ^{239}Pu through 1989. Most concentrations of plutonium measured in soil at the SRS boundary and at the 100-mile-radius were near or below the lower limits of detection in 1989.
- The maximum 1989 ^{137}Cs concentration in river sediment was 0.94 pCi/g; the 1988 maximum was 0.74 pCi/g.
- The maximum concentration of gross alpha detected in onsite vegetation was 1.3 pCi/g in a sample from H Area, which is similar to the maximum alpha concentrations measured offsite of 2.0 pCi/g at the site perimeter, and 2.7 pCi/g at the 25-mile-radius station.

10 Nonroutine Occurrences

SUMMARY—Nonroutine occurrences are unplanned releases of radioactive or nonradioactive materials to the environment. This chapter outlines the special sampling and measurements program and analytical results obtained for the nonroutine events that occurred at SRS this year.

During 1989, three atmospheric tritium releases, six liquid tritium releases, four releases involving other specific radionuclides, and two additional nonroutine events occurred at SRS. Analytical results indicate that no significant environmental impact or dose consequences occurred from these nonroutine releases.

INTRODUCTION

The environmental monitoring program at the Savannah River Site (SRS) extends beyond monitoring routine releases of radioactivity to the environment. Nonroutine releases of radioactivity from the site are also monitored.

When a nonroutine release of radioactivity is suspected, the Environmental Monitoring Section (EMS) initiates a special sampling and analysis program. Samples are first collected from the suspected source of release to confirm that a release occurred. Samples are also collected from locations within the environmental pathway of the suspected release. As the special samples are collected, they are placed into the analytical system as priority samples (see Figure 10-1 on the following page). These special samples may include air, water (process, stream, or river), vegetation, and soil.

Sample analyses and measurements taken in connection with nonroutine occurrences are used to evaluate the environmental impacts as well as dose consequences. All of the release values (both atmospheric and liquid) from the nonroutine releases are incorporated into final annual offsite dose determinations (see Chapters 4 and 5). Since annual dose calculations incorporate nonroutine release information, committed doses are not calculated for every nonroutine release.

During 1989, special samples were collected following three atmospheric tritium releases, six liquid tritium releases, and four releases involving other specific radionuclides. EMS also collected special samples during two additional nonroutine occurrences.

No significant environmental impact or dose consequences resulted from these nonroutine releases from SRS in 1989. This conclusion is based on the annual dose calculations and on the analytical results of all samples collected in connection with the nonroutine releases that occurred during the year. This chapter summarizes the samples collected and analytical results obtained following the 1989 nonroutine releases.

ATMOSPHERIC RELEASES

Tritium Release—January 3, 1989

On January 3, 1989, approximately 500 Ci of tritium (chemical form unknown) were released to the atmosphere from an H-Area tritium facility. The Weather INformation and Display (WIND) System projected a dose of 0.013 mrem to an individual at the site boundary from this release.

EMS collected eight vegetation and five water samples from locations downwind of the release. Three vegetation samples were collected from the downwind area adjacent to H Area, while the remaining samples were collected at the site perimeter near the Darkhorse air monitoring station. The water samples were collected from standing water at the site perimeter. The following table summarizes the special sampling results:

Sample	No. of Samples	Tritium (pCi/mL) Max	Min	1988 Range
Veg	8	180.0 ± 1.9	21.4 ± 0.8	1-10
Stan.Wat.	5	72.2 ± 1.3	14.8 ± 0.8	<0.28–6.7

The release was confirmed based on the special sampling results, which were compared to the range of tritium concentrations measured in vegetation and rainwater samples collected at the Darkhorse monitoring station during 1988. Elevated concentrations of tritium were detected in both water and vegetation samples collected immediately following the release.

Tritium Release—March 30, 1989

On March 30, 1989, approximately 1,100 Ci (97% tritium oxide and 3% elemental tritium) of tritium were released to the atmosphere from an H-Area tritium facility. The WIND System projected a dose of 0.01 mrem to an individual at the site boundary from this release.

Five vegetation samples and one water sample were collected downwind of the release near the East Talatha air monitoring station. The water sample was collected from standing water. The special sampling results are summarized below:

Sample	No. of Samples	Tritium (pCi/mL) Max	Min	1988 Range
Veg	5	197.7 ± 4.1	22 ± 0.9	1.7-11
Stan.Wat.	1	3.8 ± 0.9		<0.28–6.7

Based on the concentrations measured in vegetation samples from the East Talatha monitoring station and in rainwater samples collected from Darkhorse monitoring station during 1988, elevated tritium concentrations were detected in vegetation samples collected following the release. The tritium concentration for the water sample was within the range measured during 1988.

Plutonium Release—August 27, 1989 to October 8, 1989

A release of ^{238}Pu from an F-Area facility was identified on September 6, 1989 and again on September 29, 1989. Based on the analysis of stack air filter papers, the total plutonium released from August 27 to October 8, 1989 was estimated to be 13.5 mCi of plutonium.

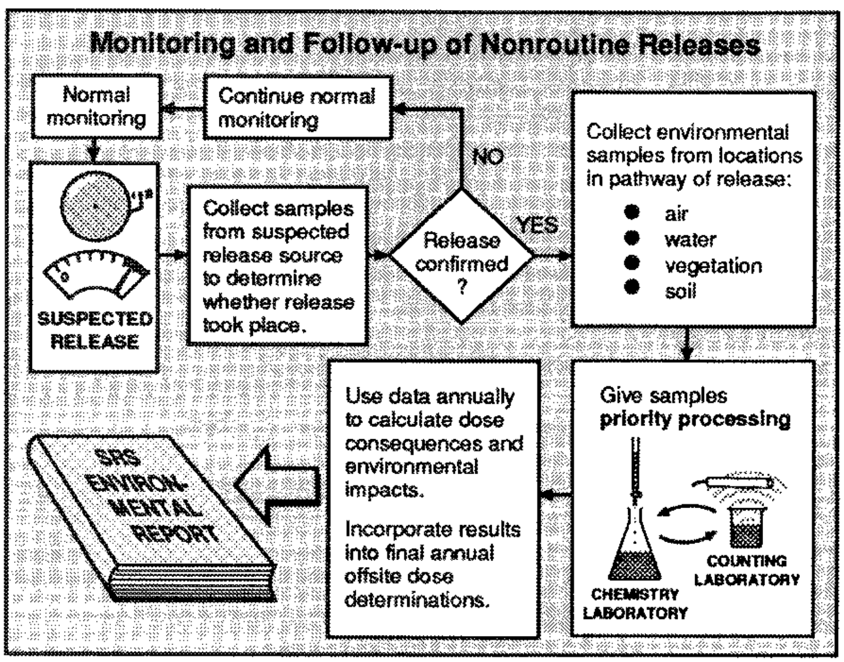


Figure 10-1. Sampling/analysis program of a nonroutine release

On September 6 and 7, 25 soil samples were collected around the F-Area facility. Plutonium-238 and ^{239}Pu deposition was confirmed outside the F-Area fence west of the facility. Air samples were collected from 200-F, 200-H, 400-D, Burial Ground South, and at the Jackson sampling locations within 24 hours of the release. Results from these samples indicated that plutonium levels were within ranges normally measured. A water sample collected from Upper Three Runs Creek revealed no increased levels of radioactivity.

On September 29, EMS was notified that additional ^{238}Pu contamination was found within 2,000 ft southwest of the F-Area facility. Twenty soil and five vegetation samples were collected downwind of the release. The results confirmed the presence of ^{238}Pu and ^{239}Pu within 2,000 ft of the facility. No special air samples were collected. However, routine weekly air samples collected by EMS indicated no increase in gross alpha, ^{238}Pu, or ^{239}Pu activity.

Results from the special samples and routine weekly samples indicated that the plutonium released from the F-Area facility was deposited within 2,000 ft of the facility and not carried offsite.

Tritium Release—October 19, 1989

Approximately 800 Ci of tritium oxide were released to the atmosphere from an H-Area tritium facility on October 19, 1989. The WIND System projected a dose of 0.002 mrem at the site boundary from this release. Figure 10-2 (above) shows the path of the plume as detailed by the WIND System

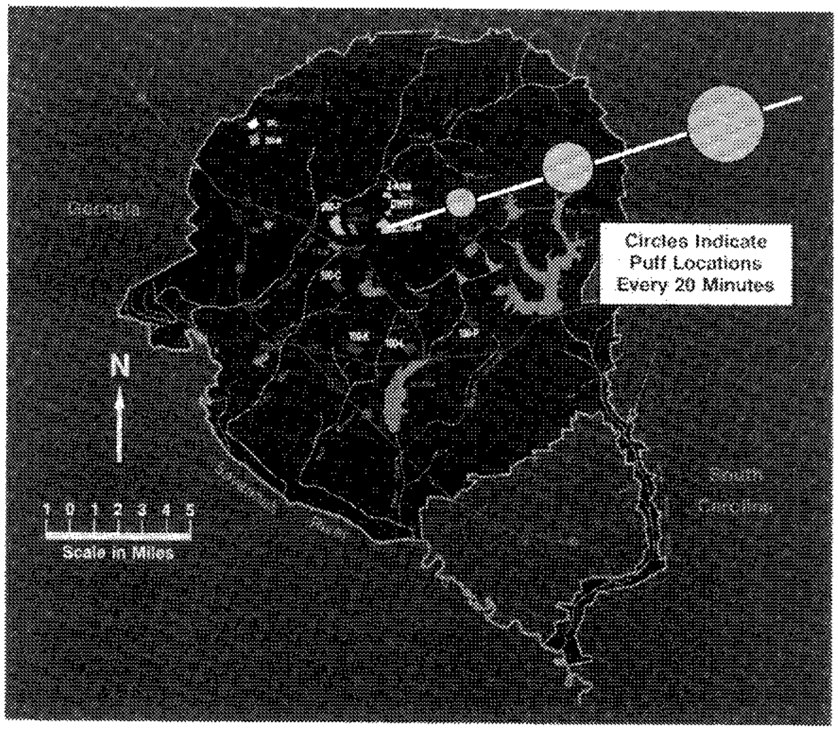


Figure 10-2. Tritium plume following October 19 release

Five vegetation and four water samples were collected downwind of the release near the Darkhorse monitoring station. The water samples were collected from standing water. The following is a summary of the special sampling results:

Sample	No. of Samples	Tritium (pCi/mL) Max	Min	1988 Range
Veg	5	15.80 ± 0.38	3.56 ± 0.28	1.0-10
Stan.Wat.	4	5.22 ± 1.04	2.88 ± 0.86	<0.28–6.7

The results were compared with concentrations of tritium in rainwater and vegetation samples collected at the Darkhorse monitoring during 1988. The special sampling results indicated that elevated tritium concentrations were present in the vegetation samples collected immediately following the release.

LIQUID RELEASES

Tritium Release—December 30, 1988 to January 1, 1989

Between December 30, 1988 and January 1, 1989, approximately 70 Ci of tritium were released to Pen Branch from the K-Area process sewer.

EMS collected two continuous stream samples on Pen Branch, downstream from the K-Area effluent. Elevated tritium activity in Pen Branch measured during the period confirmed the release from the K-Area process sewer. The maximum concentration of tritium measured in Pen Branch during 1989 (220 pCi/mL) was measured in the sample collected immediately following the release. After dilution by the stream, no elevated concentrations of tritium were measured in the Savannah River.

Tritium Release—January 3 to January 10, 1989

Between January 3 and January 10, 1989, 534 Ci of tritium were discharged to Pen Branch via the K-Area process sewer and heat exchanger cooling water effluents. The tritium release estimate was calculated from the continuous water sample collected from Pen Branch at Road A-13 during the release period and from recorded United States Geological Survey (USGS) flow rates.

The concentration of tritium in the sample collected at Road A following the release was 100 pCi/mL, which is comparable to the 1988 average tritium concentration of 120 pCi/mL. A slightly higher concentration of tritium was also measured at the down-river sampling location following the release compared to concentrations measured in 1988. In 1988, tritium concentrations ranged from 0.37 to 5.7 pCi/mL at sampling location River-10B; the 1989 maximum concentration measured after the release was 6.4 pCi/mL on January 24, 1989.

Potential Gamma-Emitting Radionuclide Release—June 17, 1989

A release of potentially contaminated water occurred at K Reactor on June 17, 1989 when approximately 3,000 gallons of water were released to the K-Reactor process sewer. This water eventually discharges to Pen Branch.

To determine whether gamma-emitting radionuclides were released to Pen Branch, a special sampling program was initiated. Dip samples and continuous water samples were collected on June 17 and June 18 from Pen Branch. The samples were analyzed for gamma-emitting radionuclides, nonvolatile beta activity, and tritium. All gamma-emitting radionuclides were less than minimum detectable levels, and the tritium and nonvolatile beta results were within ranges normally measured in Pen Branch.

Cesium Release—July 26, 1989

On July 26, 1989, approximately 3 Ci of cesium were released to an H-Area retention basin from a waste treatment facility. Water from the H-Area retention basin is eventually released to Four Mile Creek. To determine whether elevated cesium activity was released to the stream, samples from Four Mile Creek were collected and analyzed. The results confirmed that no elevated concentrations of cesium were released directly into the stream.

Following the release, a special program was initiated to remove the cesium in the water before releasing the water into Four Mile Creek. The maximum concentration of ^{137}Cs in the water before it could be released was less than 4.5 pCi/mL, an operating release limit.

A special sampling and analysis program was also initiated to monitor the releases to Four Mile Creek. The special program ensured the cesium activity was below 4.5 pCi/mL before the basin water was released.

Controlled releases to Four Mile Creek began in September. However, because of rain, clean-up of the retention basin water to remove the cesium contamination is continuing. Storm water containing less than 4.5 pCi/mL of cesium is still being released to the stream. As of December 31, 1989, approximately 58 mCi of ^{137}Cs had been released to Four Mile Creek from the retention basin.

Tritium Release—July 31, 1989

On July 31, 1989, approximately 8 Ci of tritium were released from the L-Area disassembly basin to the L-Area process sewer during a 340-minute time period. A composite sample for the release period was collected from the process sewer and analyzed for tritium. The tritium release estimate was calculated from the composite sample result and the reported effluent flow rate.

The L-Area process sewer discharges to L Lake and eventually flows into Steel Creek. Routine biweekly tritium analyses of samples collected from Steel Creek at Road A indicated that the L-Area disassembly basin release did not elevate tritium concentrations in Steel Creek.

Mixed Fission Product Release—September 25 to October 23, 1989

From September 25 to October 23, 1989, approximately 3.18 mCi of mixed fission products, mainly ^{106}Ru and $^{89,90}Sr$, were released through the H-006 outfall to McQueen Branch.

Two special stream water samples were collected from McQueen Branch. In addition, the routine weekly continuous stream samples were collected. The routine weekly samples and special release samples were analyzed for gross alpha, nonvolatile beta, tritium, $^{89,90}Sr$, and gamma-emitting radionuclides. Ruthenium-106 and $^{89,90}Sr$ activity was detected in the McQueen Branch samples.

To determine the extent of the release, a soil sample near the H-006 outfall and one at the head of McQueen Branch were collected and analyzed for gross alpha, nonvolatile beta, and gamma-emitting radionuclides. Ruthenium-106 was detected in the soil sample collected near the outfall.

A vegetation sample was also collected near the outfall and analyzed for gross alpha and nonvolatile beta activity to determine if the plant had assimilated the radionuclides. The vegetation result indicated the contamination was primarily present on the soil and not within the vegetation.

Based on the analytical results, elevated radioactivity levels were confirmed in the H-006 outfall in H Area. Residual radioactivity was also confirmed in the soil at the head of McQueen Branch. As water flows through the outfall into McQueen Branch, radioactivity may be washed into the stream. Therefore, total strontium and gamma-emitting radionuclides were added to the analysis protocol for McQueen Branch to monitor the release. These analyses continued through December 1989, and will continue until concentrations in McQueen Branch return to normal.

Tritium Release—November 18, 1989

Approximately 240 Ci of tritium were released from the D-Area process sewer to Beaver Dam Creek on November 18, 1989. Tritium analyses were performed on a daily composite sample collected on November 18 and on two biweekly composite samples collected during November to confirm the release.

Analyses of biweekly sample composites from Beaver Dam Creek following the release indicated tritium concentrations were within the range measured from January–October 1989 (0.77 to 360 pCi/mL). In addition, biweekly sample composites from the Savannah River downriver from the release point did not indicate elevated levels of tritium.

Tritium Release—December 1 to December 30, 1989

Approximately 68 Ci of tritium were released from the P-Area canal to Par Pond from December 1 to December 30, 1989. Special water samples collected from the P-Area canal were analyzed to determine the amount of tritium released.

EMS routinely analyzes stream and river samples downstream of P Area. Compared to tritium concentrations measured through November 1989, the results indicated that the concentrations of tritium in Par Pond and the Savannah River were not elevated during December.

Tritium Release on December 9, 1989

On December 9, 1989, approximately 3.2 Ci of tritium were released from the K-Area process sewer to Pen Branch. A special water sample was collected at the primary environmental sampling location for K-Area effluents (PB-3). Based on a comparison with the 1989 average concentration of tritium at PB-3 through November 1989 (53 pCi/mL), the elevated tritium concentration of 99 pCi/mL confirmed the tritium release from K Area.

OTHER NONROUTINE OCCURRENCES

Oily Substance—March 9, 1989

On March 9, 1989, an oily film was observed on the water in an F-Area delaying basin. This basin discharges to Four Mile Creek and is continuously monitored at the environmental sampling location FM-3. The routine FM-3 sample and a special dip sample were collected and analyzed for gamma-emitting radionuclides to determine if a release had occurred. Analyses results of the water indicated that no elevated levels of radioactivity were released to Four Mile Creek.

Tornado on Southeast SRS—October 1, 1989

On October 1, 1989 at approximately 8 p.m., a tornado struck the south and east sections of SRS (Figure 10-2). The Savannah River Laboratory (SRL) conducted a subsequent investigation of the path of the tornado using ground based and aerial photogra-

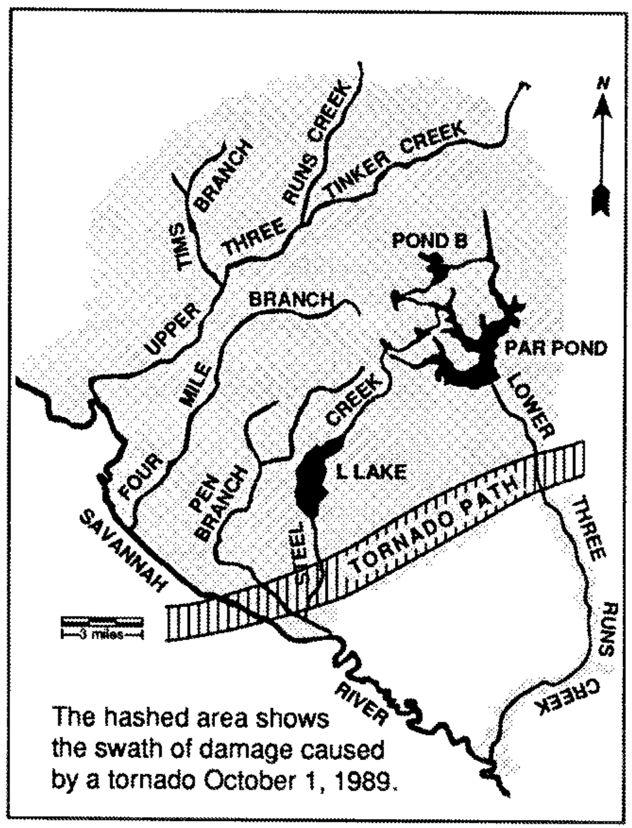


Figure 10-2. A tornado crossed SRS in 1989

phy, as well as meteorological data. The investigation revealed considerable damage to timber onsite. The tornado was spawned from a severe thunderstorm with a height of 57,000 ft in warm and humid air just to the south of a stationary front which extended from north central Georgia to extreme southeast North Carolina. Wind speeds were estimated to have ranged 110–160 mph.

Two million dollars in timber damage occurred over 2,500 acres along a 10-mile swath, but no onsite structural damage or personal injury occurred. Most of the damage was caused by a moderate tornado; however, tree-fall patterns indicated that some of this damage was the result of thunderstorm downbursts which accompanied the tornado.

Ground-based and aerial photography showed both snapped and mowed over trees which indicate that the tornado was elevated at times. The network of eight 60 m instrumented towers operated by the Environmental Technology Section of SRL were not in the swath of damage, but the towers did indicate a mesoscale cyclonic flow pattern and measured wind gusts up to 34 mph. Rainfall amounts on SRS for the 24 hr period ending October 2 ranged from 1.90 to 3.68 inches.

In addition to the investigation by SRL, EMS collected special water samples from Steel Creek, Lower Three Runs Creek, and the Savannah River at sampling location 8A to determine if any radioactivity was released during the storm. These samples were analyzed for gamma-emitting radionuclides. All results indicated no elevated radioactivity in the streams or river.

1989 HIGHLIGHTS

- The largest atmospheric release of tritium occurred on March 30, when 1,100 Ci of tritium were released from an H-Area facility. The WIND System projected a dose of 0.01 mrem to an individual at the site boundary from this release.
- Routine air samples, collected downwind after an atmospheric release of 13.5 mCi of plutonium over a six-week period, indicated no increase in gross alpha, ^{238}Pu, or ^{239}Pu activity.
- The largest liquid tritium release occurred between January 3 and 10, 1989 when 534 Ci of tritium were discharged to Pen Branch via the K-Area process sewer and heat exchanger cooling water effluents.
- After 3 Ci of cesium were released to an H-Area retention basin from a Waste Treatment Facility, a program was initiated to reduce the cesium activity in the retention basin water to less than 4.5 pCi/mL before releasing the water to Four Mile Creek.
- Water and soil samples were collected after approximately 3 mCi of mixed fission products were released through the H-006 outfall to McQueen Branch. Ruthenium-106 and ^{89,90}Sr were detected in the water samples, while ^{106}Ru was detected in the soil collected near the outfall.

11
Special Surveys

SUMMARY—This chapter focuses on surveys that are special short- or long-term assessments of certain sites to determine the effects of SRS effluents on the environment. In 1989, the Environmental Monitoring Section completed radiological surveys of the Savannah River Swamp, Pond B, the Savannah Harbor, and dry monitoring wells in the F- and H-Area waste management facilities. Survey results of Savannah River Swamp soil, vegetation and ambient radiation indicated that there was no new migration of radionuclides from the swamp in 1989. The Pond B survey was conducted to characterize and determine the radionuclide exposure pathways in the mallard duck habitat. Somewhat higher concentrations of radionuclides were present in vegetation and sediment at Pond B than at remote locations.

Two nonradiological surveys were conducted in 1989. Based on tests of a new sampling system manufactured by Isco Corporation, the Isco samplers will replace some paddlewheel samplers that have been used routinely at SRS. The annual river quality survey by the Academy of Natural Sciences of Philadelphia encompassed studies of the population dynamics of diatoms, and the chemistry and biological communities of the Savannah River.

INTRODUCTION

In addition to routine sampling and special sampling during nonroutine environmental releases, radiological and nonradiological surveys are conducted on- and offsite by the Environmental Monitoring Section (EMS) and other groups, including the Savannah River Laboratory (SRL) and the Academy of Natural Sciences of Philadelphia (ANSP). Both short- and long-term radiological surveys are used to evaluate radioactivity levels and monitor the effects of SRS effluents on the environment at SRS and in its immediate vicinity. Nonradiological surveys are conducted to evaluate water quality and to investigate new technologies.

RADIOLOGICAL MONITORING SURVEYS

Savannah River Swamp Survey

Description of Survey

In the 1960s, a portion of the Savannah River Swamp between Steel Creek Landing and Little Hell Landing was contaminated with approximately 25 Ci of ^{137}Cs and less than 1 Ci of ^{60}Co. The contaminated swamp area extends beyond the SRS boundary to private property known as Creek Plantation (see Figure 11-1 on the following page). The offsite swamp area is uninhabited and not easily accessible except for occasional hunting or fishing.

The contamination resulted from failed fuel elements that leaked radioactivity into P-Area storage basin water used to shield and cool the irradiated fuel elements. Over time, some of the fuel storage basin water containing the ^{137}Cs and ^{60}Co was discharged to Steel Creek. The radioactivity settled in the swamp during periods of high water 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 and migration of radioactivity within the Creek Plantation swamp.

Comprehensive surveys were conducted annually along the trails between 1974 and 1977. These comprehensive surveys included ambient (environmental) gamma radiation measurements with thermoluminescent dosimeters (TLD) and analysis of vegetation, soil, and fish samples. The frequency of comprehen-

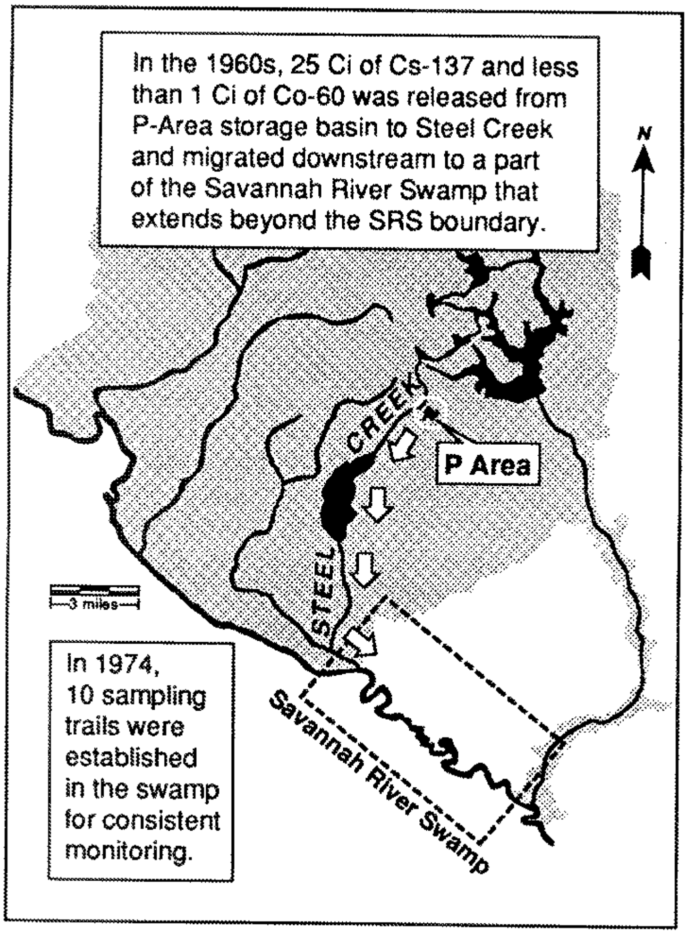


Figure 11-1. Location of ^{137}Cs migration following a release in the 1960s

sive surveys was reduced to five-year intervals after 1977 because no significant changes in radiological conditions were measured. The most recent comprehensive survey was performed in 1985 during construction of L Lake. See Figure 11-2 (right) for a detailed view of sampling in the vicinity of the swamp.

Cursory surveys consisting of ambient gamma radiation measurements and sampling at selected locations are conducted annually to provide interim monitoring of the swamp. The following tasks were performed during the 1989 cursory survey:

- Soil and vegetation samples were collected at selected locations along Trails 1, 5, and 10. Soil samples were analyzed for gamma-emitting radionuclides, ^{90}Sr, ^{238}Pu, and ^{239}Pu. These specific analyses are performed to monitor any radionuclides that may have been present in the failed fuel elements. Vegetation samples were analyzed for gross alpha and gamma-emitting radionuclides.
- TLDs were placed 1 m above ground at 54 locations along the 10 established trails to measure ambient gamma radiation.
- A fish was collected from one of the three lakes near the swamp trails and analyzed for ^{137}Cs. Because of high water, no fish were caught during the sampling of Boggy Gut and Cannuck lakes.
- Exposure rate measurements were taken every 100 ft along the 10 established trails with portable survey instruments.

Survey Results

The radionuclides detected and their concentrations were consistent with results from previous Savannah River Swamp surveys. The 1989 survey results showed that there was no new migration within the swamp.

Soil

Soil samples, collected on Trails 1, 5, and 10, were analyzed for gamma-emitting radionuclides, ^{90}Sr, ^{238}Pu, and ^{239}Pu. Concentrations 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.

Cesium-137 was the only gamma-emitting radionuclide detected in the soil samples in 1989. The concentrations of ^{137}Cs in soil were within ranges observed during recent years and showed a maximum of 155 pCi/g. Strontium-90 concentrations in soil showed a maximum of 0.34 pCi/g and were within ranges observed in previous years. The maximum ^{238}Pu and ^{239}Pu concentrations in soil were 0.34 and 0.08 pCi/g, respectively. Analytical data are presented in Tables 11-1, and 11-2, Vol. II.

Vegetation

Vegetation samples collected along Trails 1, 5, and 10 were analyzed for gross alpha and gamma-emitting radionuclides. Gross alpha concentrations were within the ranges observed in previous years and showed a maximum of 2.7 pCi/g. Table 11-3, Vol. II, gives gross alpha concentrations in vegetation.

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 9.6 and 45 pCi/g, respectively. Cesium-137 and ^{40}K sample concentration results are presented in Table 11-4, Vol. II.

Environmental Gamma Radiation

In 1989, exposure rates were measured at 100 ft intervals along each transect using portable survey instruments. These measurements were used to define the contaminated area and were compared with ambient gamma radiation measured by TLDs.

Measurements were taken with a MicroR meter at ground level and 1 m above the ground. The measurements ranged from 5 to 50 µR/hr at both ground level and 1 m. The MicroR survey results are presented in Table 11-5, Vol. II.

TLDs were placed 1 m above the ground at 54 identified locations along the sampling trails to measure ambient gamma radiation. The TLDs were collected for processing after an exposure period of approximately 30 days. The 1989 results ranged from 0.10 to 0.58 mR/day. The 1989 TLD results were generally lower than the 1988 results and may be attributed to the following factors:

- Transport dosimeters were placed in shielded storage for the duration of the field cycle. This procedure resulted in a more accurate correction factor for the field dosimeters, but lowered the apparent exposure.
- Weather conditions following TLD placement caused high water in the swamp. This standing water may have attenuated the gamma radiation resulting in a lower exposure.

Ambient gamma radiation levels measured by TLDs are presented in Table 11-6, Vol. II.

Both TLD and MicroR meter exposure measurements were obtained at 25 locations when the established TLD monitoring point coincided with the 100 ft survey meter measurement location. The values for both TLD and survey meter measurements are compared in Figure 11-1, Volume II.

As the figure illustrates, the TLD readings are lower than the survey meter measurements. Most likely, this discrepancy resulted from converting short-term exposure rates measured with the MicroR meter (µR/hr) into units compatible with long-term exposure rates measured with TLDs (mR/day). In addition, the

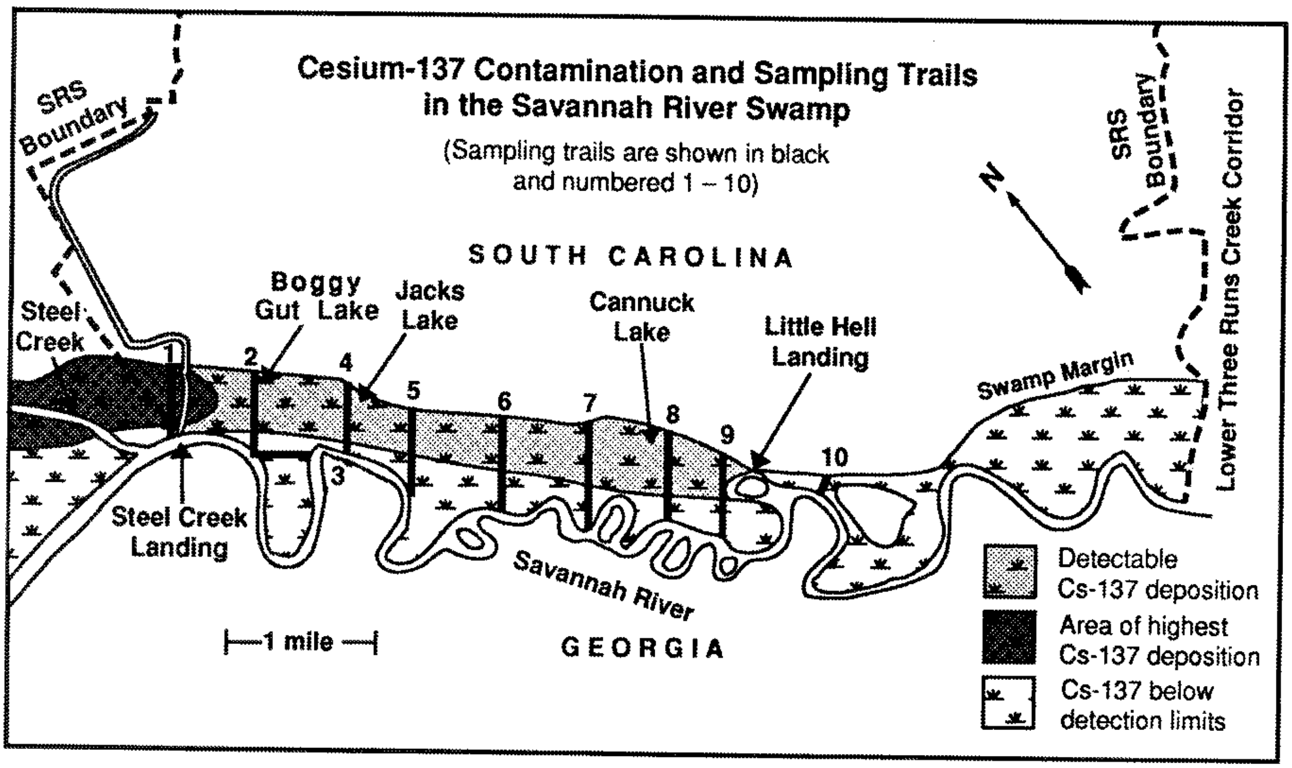


Figure 11-2. SRS has conducted surveys of the Savannah River Swamp since 1974

relatively low TLD results may have affected the comparison.

Fish
Only one fish (sucker) was caught from Jack's Lake located near the swamp trails. The ^{137}Cs concentration in this fish was less than 1 pCi/g. A summary of fish monitoring data from the 1974 to 1989 surveys are presented in Table 11-7, Vol. II

Pond B Survey

Description of Survey
Pond B is an 87 hectare man-made impoundment that received reactor cooling water and occasional releases of fission products from 1961 to 1964. During that period, approximately 170 Ci of ^{137}Cs were released from R Area. Since the decommissioning of R Reactor in 1964, Pond B has been largely undisturbed. Figure 11-3 (below) gives the location of Pond B and the background of its contamination in the 1960s [WHI89].

Research studies conducted by the Savannah River Ecology Laboratory of the mallard duck population residing at Pond B led to a special radiological survey in 1989 to characterize the Pond B environment.

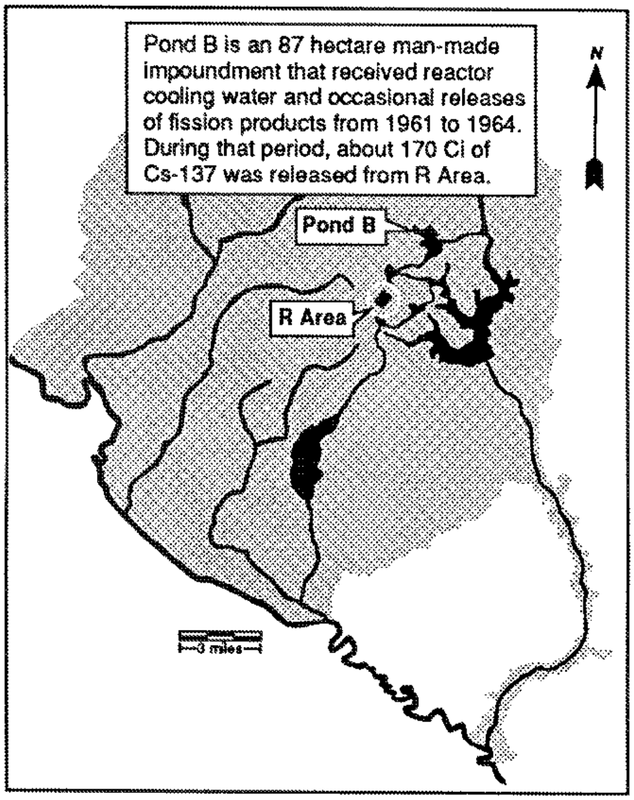


Figure 11-3. A survey of Pond B resulted from research studies of the mallard duck

The radiological survey conducted by EMS focused on characterizing and determining the exposure pathways in the duck habitat. EMS used the following sampling and analysis plan to accomplish the study:

- Ambient gamma radiation was measured by placing five TLDs at 10 locations on the 9-km perimeter of Pond B. The TLDs were placed at water level, approximately 1 ft from the shoreline. One TLD was removed from each location after 48 hours to obtain preliminary exposure data. The other TLDs remained at Pond B for 31 days.
- For comparison with TLD exposure data, ambient gamma radiation was measured at each location using a MicroR meter.
- Aquatic vegetation and sediment samples, two primary exposure pathways for the mallards, were collected from each of the 10 locations. The samples were first analyzed as "wet" samples for gamma-emitting radionuclides to obtain preliminary data.
- The same vegetation was then prepared for dry weight analysis of gross alpha, nonvolatile beta, gamma-emitting radionuclides, strontium, and tritium. Sediment samples were analyzed for the same constituents except tritium.

Survey Results
The highest exposure to the mallard ducks residing in Pond B results from ^{137}Cs in vegetation and sediment. The maximum concentrations of ^{137}Cs measured in vegetation and sediment samples were 300.6 and 67.1 pCi/g, respectively, as shown (above right) in Table 11-1.

Table 11-1 summarizes and compares the survey results to "remote" values. For sediment and vegetation, "remote" values are averages of routine 100-mile-radius vegetation samples and routine Savannah River sediment samples collected upriver from SRS. The "remote" values for ambient gamma radiation are averages of TLD measurements at the 100-mile-radius TLD locations.

Analytical results confirm that higher concentrations of radionuclides are present in the vegetation and sediment pathways at Pond B compared to the remote locations. Ambient gamma exposure is comparable with values observed on and around SRS.

Table 11-1. Summary of Pond B Survey Results

	Average	Maximum	Minimum	Remote[a]
Ambient Gamma Radiation[b] (mR/day)	0.29	0.53	0.20	0.21
Vegetation Pathway (pCi/g)				
^{137}Cs (dry weight)	183.1	300.6	79.5	0.29
^{60}Co(dry weight)	0.6	1.4	c	c
Total strontium	10.7	27.4	3.9	0.79
Gross alpha	1.9	12.4	-6.2	0.07
Nonvolatile beta	163.9	385.2	48.9	14
Tritium	5.1	5.9	3.2	0.93
Sediment Pathway (pCi/g)				
^{137}Cs(dry weight)	29.5	67.1	14.0	0.18
^{60}Co(dry weight)	0.77	0.12	c	c
Total strontium	0.02	0.1	0.00	
^{90}Sr[d]				0.07
Gross alpha	1.7	4.2	0.24	
Nonvolatile beta	18.8	32.6	6.9	

[a] "Remote" values are 1987 averages of routine 100-mile-radius vegetation samples and routine Savannah River sediment samples collected from a location above SRS. The "Remote" values consistant for ambient gamma exposure are averages of TLD measurements at the 100-mile-radius locations.
[b] Measured at water level with TLDs.
[c] Less than the lower limit of detection.
[d] Only ^{90}Sr analyzed at remote location.

Measurements of Iodine-129 in Groundwater and Surface Water

The Savannah River Laboratory (SRL) has conducted studies at irregular intervals since 1970 to investigate the ^{129}I content of groundwater and surface water at onsite and offsite locations [Ka87].

Measurements were made by neutron activation analysis. Listed below are some results of previous studies:

- In 1977, iodine-129 was detected in ground water near the F- and H-Area seepage basins.
- In 1979, iodine-129 was detected in ground water near the Radioactive Waste Burial Ground.

Iodine-129 concentrations in the groundwater samples collected during these studies were 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. Figure 11-4 on the following page identifies the on- and offsite locations that showed concentrations of ^{129}I.

Studies in 1977 and 1978 indicated that in surface water, Four Mile Creek was the only SRS stream transporting significant levels of ^{129}I to the Savannah River. Dilution by C-Reactor effluents and the Savannah River reduced the offsite ^{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.

SRL reactivated a quarterly sampling program for ^{129}I in Savannah River water upriver and downriver from SRS in 1986 after five years of dormancy. However, ^{129}I analyses were discontinued in 1987 due to removal of the neutron activation capability at the reactor facilities.

Another method of analysis is by inductively coupled plasma/mass spectrometry. SRL plans to perform ^{129}I analyses on samples collected since 1987 after an

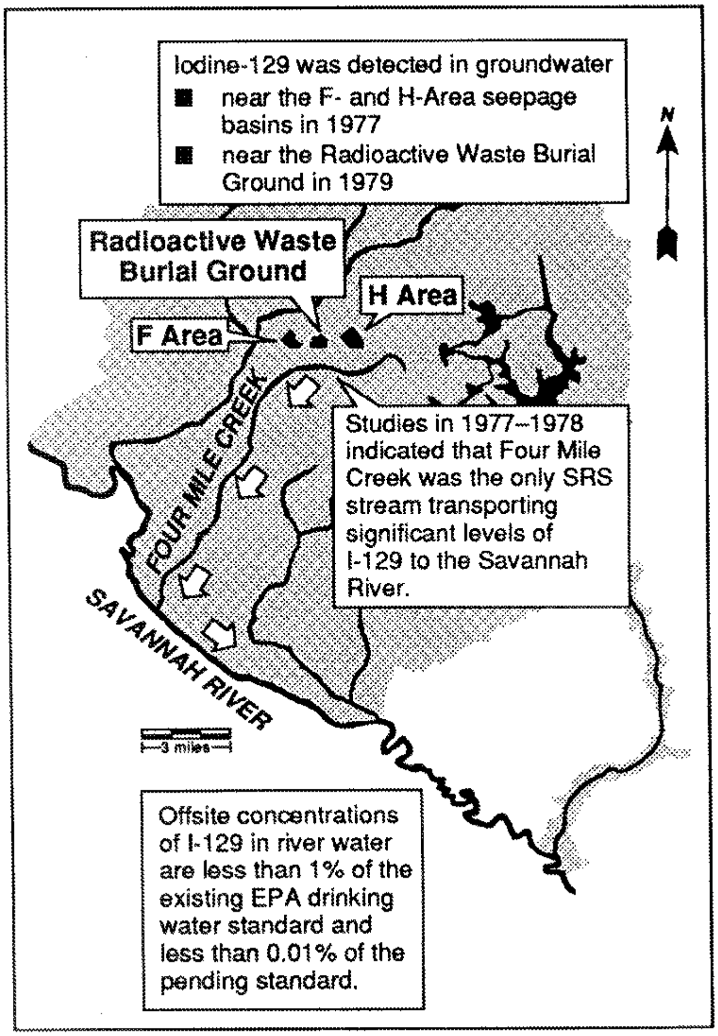


Figure 11-4. SRL conducts studies of ^{129}I in on- and offsite groundwater and surface waters

inductively coupled plasma/mass spectrometer becomes operational in late 1990 or 1991.

Savannah Harbor Sediment Survey

Description of Survey

EMS, in cooperation with the Georgia Department of Natural Resources (GDNR), measured and compared ^{137}Cs concentrations in sediments from the Savannah Harbor area in order to determine environmental impacts resulting from Savannah River Site operations.

In December 1989, EMS and GDNR jointly sampled 20 sediment locations from the Interstate 95 bridge to the city of Savannah, GA and Savannah River Harbor/Port area (see Figure 11-5 on facing page). All major river channels were sampled.

In addition, GDNR collected sediment samples farther downriver in the river mouth and in the Ogeechee River in Georgia for control samples. Approximately 1 gal of sediment was collected at each sampling location.

Survey Results

Concentrations of ^{137}Cs in the Savannah Harbor sediment were at or below minimum detectable levels and are presented in Table 11-8, Vol. II. Based on the limited amount of data collected, no conclusions could be drawn on any effects that SRS operations may have on sediment from the Savannah Harbor. Studies on soil matrices and composition would help in developing a larger and more useful database. These data will aid EMS in developing further offsite sampling plans.

Surveys of Dry Monitoring Wells in F- and H-Area Waste Management Facilities

Health Protection Operations Department takes profile radiation measurements annually in dry monitoring (DM) wells in both the F- and H-Area waste management facilities. The wells are located at points considered most vulnerable to leaks from piping that serves the storage tanks. Figures 11-2 and 11-3, Vol. II show locations of the dry monitoring wells.

Dry monitoring 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 shallow groundwater leaking into the well. The top of the well is either capped or sealed to prevent introducing atmospheric water into the well.

Eleven DM wells that monitor diversion box #1 in F-Area facilities were surveyed in 1989 and all wells showed background radiation levels.

Radiation measurements were taken in 38 additional DM wells installed in a contaminated area near Tank 8 in the F-Area waste management facilities. This contamination is attributed to overfilling the tank in 1961. Radiation levels measured in the Tank 8 wells define the zone of major contamination, as shown in Figure 11-4, Vol. II. Radiation levels

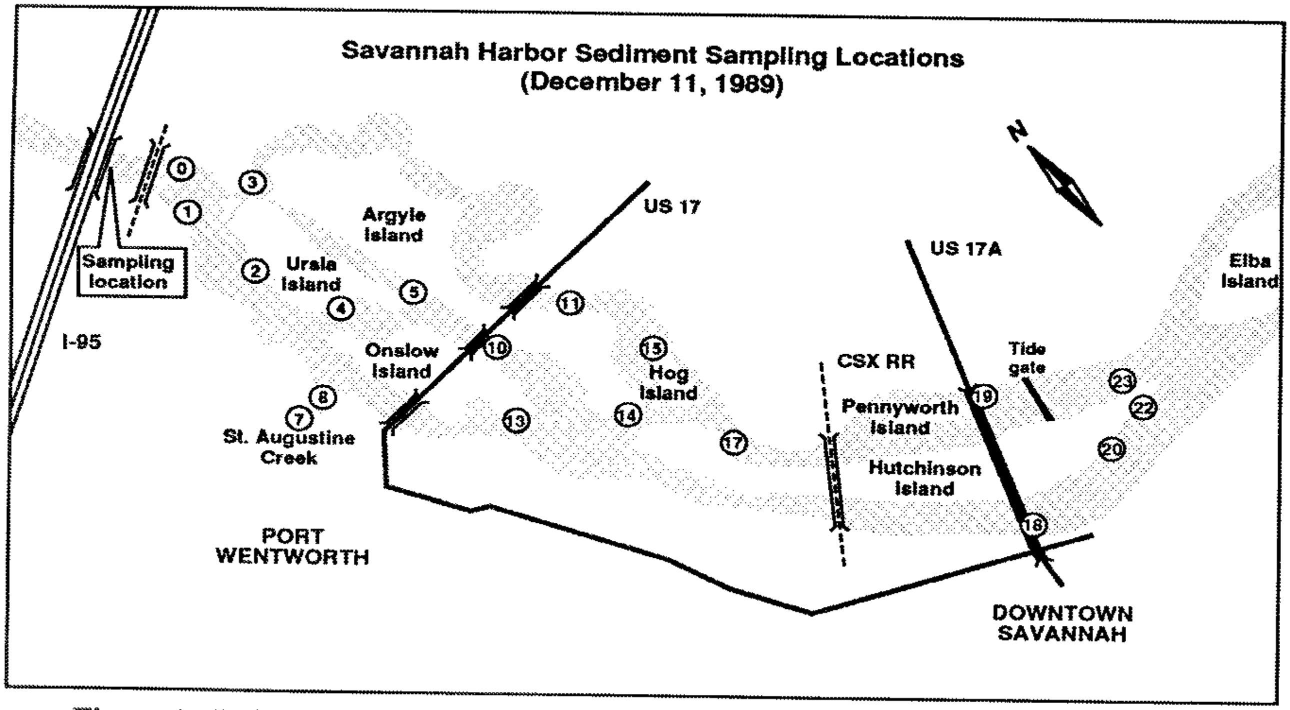


Figure 11-5. Savannah Harbor samples were taken in the vicinity of Savannah, Ga

around Tank 8 remained high during the 1989 survey. The maximum radiation level in the wells was 83 R/hr in RP-6 well at a depth of 18 ft.

Seventeen DM wells in service in the H-Area waste management facilities were surveyed in 1989. These wells showed no significant changes in 1989 from previous years. Radiation levels for dry wells in the F- and H-Area waste management facilities are represented in Figures 11-4 and 11-5, Vol. II.

NONRADIOLOGICAL SURVEYS

Isco/Paddlewheel Sampler Comparison

In 1989, EMS tested a new sampling system, a self-contained unit designed to collect composite samples, manufactured by Isco, Corp. The sampler, shown in Figure 11-6 (right), has a microprocessor-controlled peristaltic pump, control panel, sample collection jug, and a protective case.

As part of the survey, the Isco sampler was tested for ease of use, reliability, and consistency of sample collection. In addition, the Isco system and paddlewheel samplers currently in use at SRS were compared for reproducibility of sample collection volume and radiological analytical results.

All Isco systems proved to be trouble-free and easy to operate. Paddlewheel samplers showed a larger variation in sample volume than the Isco; paddlewheel samplers are not flow-proportional. Rather, the rotation of the paddlewheel is proportional to the velocity of the stream. The larger variation with paddlewheel samplers is likley due to stream flow variations, debris blockage of the paddlewheel, or variations in the alignment of the paddlewheel trough. The Isco sampler avoids these problems because it is a pump.

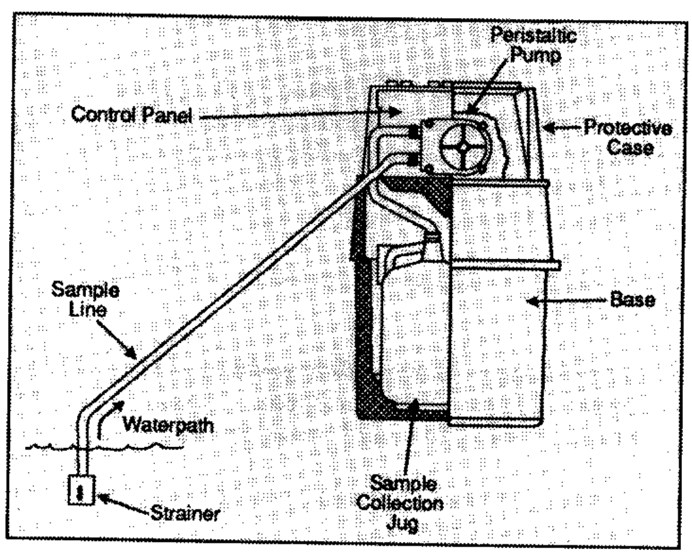


Figure 11-6. Diagram of an Isco sampler

The analytical results from the Isco and paddlewheel samples were similar. Some differences were observed in the results at levels near detection limits, but were attributed to the differences in sampling systems and sampling locations. The paddlewheel continuously collects small volumes of water (several drops), while the Isco collects larger volumes (10 mL) less frequently. Also, the paddlewheel sampler samples only the surface of the stream, while the Isco sampling line can be placed at any depth in the stream to provide a more representative sample.

From the survey results, EMS concluded that the Isco samplers can support a wide variety of sampling applications including flow-proportional sampling. In addition, the samplers provide a high quality sample with easy volume adjustment.

On the basis of the results of this study, an Isco sampler will replace the paddlewheel sampler at sampling location Four Mile-2, a key location in monitoring radioactivity levels in Four Mile Creek. In 1990, the Isco will also be placed at other sampling locations.

Academy of Natural Sciences of Philadelphia—River Quality Surveys

Description of Survey

The Division of Environmental Research of the Academy of Natural Sciences of Philadelphia (ANSP), under contract to WSRC, has carried out continuing surveys of the aquatic environment and water quality of the Savannah River since 1951. These studies are designed to determine the effect, if any, of SRS effluent discharges on general river health.

The ANSP surveys are conducted both upriver at Station 1 (reference station) and downriver from SRS at Station 6. In 1982, these studies were expanded to include Station 5, located below Steel Creek. Survey locations are shown in Figure 11-4 (facing page).

Several types of studies conducted by ANSP since 1951 include:

- detailed surveys every four years of algae and rooted aquatic plants, protozoa, macroinvertebrates, insects, fish, and water chemistry
- quarterly cursory studies of aquatic life to study algae, insects, and fish
- semi-monthly surveys of diatom communities

Diatometer Monitoring

For 26 two-week exposure periods from December 27, 1988 to December 28, 1989, artificial substrates (Catherwood Diatometers®) were deployed on the Savannah River at three sampling sites near SRS. For each exposure period, one sample from each site was analyzed to determine diatom community structure. These analyses provided data on diatom species diversity (community richness) and the relative abundances of all diatoms within the communities that developed on the substrates. Evaluations of water quality among stations and sampling periods were made based on the relative abundance of individual species' populations, the ecological requirements and tolerances of the diatoms, and the diversity of the communities.

As in recent years of study, only minor differences in diatom communities between those at the reference station (Station 1) and those at Station 5 (downriver from the juncture with Steel Creek) were noted. However, the diversity (number of observed species) and dominance (percent dominance) in the diatom communities indicated deteriorating conditions at Station 6 (downriver from the juncture with Lower Three Runs). This trend is most evident for the exposure periods after April 5, 1989 when the number of observed species at Station 6 was less than 100 for 18 of the 20 exposure periods and percent dominance was greater than 80% for 19 of the 20 exposure periods.

In contrast, the number of species usually was greater than 100 (13 of the 20 exposure periods) and percent dominance was usually less than 80% (15 of the 20 exposure periods) at the reference station.

Trends in the relative abundance of the dominant diatom species are not as clear; however, *Gomphonema parvulum*, the dominant species at all three stations, was more abundant at Station 6 than at the other stations.

The 1989 data indicate that few differences existed between the reference station (Station 1) and Station 5 during the study year; however, as in the previous two years, there were marked differences between the reference station and Station 6. These differences, including lower species richness and higher dominance at downriver Station 6 indicate a continued deterioration of water quality at Station 6 with respect to the upriver stations. It is unclear, given the placements of the existing program, whether the poorer water quality at Station 6 is related to opera-

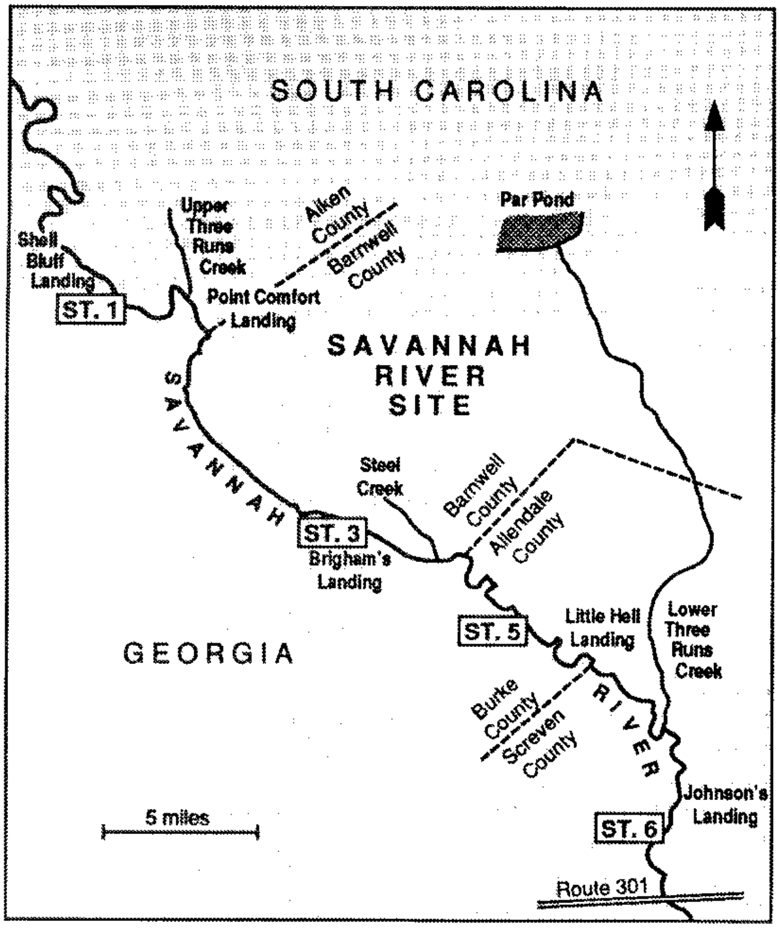


Figure 11-4. ANSP survey locations

tions of the SRS or other activities not related to the SRS which may influence the water quality of Lower Three Runs Creek. This question will be investigated during ANSP's 1991 survey.

Biological Surveys

As part of the continuing long-term biological monitoring studies, ANSP conducted two comprehensive biological surveys of algal, macrophyte, macroinvertebrate, and fish communities of the Savannah River in the vicinity of SRS during June and September 1989. In addition, two cursory surveys of algae, macrophyte and insect communities were carried out during April and November 1989.

Hurricane Hugo moved onto the Georgia/South Carolina coast during the September comprehensive survey. Although high winds and rain resulted in a rapidly increasing river stage, most of the biological and chemical sampling was completed before the study area was affected by the storm.

Preliminary information resulting from the four surveys is summarized below for each major biological group as well as for the physico-chemical parameters that were measured.

Algae and Aquatic Macrophytes

In 1989, algae and aquatic macrophytes were hand collected in the Savannah River on April 5–7 and November 28–30, 1989 at Stations 1, 5, and 6 and on June 26–29 and September 19–21, 1989 at Stations 1, 3 (upriver from the confluence with Steel Creek), 5, and 6.

The algal and aquatic macrophyte communities observed during the April and November studies were similar to the algal and aquatic macrophyte communities observed during previous Savannah River studies.

The field observations and the data available to date for the June and September studies do not indicate any deterioration of water quality when compared to recent Savannah River studies. The numbers of diatom species present during 1989 at each of the four stations were the highest recorded since 1965, with the exception of September 1972.

Non-Insect Macroinvertebrates

Comprehensive surveys were conducted on June 26–29 and September 19–21, 1989 to compare the non-insect macroinvertebrates population diversity among survey Stations 1, 3, 5, and 6 and to compare it to that seen in previous surveys.

Water levels were relatively low during the June survey. On visual inspection, most taxa that typically dominate the area (primarily molluscs and crustacea) were present, with the exception of bivalve molluscs, which had reduced numbers of species at all stations.

In September, non-insect macroinvertebrates were collected at some stations under conditions of rising water levels. Non-insect macroinvertebrates were collected at Station 1 under normal seasonal river height, while the samples from remaining stations were collected in progressively rising river stages. Because macroinvertebrates are collected from natural substrates by hand and by collecting nets, fewer habitats could be examined as the river rose, resulting in a decreased number of species collected.

Laboratory analyses of the June and September samples are ongoing. Detailed findings will be reported to WSRC in a comprehensive survey report in May 1990.

Aquatic Insects

Aquatic insect cursory surveys were conducted on April 5–7 and November 28–30, 1989, while comprehensive surveys were conducted on June 26–29, September 19–21, and October 26—27, 1989. Artificial insect substrates (traps), deployed at stations approximately one month before each field effort, were collected during each survey. In September, ANSP collected insect traps at all four stations before personnel were forced off the river by the rising waters caused by Hurricane Hugo. Hand collections of the river's natural insect substrates were conducted in October.

The patterns of variation exhibited by the aquatic insect population during the 1989 cursory survey were similar to patterns observed during previous years. In particular, significant differences among stations in taxa richness, community evenness, and Shannon-Wiener diversity were again noted. Richness, evenness, and Shannon-Wiener diversity values are all relatively high in areas of good water quality, tending to decline where water quality has become limiting to the growth success of various species. For all of these parameters, the values at Station 1 were significantly less than at either Station 5 or Station 6. The number of species obtained in the qualitative collections was also lower at Station 1, although this trend was much stronger in April than in November.

Hilsenhoff's biotic index ranks species with respect to their ability to tolerate pollution, with the higher index values indicating greater pollution tolerances. In 1989 the biotic index tended to decline downriver and was significantly lower at Station 6 than Station 1. This fact suggests that the degree of pollution tolerance, which characterizes the aquatic insect population, is greater at the upriver station. This pattern implies that water quality is reduced upriver from SRS presumably due to some pollution source located upriver from Station 1 that has a local, adverse effect on the aquatic insect population. The fact that the population's pollution tolerance decreases significantly by Station 6 implies some degree of recovery.

Consistent patterns of variation in taxa richness are also evident in the long-term database on Savannah River aquatic insects that have been collected by ANSP during the last 31 years. Species richness at the upriver reference station has been consistently lower than the downriver stations in recent years. However, the average number of taxa per trap has increased across the various insect groups at all stations, especially during the last 15 years, suggesting that there have been improvements in water quality and habitat during this period.

Although ANSP has not analyzed the June and September trap samples, results from the June comprehensive hand collections indicate that insect diversity was generally higher in 1989 compared to 1984. However, diversity in October 1989 was lower than in 1984, probably due to the adverse effects of Hurricane Hugo on collecting conditions. A detailed statistical analysis of all trap samples will be included in the comprehensive survey report to be issued in May 1990.

Just before the November cursory survey, approximately 54 million gallons of raw sewage was discharged into the Savannah River from the Augusta Sewage Treatment Plant in Augusta, GA. The insect trap data do not suggest that the insect communities in the studied portions of the river were adversely affected by the sewage release.

Fish

Fish collections were made during two surveys—June 23–29, 1989 and September 19–23, 1989 at Stations 1, 3, 5, and 6. Because storms associated with Hurricane Hugo curtailed the September survey, additional collections were taken at Stations 3 and 5 on October 31, 1989. In the summer survey, 40–42 species were caught at Stations 1, 5, and 6, and 46 species were caught at Station 3. In the fall survey, 37–39 species were caught at Stations 1, 3, and 5, and 34 species were caught at Station 6. Overall, 65 different species were caught during the two surveys. Some occurrences noted during the surveys are listed below:

- Spotted bass were usually found further upriver.
- Needlefish were dominant in the summer.
- Several species typical of small tributaries such as Savannah darter and dusky shiner were dominant in the fall survey.

- Species richness at each station was higher in the summer survey than in the fall survey, possibly because of lower collecting effort and efficiency during flood conditions.

Statistical analyses of the fish collection data designed to examine possible differences among stations and between years will be included in the ANSP comprehensive report to be issued in 1990.

Physico-Chemical Parameters of the River

Chemistry sampling was performed during the two comprehensive surveys in June and September. Stations 1, 3, 5, and 6 were sampled for three consecutive days during each survey. Physico-chemical measurements were made onsite at all stations and water samples were collected for subsequent analysis for a variety of parameters including nutrients and metals. Selected fish specimens collected during the comprehensive surveys were prepared for metal analysis.

Preliminary data indicate that there were only minor station differences in the physico-chemical parameters. For both the June and September surveys, silica, nitrite-nitrogen, calcium, total hardness, conductivity, and sulfate were generally higher than the previous comprehensive survey conducted in 1984. Concentrations of nitrate-nitrogen, ortho- and total phosphorus, dissolved organic carbon, alkalinity, total dissolved solids and water temperature were comparable or slightly higher than the previous study. Total Kjeldahl nitrogen, ammonia-nitrogen, pH, and zinc were comparable to the previous survey. Biological oxygen demand and turbidity remained about the same or slightly lower than 1984, while total suspended solids and fecal coliform bacteria counts were lower.

In general, all parameters fell within ranges seen in recent years. Analyses of water samples and fish tissue for metal content will also be included in the comprehensive report to be issued in May 1990.

1989 HIGHLIGHTS

- Soil samples from the Savannah River Swamp had concentrations of ^{137}Cs and ^{90}Sr within ranges observed in recent years. The maximum concentration of ^{137}Cs was 155 pCi/g and of ^{90}Sr was 0.34 pCi/g.

- The 1989 ambient gamma radiation measurements at the Savannah River Swamp were generally lower than the 1988 results, ranging from 0.12 to 0.58 mR/day.

- The highest exposure to mallard ducks residing in Pond B comes from ^{137}Cs in vegetation and sediment. The maximum concentrations of ^{137}Cs were about 300 pCi/g in vegetation and about 67 pCi/g in sediment samples.

- Radiation levels in dry wells near Tank 8 in the F-Area define a zone of contamination from overfilling the tank in 1961. The levels remained high in 1989, with a maximum radiation level of 83 R/hr measured in RP-6 well at a depth of 18 ft.

- The numbers of diatom species present in the Savannah River in 1989 were the highest recorded since 1965, except for September 1972.

Part IV

Environmental Management and Research Programs

12
Savannah River Site Environmental Management Programs

SUMMARY—This chapter summarizes the audits and compliance activities of environmental protection efforts at SRS in 1989. In particular, the compliance history and restoration activities for groundwater, surface water, air and waste sites are reported. In 1989, SRS began closure and reclamation activities for the M-Area settling basin, F- and H-Area seepage basins, and the Mixed Waste Management Facility (MWMF).

In response to the DOE Environmental Restoration and Waste Management Five Year Plan, WSRC developed a Site-Specific Plan that outlines onsite waste management environmental needs and costs for the next five years. WSRC also completed an Environmental Implementation Plan which defines the site's environmental policies and objectives for the same time period.

Finally, results of an environmental self-assessment, and several compliance inspections by onsite and offsite groups are reported. WSRC has implemented an environmental training program for its employees for various topics including RCRA, storage, and environmental regulations.

INTRODUCTION

A major effort at the Savannah River Site (SRS) is to ensure that onsite processes do not adversely impact the environment. Part of this task involves bringing the site into compliance with all applicable environmental regulations and DOE orders. Consequently, the Westinghouse Savannah River Company (WSRC) is developing a comprehensive program to determine the environmental effects of past waste disposal practices and to proceed with remedial action as necessary.

This chapter describes the environmental management and compliance activities conducted at SRS during 1989.

COMPLIANCE SUMMARY

Comprehensive Environmental Response, Compensation, and Liability Act

National Priority List

On December 21, 1989, SRS was officially included on the National Priority List, also known as the Superfund list. As a result, SRS must meet the remedial response provisions of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA).

To satisfy one of the CERCLA requirements, DOE is developing a formal tri-party agreement with the Environmental Protection Agency (EPA), and the

South Carolina Department of Health and Environmental Control (SCDHEC). The agreement will outline a plan for cleaning up and restoring waste sites, the method of remediation, and the schedules for producing work plans and site investigations. The parties must also reach agreement on coordinating Resource Conservation and Recovery Act (RCRA) and CERCLA requirements covering waste sites. Discussions on this agreement, known as a Federal Facilities Agreement, began in 1989.

Before SRS became a Superfund site, closure of several SRS waste sites was underway as required by RCRA hazardous waste regulations. Other closures were in the planning stages. These closures are discussed in the "Waste Site Closures" section of this chapter.

CERCLA 'Superfund' Reportable Releases

A sitewide procedure from Site Item Reportable Issue Management (SIRIM) MRP 4.072.410, requires reporting of all oil and chemical releases to the Technical Support Center. The Technical Support Center then notifies the spill coordinator who ensures that the spill is reported to DOE, SCDHEC, and EPA as appropriate to satisfy regulatory requirements.

CERCLA requires that notification to the EPA be made for any non-permitted release to the environment exceeding its reportable quantity.

Under CERCLA, a release is defined broadly so that almost any substance that enters the environment is covered. Releases include spilling, leaking, and pumping. Environment is defined as any water, land, or ambient air. The only things that are not considered the environment under CERCLA are the indoor air and the inside of a building.

A reportable quantity is the amount of substance over a specified limit that, if released, requires reporting to the EPA. The reportable quantity for a hazardous substance, any substance specifically listed under CERCLA, is variable depending on the substance. By reference, CERCLA hazardous substances include substances such as those listed in the Clean Air Act, Clean Water Act, Toxic Substances Control Act, and the Resource Conservation and Recovery Act.

In general, if a substance is spilled on a concrete floor inside a building, it is not reportable under CERCLA because it does not reach the environment. However if the same spill were to go down a drain to a sewer line, it would be reportable if it were above its reportable quantity. All chemical releases to the atmosphere (e.g., chlorine gas) are considered releases for reporting purposes.

SRS had two Superfund reportable releases during 1989—the first Superfund reportable releases at the site since 1986. The Superfund reportable releases during 1989 were reported to DOE, SCDHEC, and EPA.

The first release occurred when acidic wastewater containing trace quantities of radioactivity leaked from a broken terra-cotta pipe in F Area near the chemical separations facility. Following discovery of the leak, WSRC tested all similar piping and repaired or replaced the piping as needed. Workers excavated soil contaminated by the release and disposed of it in the low-level waste burial ground.

In the second release, a leak of high-level radioactive waste was discovered in piping used to transfer waste from a processing area into a waste storage tank in H Area. WSRC Waste Management Department isolated the pipe and removed it from service. Soils contaminated by the spill were excavated and disposed of in a low-level waste burial ground. The high level waste pipes have double walls with leak detection systems, but were still involved in these releases. The Waste Management Department is evaluating operating procedures to determine how to prevent a recurrence in similar piping.

Resource Conservation and Recovery Act

Waste Site Closures

The WSRC waste management policy calls for the onsite treatment and disposal of wastes whenever practical. Currently, SRS has 262 waste management units that are specific defined sites or areas of waste or contamination. Active and inactive waste sites comprise 207 of these units, while the remaining areas are contaminated from spills, leaks, or other similar events. The waste management units at SRS may contain the following materials:

- radioactive materials
- hazardous materials
- mixture of radioactive and hazardous materials
- nonhazardous materials
- nonradioactive materials

M-Area basin closure is projected for completion in 1990

Five groundwater units located in A, M, F, H, and TNX Areas are being investigated or treated for contamination. Currently, WSRC is closing 10 units and is investigating the environmental impact and specific remediation requirements for each waste site.

M-Area Settling Basin
Final closure stages were underway at the M-Area settling basin at the end of 1989. To close the basin, water in the basin was removed and cleaned at a temporary treatment facility; then discharged through a National Pollutant Discharge and Elimination System (NPDES) outfall. The contaminated soils were stabilized with cement. The basin was filled with soil and then capped using clay and a special fabric to prevent water from passing into the basin. In the final closure stage, WSRC will plant grass over the former basin, and an adjacent Carolina bay will be replanted to restore it to a natural wetland.

While in operation, the M-Area settling basin contained effluents from the fuel and target fabrication processes in M Area. Degreasing solvents from these processes seeped out of the basin and contaminated the groundwater. The contamination is confined to the site and is not expected to affect offsite groundwater. To decontaminate the area, WSRC is pumping the onsite groundwater through a stripping column that exposes it to air, where solvents are evaporated and then degraded naturally by sunlight.

F- and H-Area Seepage Basins
WSRC began closing the seepage basins in F and H Areas during 1989. These basins received low-level radioactive wastewater from the chemical separations areas in F and H Areas until 1988. The Effluent Treatment Facility (ETF) now treats water formerly discharged to the basins. The basins have been filled with carbonate rock, furnace slag, and gravel to stabilize the soil and chemicals in the basin. The closure process was about 20% complete at the end of 1989.

Mixed Waste Management Facility
Closure of the Mixed Waste Management Facility (MWMF), which received hazardous wastes contaminated with radioactivity, began in February 1989. The closure project involves 58 of the 195 acres of the existing low-level waste burial ground. Remediation measures include compacting the covered waste trenches and constructing a 3-ft clay cap over the facility to prevent water from passing through the wastes. The project was approximately 35% complete at the end of 1989.

In 1989, SCDHEC indicated that post-closure plans for groundwater monitoring of the MWMF, which had been submitted, were inadequate. In response, plans were developed to install additional monitoring wells for additional data collection. SRS and SCDHEC will agree on closure of the facility after MWMF monitoring data is submitted for one year.

Closure plans are currently under review for the following waste sites:

- Savannah River Laboratory seepage basins
- Metallurgical Laboratory seepage basin

- acid/caustic basins
- new TNX seepage basin

RCRA Corrective Action Program
The SRS hazardous waste permit (RCRA Part B Permit), issued in 1987, requires the site to maintain a program for investigating hazardous waste units. This program, called a RCRA Facility Investigation (RFI) Program, outlines how WSRC will investigate the environmental impacts of the waste areas.

EPA approved the site RFI program in September 1989. Seventy-nine waste units are currently in the RFI program with site-specific work plans submitted for three of the units. WSRC will submit site-specific work plans for investigating all 79 waste units as required by the RFI program schedule.

National Pollutant Discharge Elimination System

Some SRS streams, including L Lake and Par Pond, receive treated wastewater discharges containing small concentrations of radionuclides, heated water, and traces of typical industrial chemicals from SRS operations. These bodies of water are monitored for nonradiological constituents to ensure that the discharge limits set under the National Pollutant Discharge Elimination System (NPDES) permit are not exceeded during the year.

Discharges are currently monitored through a system of 76 permitted NPDES outfalls. The permit covers discharges from 31 SRS water treatment facilities including the F- and H-Area Effluent Treatment Facility (ETF), similar effluent treatment plants in the fuel and target fabrication area and the equipment testing area, and sanitary sewage treatment facilities. Discharge limits are set for each treatment facility to ensure that SRS operations will not adversely impact aquatic life or decrease water quality.

As shown in Figure 12-1(facing page), SRS NPDES permit compliance has improved continuously over the past six years, reaching a 99.9% compliance rate in 1989. Only nine of the 6,859 analyses performed during 1989 exceeded NPDES permit limits. The NPDES monitoring program is discussed in Chapter 5 of this report.

SRS NPDES Program

The National Pollutant Discharge Elimination System (NPDES) is the primary regulator of the Clean Water Act of 1972. This system, regulated by SCDHEC under the authority of the EPA, prohibits the release of effluents into surface waters without a permit.

The SRS NPDES permit, which applies to streams, reservoirs, and all wetlands, ensures that the quality of surface water is protected on SRS.

1989 Activities

76 active permitted outfalls

6,859 compliance analyses

99.9% compliance rate

Clean Air Act

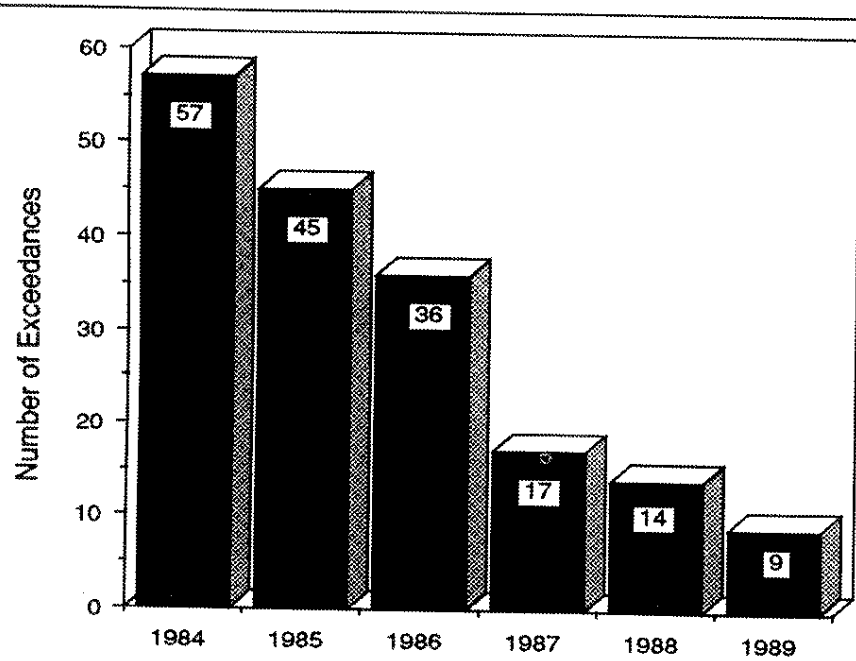
The federal Clean Air Act establishes air quality and emission limits throughout the United States. SCDHEC, which regulates most provisions of the Clean Air Act for South Carolina, conducted over 100 inspections at SRS and noted one noncompliance in 1989.

SRS has 13 air quality permits covering 130 point sources for air emissions. The WSRC is currently assessing all its facilities to ensure that all release points have been identified and are permitted.

CURRENT ISSUES AND ACTIONS

Environmental Protection Programs

Environmental Restoration and Waste Management Plan
During 1989, the Department of Energy (DOE) issued an Environmental Restoration and Waste Management Five Year Plan outlining waste management and environmental restoration plans for all DOE sites. Based on the Five Year Plan, WSRC developed a Site-Specific Plan that detailed onsite



	1984	1985	1986	1987	1988	1989
No. Parameters	3162	3750	6240	6560	6250	6859
% Compliance	98.2	98.8	99.4	99.7	99.8	99.9

Figure 12-1. Savannah River Site NPDES compliance history

waste management, and environmental needs and costs for the next five budget years.

Over the next five years, WSRC management projects a total expenditure of $4.2 billion on environmental and waste management activities. Nearly $460 million of the money will be used specifically for environmental restoration projects to correct the effects of past waste disposal practices.

Environmental Implementation Plan
During 1989, WSRC completed an Environmental Implementation Plan (EIP), which defines the site's environmental policies, objectives, and implementation strategies for the next five fiscal years (1989–1994). The EIP outlines specific programs to maintain air quality, prevent surface water and groundwater contamination, protect wildlife, and properly handle wastes. The EIP also sets manpower, budget, and activity requirements for meeting these objectives.

Waste Minimization
WSRC developed a waste volume minimization program to decrease the volume of solid waste generated by site operations. The Waste Minimization Program consolidates all waste prevention activities into a centralized site program, headed by the Waste Action Team. This team, which solicits employee input, is responsible for developing plans, guidance, goals, and documentation for the Waste Minimization Program. The availability of resource materials, training of personnel, and waste awareness activities are key features of the program, which should lead to waste reduction and recycling of waste materials at SRS.

Each department and site facility selects a waste coordinator who acts as liaison between the department and the Waste Action Team. They identify and characterize their specific waste streams. Each department also evaluates and implements methods to reduce or eliminate waste generation, and prioritizes waste streams for the minimization project.

Natural Resources Defense Council Lawsuit
In May 1988, SRS, SCDHEC, and NRDC entered into a consent decree to resolve a lawsuit by NRDC and SCDHEC regarding SRS compliance with RCRA. The decree established several compliance milestones and Table 12-1 (following page) summarizes those milestones met in 1989.

Salvage Yard Silver Recovery
SRS notified SCDHEC that spent photographic fixer solution was being stored at SRS longer than RCRA allows. SCDHEC and SRS reached a settlement agreement, and the terms were approved by DOE. The fixer solution was shipped offsite and is no longer reclaimed in the Salvage Yard. SCDHEC has closed the issue.

Air Quality Programs

National Emissions Standards of Hazardous Air Pollutants
The National Emissions Standards of Hazardous Air Pollutants (NESHAP), one section of the Clean Air Act, sets air quality standards for air emissions con-

Table 12-1
Milestones Completed in 1989 for the Natural Resources Defense Council Lawsuit (NRDC)

Date	Action
7/7/89	Submitted Metallurgical Laboratory Seepage Basin Permit Application to SCDHEC. Additional groundwater monitoring wells were installed in October 1989
8/18/89	Submitted Metallurgical Laboratory Seepage Basin Closure Plan to SCDHEC
9/19/89	Submitted Savannah River Laboratory Seepage Basins Site Assessment to SCDHEC and NRDC

taining hazardous constituents such as radionuclides and benzene.

Benzene is produced during waste management processes that separate high-level radioactive wastes from less radioactive salts. WSRC does not expect new benzene regulations to affect current waste management processes, but gasoline stations at the site may require some process-modification as a result of the new regulations.

During 1989, the EPA issued new regulations for determining the radionuclide levels in air emissions, and radiation dose from air emissions. As a result, WSRC will change its dose calculation methods and the operating guidance issued to personnel in 1990. Current methods for determining radiation dose to the public appear to be as conservative, if not more conservative, than the new methods.

The Environmental Protection Section (EPS) issued a draft NESHAP Radionuclide Compliance Manual during 1989 to provide guidance on regulation requirements, administrative procedures that will enhance regulatory compliance, and technical guidance in preparing applications for EPA approval. The draft manual, being revised to incorporate the new regulations, is scheduled for release in August 1990.

Asbestos Removal Program

Early construction projects at the SRS used a significant amount of asbestos in fireproof wallboard (transite), gasket materials, ceiling tile, insulation, floor tiles, roofing felt, and electric wiring. Consequently, the site has maintained an active asbestos removal program for the past six years.

WSRC removes asbestos when it is found during maintenance and renovations of equipment and buildings. Only personnel trained and licensed by SCDHEC perform the asbestos removal.

In 1989, WSRC removed 66,568 linear feet and 122,862 square feet of asbestos. This is roughly equivalent to 12.6 miles of linear asbestos used in materials like pipe insulation and 2.73 football fields of asbestos building materials.

During 1989, WSRC began a program to identify and label all friable asbestos onsite. Asbestos is friable when it can be crumbled or pulverized with hand pressure when dry.

Safe Drinking Water Act

On July 28, 1989, the drinking water system in Building 722-5A was down for repair. At that time, WSRC discovered that when the system was installed in January 1988, it had been connected inadvertantly to the area process sewer system. The system was disconnected and SCDHEC was notified of the error. SRS implemented the corrective actions developed with SCDHEC and properly reconnected the system.

Groundwater Programs

SRS has an extensive groundwater monitoring program which is discussed in Chapter 6, with the 1989 monitoring data compiled in Volume II of this report. Several groundwater monitoring projects completed during 1989 are listed below:

- The Hydrogeologic Data Collection Procedures, WSRC-3Q, (formerly, DPSOP 254) were revised to reflect current and recommended practices.
- WSRC initiated a redevelopment program of existing monitoring wells around the F- and H-Areas seepage basins and the MWMF to rehabilitate some of the monitoring wells. The redevelopment techniques, employed to lower pH levels and to increase pumping rates, were successful for several monitoring wells.

- In October a draft report titled, "Assessment of SRS Groundwater Monitoring Wells Impacted by Turbidity", was submitted to DOE for review and comments.

- A computer database, redesigned to collect well construction information, can generate water-well records that are required by SCDHEC for all well installations.

WSRC produces several specific groundwater reports during the year as required by various state and federal environmental regulations. Groundwater reports submitted to SCDHEC during 1989 are listed below:

- quarterly "Groundwater Quality Assessment" reports for F and H Area, and the MWMF

- quarterly "Groundwater Monitoring" reports for the F-, H-, K-, and P-Area acid/caustic basins

- quarterly "Groundwater Monitoring and Corrective Action" reports for M Area

The South Carolina Water Use and Coordination Act stipulates that all users of 100,000 gallons or more of water per day on any day must report their water use for that quarter to the South Carolina Water Resources Commission and the maximum amount of water withdrawn in a single day for each month of the quarter.

During 1989, WSRC compiled four quarterly reports on water usage from nearly 50 production wells operating at SRS. The total amount of water use by the site in 1989 was approximately 68 billion gallons with an average use of 17 billion gallons per quarter (5.7 billion gallons per month).

Underground Storage Tanks

SCDHEC regulates underground storage tanks, which are a potential source of groundwater contamination. In 1989, there were 102 underground storage tanks for the storage of petroleum products such as gasoline and diesel fuel and hazardous substances as defined by CERCLA.

During 1989, WSRC tested 25 of 27 regulated tanks placed in service prior to 1965 for leakage. The remaining two tanks are out of service until testing is completed in January 1990. The tests indicated leakage in five tanks: four diesel fuel tanks and one gasoline tank. All of the tanks are located in the Central Shops area. The fuel was removed from the tanks and WSRC is conducting an assessment of the area to determine the environmental impact.

DOE began a program to abandon or remove all regulated single-wall tanks at SRS by 1995. During 1989, 13 single-wall tanks were removed. In areas where underground tanks are still needed, WSRC will replace the tanks with double-wall tanks having leak detection systems. Six of the 13 tanks removed in 1989 were replaced with new tanks.

Surface Water Programs

Thermal Mitigation

SRS streams are also monitored for compliance with water quality standards regarding temperature, which are established by the SRS-NPDES permit. Pen Branch, which receives discharges from K Reactor, has shown adverse thermal effects from SRS operations. A consent agreement between SRS and South Carolina mandates that SRS construct and operate a cooling tower by 1992 to ensure that discharged water temperatures do not exceed 90°F.

When K Reactor is operating, water is discharged into Pen Branch at temperatures of 130 to 180°F. During 1989, construction of a recirculating cooling tower began that is designed to bring the discharge temperature below the 90°F regulatory limit.

The project will reduce the discharge flow rate from 179,000 gal/min to a sustained constant flow of 20,000 gal/min regardless of whether or not the reactor and its associated cooling towers are operating. This lower flow rate will reduce streambank erosion and the associated stress of fluctuating flow on plant and animal life in Pen Branch.

Greenpeace Report on Cesium-137 in the Savannah River Estuary

On August 7, 1989, Greenpeace issued a press release on the publication of their report, "Rad-Scan on the Savannah River Estuary". The release stated that ^{137}Cs was detected in the dredge material taken from the mouth of the Savannah River. Initial SRS analyses indicate that ^{137}Cs levels reported are within the expected levels for radioactive fallout in an estuary and are well below regulatory and health risk levels. The Georgia Department of Natural Resources(GDNR) issued a statement that reached similar conclusions.

ENVIRONMENTAL PERMITS

Environmental permits, including permit number, type of permit, and the permitted source are listed in Appendix E of Volume I.

NATIONAL ENVIRONMENTAL POLICY ACT ACTIVITIES

The National Environmental Policy Act (NEPA) provides a means to evaluate the potential environmental impacts of proposed federal actions and to examine alternatives to those actions. A formal review program for NEPA compliance was established at SRS in 1982.

Since then, approximately 200 to 300 NEPA reviews and associated documentations are conducted every year, and in 1989, WSRC conducted 237 reviews. WSRC documents each review through formal Memorandums-To-File, Environmental Assessments, or Environmental Impact Statements (EIS).

Several NEPA activities conducted during 1989 include the following:

- An Environmental Assessment on the planned Consolidated Incineration Facility in H Area was submitted to DOE for review in December 1989. This facility will treat certain hazardous and mixed wastes.
- An Environmental Analysis of the Defense Waste Processing Facility (DWPF) modifications was prepared and submitted to DOE in September 1989 and later revised. This Environmental Analysis was developed to determine the need for preparing a supplement to the prepared EIS on operations of the DWPF.
- In 1989, DOE proposed sending transuranic waste from Rocky Flats to other DOE sites including SRS. If the waste were sent to SRS, it would be processed in the Transuranic (TRU) Waste Facility, packaged in TRU packs, and shipped to the Waste Isolation Pilot Plant in New Mexico. The Savannah River Site collected data in anticipation of an Environmental Assessment to determine the impact to site operations if any of this waste is sent to the site.
- In March 1989, DOE published a Notice of Intent to prepare an EIS on the continued operation of K-, L-, and P- Reactors. Public meetings on the scope of the EIS were held during April in Aiken and Columbia, SC and in Savannah, GA. Engineers and scientists at SRS gathered technical data and made calculations to determine the safety and environmental effects of continued reactor operation for the EIS. The EIS is approximately 60% complete and a draft EIS is expected to be available for public review and comment in the second quarter of 1990.

NEPA Activities at SRS

The National Environmental Policy Act (NEPA) of 1969, the Council on Environmental Quality implementing regulations (40CFR 1500-1508), and DOE guidelines (52 FR 47662) require that environmental factors during the planning and assessment process for all proposed federal actions be considered. The NEPA Group of EPS prepares and coordinates NEPA documentation for SRS/SRL activities under oversight from DOE-Savannah River (DOE-SR). The NEPA group manages the transmittal of NEPA documentation and information to the DOE-SR.

In December 1989, an Environmental Assessment for planned consolidated Incineration Facility was submitted to DOE.

NEPA ACTIVITIES —1989
Memoranda-To-File

- 100-Area Fire Station
- Fire Alarm and Safeguards Support Building, A Area
- Engineering Complex, B Area
- Primary and Backup Domestic Water Well, D Area
- Receiving and Storage Warehouse Facilities, Central Shops
- Reactor Charge/Discharge Training Facility

- The SRS reactors are currently the only operational production reactors that supply tritium and plutonium for the nation's weapons program. Because these reactors are aging, one or more new production reactors (NPR) were proposed to replace the older reactors at one or more government-owned sites. DOE is preparing an EIS that outlines options for reactor types, siting, construction, and operation for the NPR, while a site-selection committee is evaluating possible locations onsite. A draft EIS is scheduled for release in early 1991, and the final document, including the Record of Decision, should be complete by the end of 1991.

APPRAISALS OF ENVIRONMENTAL PROGRAMS AND FACILITIES

The number of audits, appraisals, and surveillances has increased significantly over the past several years (Figure 12-2), with many internal and external organizations participating in these activities. Most audits, appraisals, and surveillances in 1989 focused on compliance with regulatory issues, inspections of facilities, and site programs dealing with environment, safety, and industrial hygiene.

Internal Reviews

Environmental Self-Assessment

WSRC conducted an extensive self-assessment during the summer of 1989 to monitor compliance with environmental regulations. WSRC identified 333 noncompliance items and by the end of the year, had resolved 311 of these and developed plans or procedures to resolve the remaining 22 items.

The assessment also identified 25 "gray" issues—areas where compliance and applicability of regulations were unclear. Since the assessment, 11 "gray" issues were closed; eight remain unresolved, but will be addressed through agreements with regulatory authorities and seven issues are currently being evaluated internally at SRS.

Several "gray" issues pertain to SRS wastes containing both hazardous and radioactive contaminants. As an example, the Resource Conservation Recovery Act (RCRA) places restrictions on the storage and land disposal of certain hazardous constituents. Thus, these wastes cannot be treated or disposed of through conventional methods for RCRA compliance. DOE, EPA, and SCDHEC will develop an agreement on proper handling of these wastes through a Federal Facilities Compliance Agreement.

Comprehensive Environmental Protection Evaluation Program

DOE Savannah River Site Environmental Division (DOE/SR-ED) conducts environmental oversight evaluations under the Comprehensive Environmental Protection Evaluation Program (CEPEP). In 1989, DOE/SR-ED conducted two major CEPEP evaluations in the areas of environmental radiological release monitoring and hazardous waste storage.

DOE/SR-ED also expanded its surveillance activities to investigate compliance-related concerns associated with emergencies, to randomly evaluate site programs and facilities, and to supplement other CEPEP evaluations. In 1989, they completed 37 evaluations of spills and releases, drinking water systems, waste sites, water treatment systems, and waste storage.

DOE/SR-ED issued nine final reports in 1989 following CEPEP evaluations:

- Nonhazardous Solid Waste Management Appraisal
- Satellite and Staging Area Inspection
- Water Supply Treatment Operator Certification Appraisal
- Water Pollution Control Program (NPDES) Appraisal
- Discharge of Dredged and Fill Material Appraisal
- Groundwater Facility and Services Appraisal
- Nonradiological Air Pollution Control Emissions Sources Appraisal
- Savannah River Ecology Laboratory (SREL) Radiological and Solid Waste Management Appraisal
- Hazardous Waste Management Sources and Waste Streams Appraisal (U.S. Forestry Service)

While most findings in these reports dealt with deficiencies in administrative matters, none of the

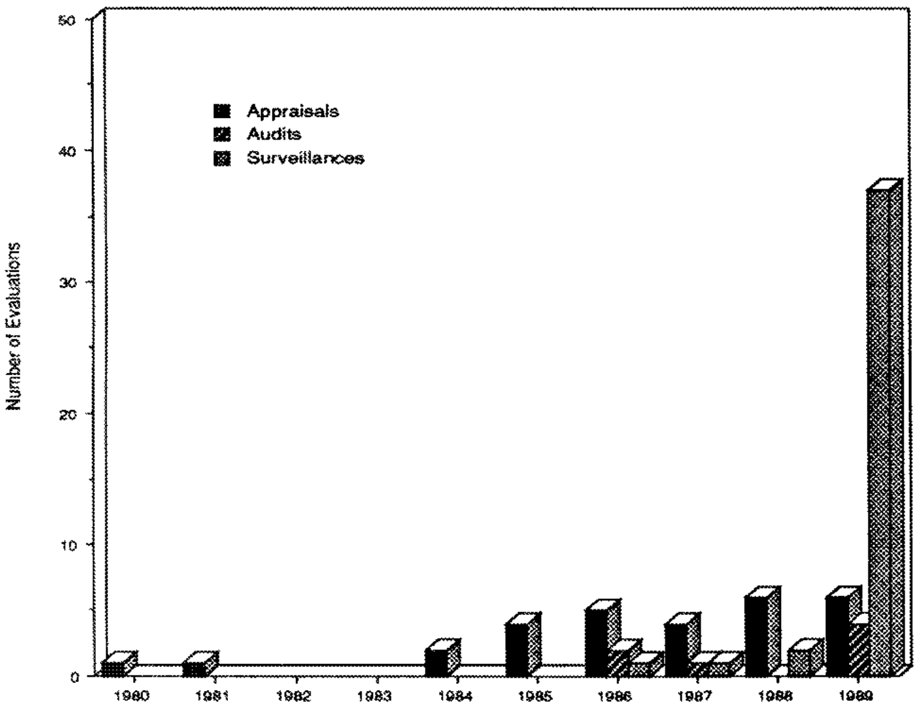


Figure 12-2. Appraisals, audits and surveillances of SRS programs

findings revealed an imminent threat to human health or the environment. However, correction of the findings is underway.

Westinghouse Environmental Affairs Program Review

Prior to the Westinghouse transition, a Westinghouse Environmental Affairs Program Review/Audit was conducted from January 31–February 3, 1989 to assess the status of specific programs issues related to environment, safety, and industrial hygiene.

WSRC, with the help of EPS, conducted management and facility appraisals under the Comprehensive Environmental Compliance Assurance Plan from June 28–September 7, 1989 on 19 site organizations. EPS focused on RCRA compliance in evaluating 19 site organizations. The results were reported to DOE/SR-ED, an action plan for resolving the items was completed, and the status of the resulting actions were reported to DOE biweekly. These activities were verified to ensure completion of the corrective actions.

External Reviews

Compliance Inspections

The EPA and SCDHEC continued onsite evaluations in 1989, with the annual EPA and SCDHEC Compliance Evaluation Inspection on March 13–17, 1989. The inspection focused on Compliance with RCRA regulations. WSRC corrected and SCDHEC verified the 11 findings that resulted from this evaluation. Six of these finding dealt with inspections of facilities and equipment. Other findings were in the areas of training, storage, and documentation.

In addition to the Compliance Evaluation Inspection, SCDHEC also conducted two other inspections in 1989. An audit of the continuous emissions monitor was conducted on May 17, 1989 and the annual NPDES compliance sampling inspection was done on November 6–17, 1989. WSRC addressed the two areas of noncompliance cited while the inspections were held.

Academy of Natural Sciences of Philadelphia Review

A panel from the Academy of Natural Sciences of Philadelphia visited SRS in May 1989 as part of an audit of all DOE sites and contractors. The audit focused on the areas of environment, safety, health, and management. The findings of this audit are expected to be submitted to WSRC in 1990.

OTHER ENVIRONMENTAL ACTIVITIES

Environmental Training Programs

In 1989, the Environmental Protection Section (EPS) provided the following environmental training programs for SRS employees and managers:

- Government Institutes, Inc. conducted three sessions of "Basic Environmental Regulations" at SRS. About 150 senior managers, environmental professionals and other staff members from across the site attended the two-day course.

- Employees at the Defense Waste Processing Facility (DWPF) attended a pilot program called "Spill Response Training" that uses computer-aided instruction. If evaluations suggest the course is effective, similar programs will be given across the site.

- Professional employees hired by WSRC receive an Employee Orientation Seminar that includes a section on environmental protection at SRS. Nearly 1,600 employees attended this seminar during 1989.

- "RCRA and 90-Day Storage" is a course that was developed for managers and coordinators of hazardous waste storage areas. In the future, the course may be extended to personnel in the Construction and Reactor departments.

- "Right-to-Know and 90-Day Storage," a course for personnel in the Procurement and Materials Management Department, began in 1989.

1989 HIGHLIGHTS

- On December 21, 1989, SRS was officially included on the National Priority or Superfund List. This requires that SRS meet the provisions of the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA).

- In a DOE program designed to abandon or remove all regulated single-wall tanks at SRS by 1995, 13 single-walled tanks were removed in 1989. Six were replaced with double-walled tanks having leak detection systems.

- SRS NPDES permit compliance has improved again, with a 99.9% compliance rate in 1989. Only nine of the 6,859 analyses exceeded NPDES permit limits.

- In 1989, SRS had two Superfund reportable releases— the first since 1986.

- Over the next five years, SRS will spend $4.2 billion on environmental and waste management activities. Nearly $460 million of this money will be used for environmental restoration projects.

13 Savannah River Laboratory Environmental Management and Research Programs

SUMMARY—This chapter summarizes the environmental research programs performed by the Environmental Technology Section and the Environmental Sciences Section of the Savannah River Laboratory (SRL). The research activities cover a range of environmental areas, including dosimetry of the SRS reactors, airborne and aqueous radionuclide effluents studies, development of the ultra-low level mass spectrometry facilities, and emergency response capabilities based on SRL's Weather INformation and Display (WIND) System.

Activities to meet permit or environmental impact statement requirements were supported by the development of the IMPACT computer system which will improve the quality of SRS environmental assessments. Compliance with Section 316(a) of the Clean Water Act is being demonstrated for K-Reactor discharges into Pen Branch and Indian Grave Branch, the 400-D Area outfall into Beaver Dam Creek, and L-Reactor effluents into L Lake and Steel Creek.

Finally, numerous research activities are directed toward determining the nature and distribution of SRS pollutants, and outlining possible remediation plans.

INTRODUCTION

The Environmental Technology Section (SRL/ETS) and the Environmental Sciences Section (SRL/ESS) of the Savannah River Laboratory (SRL) conduct ongoing environmental management and research programs in support of SRS operations. This chapter summarizes the activities performed by these groups in 1989.

ENVIRONMENTAL TECHNOLOGY SECTION

Environmental Dosimetry

New Production Reactor Environmental Impact Statement

In 1989, the Environmental Dosimetry Group of SRL estimated the maximum individual and collective (population) doses resulting from operation of a New Production Reactor (NPR) at SRS and also evaluated health risks from normal operations of the new reactor and support facility, accidental releases from support facilities, and onsite transportation. These dose estimates will be included in the Environmental Impact Statement (EIS) scheduled for release in 1991. Estimated doses from normal operations of the NPR reactor and support facilities were less than 1% of the annual Central Savannah River Area (CSRA) natural background radiation level of 295 mrem.

Reactor Operations Environmental Impact Statement

An EIS was prepared for operation of the three functional SRS reactors. The Environmental Dosimetry Group provided support for the EIS by performing dose calculations considering operations of one, two, and all three reactors. Based on the calculations, if all three reactors operated at full power, the maximum individual's dose is expected to increase by approximately 0.5% over the annual CSRA natural background radiation level of 295 mrem. The EIS is expected to be released in mid-1990 prior to restart of the SRS reactors.

Radiological Assessment Program
A comprehensive study of radionuclides in and around SRS was initiated in 1989. The program objectives of the study included compiling and interpreting specific radionuclide monitoring data and identifying areas requiring additional study.

The SRL and the Savannah River Ecology Laboratory (SREL) researchers are currently reviewing data on a radionuclide-specific basis. Activities in 1989 focused on the characterization of tritium in the SRS environment. Annual tritium release data from site startup through 1988 were collected to calculate offsite doses from releases of those radionuclides.

SRL and SREL also estimated concentrations of tritium in the atmosphere, surface water, and groundwater. Comparable studies of ^{134}Cs, ^{137}Cs, ^{129}I, ^{131}I, ^{235}U, and ^{238}U are now underway.

Radionuclide Effluent Studies

Long-Lived Airborne Radioisotopes
New ^{14}C sampling systems were installed in F and H Areas which enable direct recordings of air flow data for more accurate emission calculations. Identical sampling systems, constructed for use in reactor areas, will be installed when clearance is granted for placement of the sampling units.

Samples prepared using a new sample preparation system for ^{14}C analysis, will be counted by liquid scintillation. This system should provide sensitivity that compares with gas-flow proportional counters having anticoincidence shielding. The new system will also allow analysis of vegetation and other biosamples for the first time.

Iodine-129 was monitored for EPA compliance at both separation areas (F and H Areas) and the three functional reactor areas (P, K, and L Areas). Existing Environmental Monitoring sampling systems—charcoal cartridges—were used for this purpose.

Uranium Analysis by Laser Fluorescence
The laser fluorescence technique for chemical uranium analysis in surface waters is valuable for monitoring concentration changes in streams. Laser fluorescence is also valuable in screening samples before alpha spectrometry or mass spectrometry analysis.

The continued use of this system for analysis of SRS stream water allows plotting of yearly uranium concentration trends, such as that shown in Figure 13-1 (below). Further developmental work is in progress to extend the detection limit below the current 1.0 µg/L level.

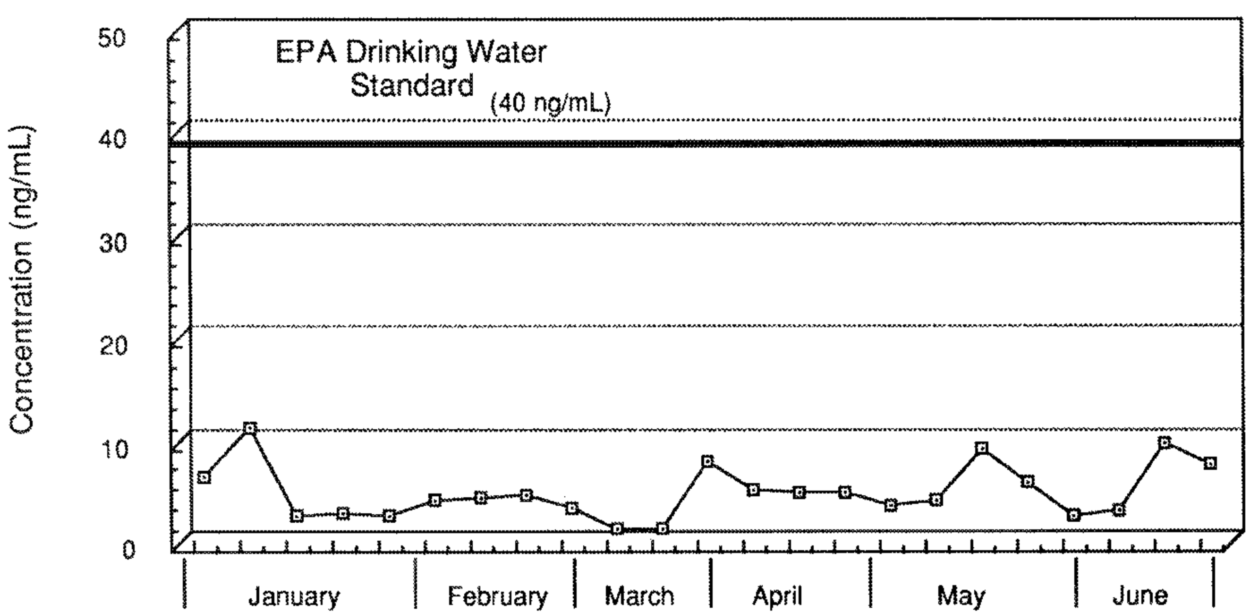


Figure 13-1. Chemical uranium concentrations in Tims Branch, January through June 1989

Table 13-1. Contributions of Radioactivity from SRS and Plant Vogtle

	Maximum[a] (pCi/L)	DOE Guide[b] (pCi/L)	Drinking Water Standard[c] (pCi/L)
From SRS			
Tritium	6,000	2,000,000	20,000
Cesium-137	0.2	3,000	200
From Plant Vogtle			
Cobalt-58	3.9	40,000	9,000

[a] Concentrations at the mouth of some effluent streams may be greater than the above maximums before their dilution by the river.
[b] Draft DOE Order DOE 5400.xx (Rev. 10/10/88) for soluble forms.
[c] [EPA77],[CFR87]

1989 Radiometric Analyses of SRS and Plant Vogtle Effluents in the Savannah River

SRL/ETS continually studies trace levels of radionuclides in the Savannah River to distinguish SRS and Plant Vogtle effluents. During 1989, the concentrations of radionuclides in these effluents were well below DOE Derived Concentration Guides for Drinking Water draft DOE Order 5400.xx and EPA Drinking Water Standards [EPA76]. The largest gamma component in the Plant Vogtle effluent during 1989 was ^{58}Co. Major components of the SRS effluents were tritium and ^{137}Cs. The maximum concentrations of these components and the corresponding DOE guide and EPA drinking water standard are summarized in Table 13-1 (above).

SRL/ETS used several methods to determine concentrations of radionuclides in the river. The most sensitive method was to collect the samples on resins for about two weeks. The samples were then counted overnight for gamma-emitting radionuclides on high purity germanium (HPGe) and sodium iodide [NaI(Tl)] detectors in the Underground Counting Facility. Periodic sediment samples were also counted in this fashion. A better time-resolution sampling mode involved consecutive one-day counts using an underwater NaI(Tl) detector located on the SRL/ETS monitoring platform at the Highway 301 bridge. Tritium concentrations were measured with a low-level liquid scintillation counter.

All results were consistent with reported effluent release activities of both Plant Vogtle and SRS. Plant Vogtle releases during 1989 were significantly lower because no large batch releases were required and effluent prefiltering was improved. The results continue to show that Plant Vogtle effluents contain primarily neutron activation products (e.g., ^{51}Cr, ^{54}Mn, ^{57}Co, ^{58}Co, ^{59}Fe, ^{60}Co, ^{95}Zr, and ^{95}Nb), although trace-level fission products (e.g., ^{137}Cs) may also be present.

During 1989, no SRS releases occurred that would significantly alter radioactivity levels in the Savannah River. The primary isotopes detected in the SRS effluents were tritium and ^{137}Cs.

These low-level radiometric studies provide data for detecting trends. For example, in Plant Vogtle effluents, trace-level ^{137}Cs is expected from pin-hole leaks in the fuel assemblies. The amount of ^{137}Cs that can leak increases with fuel burnup. Before Plant Vogtle began operation in 1987, ^{137}Cs concentrations just above and below the plant's outfall were indistinguishable. From 1987 to 1989, ^{137}Cs concentrations below the outfall have generally increased relative to the concentrations measured above the outfall. The 1989 maximum ^{137}Cs concentration was 0.04 pCi/L below Plant Vogtle's outfall.

Scoping Study to Identify SRS Deer Using Cesium-134/Cesium-137 Ratios

SRL/ETS initiated a scoping study to measure the ^{134}Cs/^{137}Cs ratios in deer. This ^{134}Cs/^{137}Cs ratio may be used to identify those deer native to SRS. The ratios of ^{134}Cs/^{137}Cs over land are generally influenced by worldwide fallout (i.e., weapons or Chernobyl). Effluent releases into streams and the Savannah River may influence cesium ratios over flood plains. The deer in the present study had $^{134}Cs/^{137}Cs$ ratios of 1–3 ng/L (parts per trillion). These ratios are too low to discern the animals' origin.

In Figure 13-2 (right), the graph shows $^{134}Cs/^{137}Cs$ ratios of six deer compared with the ratios for land soils collected within one mile of the corresponding kill sites. The cesium ratios in deer correlate reasonably well with cesium ratios in land soils. However, the deer ratios differ appreciably with some of the stream bank soils. The data used in developing this plot imply that the deer feed primarily over land areas, while approximately 5% feed over bank areas.

Air Particulates - Aiken Airport Collections
Particulate samples from large volumes of air (105 m³) were collected at the Aiken Airport at two to three-day intervals in 1989. These samples were counted on HPGe detectors in the Ultra-Low-Level Counting Facility (ULLCF). Cesium-137 was the only significant man-made radionuclide detected, with levels ranging from 0.01 to 0.10 fCi/m³. The DOE Derived Concentration Guide value for ^{137}Cs in air is 400,000 fCi/m³ [DOE88].

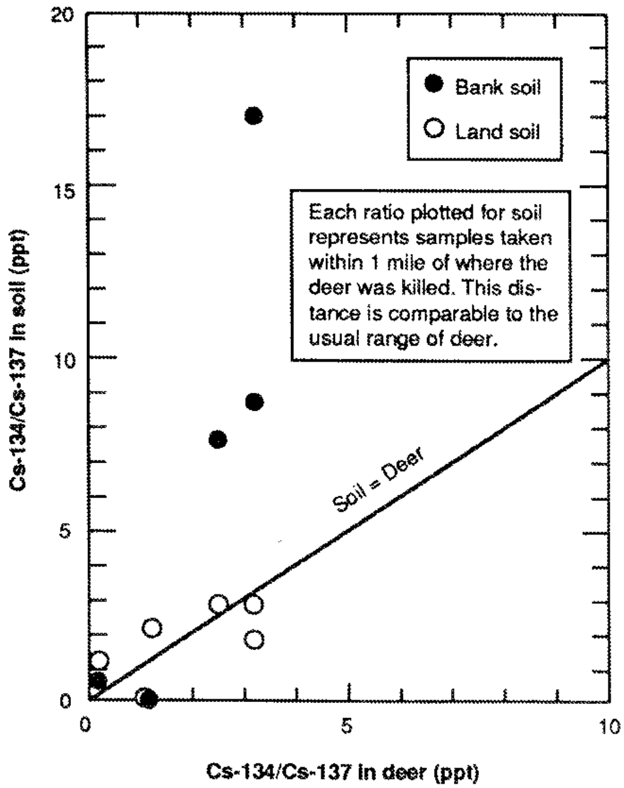


Figure 13-2. Ratio of $^{134}Cs/^{137}Cs$ in deer and soil

Mass Spectrometry Environmental Research

Long-Lived Isotope Mass Spectrometry
SRL/ETS completed an expansion of the ultra-low-level mass spectrometer laboratory facilities in December 1989. The laboratory expansion provides space for a laser facility and four additional mass spectrometers. An existing single stage thermal ionization mass spectrometer (TIMS) is being upgraded for ultra-low-level isotopic analyses and will be installed in March 1990.

Installation of an inductively coupled plasma-mass spectrometer (ICP/MS) to measure low-level ^{129}I in the environment is planned for the third quarter of 1990. The ICP/MS determines ^{129}I by measuring the ratio of ^{129}I to naturally occurring ^{127}I. This method is rapid and eliminates the use of a nuclear reactor which is necessary for the usual environmental level neutron activation technique. The new ICP/MS is expected to be operational by late 1990.

Noble Gas Mass Spectrometry
The analyzer for a mass spectrometer used to measure the nonradioactive fission product isotopes of the noble gases krypton and xenon at ultra-low levels was designed and is being fabricated. The inlet and ion detection systems are currently being developed. These systems will provide direct measurement of the noble gas isotopes, which enables an accurate assessment of environmental releases of the short-lived radioactive krypton and xenon isotopes.

Plutonium Bioassay
A new plutonium bioassay method is under development to meet the Environmental and Health Protection Department's need to monitor low-level plutonium uptake in individual urine samples. The bioassay method, based on Isotope Dilution Mass Spectrometry (IDMS), was selected because it is faster than alpha counting, it yields an isotopic fingerprint, and it requires relatively small samples.

The detection limit for the present alpha counting is 2×10^{-2} dpm ^{239}Pu. The IDMS method will likely lower that limit to $<2 \times 10^{-5}$ dpm ^{239}Pu.

SRL/ETS directed their initial efforts toward identifying the best chemical separation procedure before analysis by mass spectrometry. Additional studies are underway to optimize electrodeposition of the separated plutonium on the rhenium mass spectrometer filaments to ensure maximum ionization efficiencies.

Radiometric Detector Development

High-Sensitivity, Solid-State Gamma Detector

In 1989, a low-background HPGe detector was put into service in the ULLCF. This detector has 91% efficiency relative to a 3 × 3-in. NaI detector. The large detector head does not accommodate standard 1- and 2-L Marinelli beakers, but will accommodate a commercially available 3-L Marinelli beaker. The vendor redesigned the proposed active/passive gamma shield for the new detector to address the larger Marinelli beaker.

Real-Time Aqueous Tritium Monitor

A detection system capable of measuring low levels of tritium in aqueous streams on a real-time basis is currently being developed. Using this type of monitoring system at outfalls from production reactors and at processing facilities will improve responses to unplanned tritium releases into SRS streams.

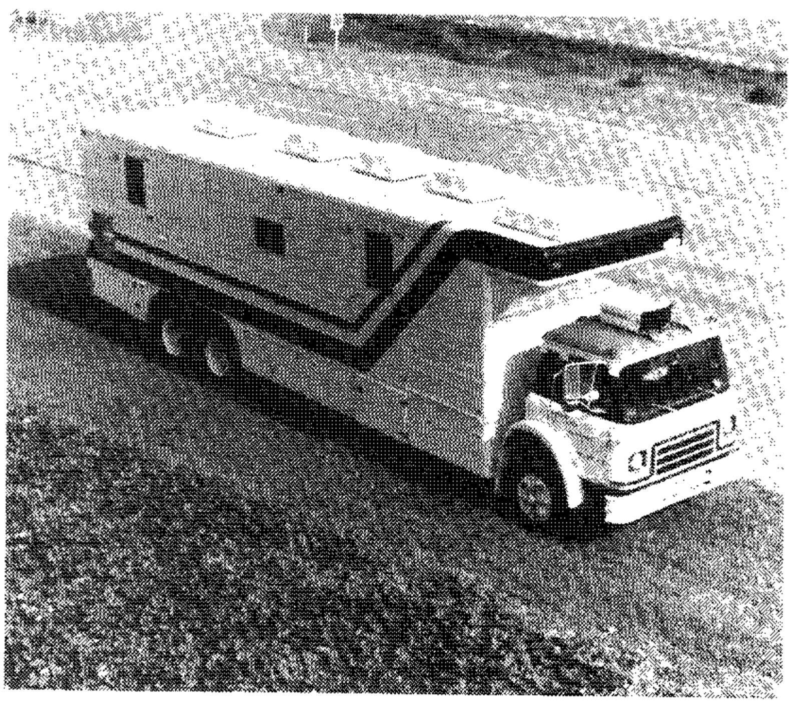
SRL tested a tritium detection system on tritium-spiked river water samples with crushed inorganic scintillator in the laboratory. While this system may be effective for in-line process monitoring, the tests revealed that the system could not reliably measure tritium concentrations below 200 pCi/mL. During the measurement, large errors were associated with the calibration data at such low concentrations. In addition, the detection system was easily plugged with small quantities of silt in the samples and was highly affected by biological contaminants.

A new tritium detection system was designed and constructed using thin fibers of plastic scintillator material. The principal advantage of this type of system is its tolerance to small amounts of insoluble material in the sample. In addition, the plastic scintillator provides pulse shape and timing discrimination that can be used to reduce the background from bioluminescence. The tritium detection system is currently being tested in the laboratory.

TRAC Mobile Laboratory Road Monitors

SRL/ETS installed a new ground monitoring system on the TRacking Atmospheric Contaminants (TRAC) mobile laboratory to enhance its ability to detect roadway contamination. A large NaI(Tl) detector was mounted under the vehicle chassis about 22 in. above the road surface. Before installing the new system, the TRAC mobile laboratory detected roadway contamination with side-log terrestrial monitors.

The new NaI(Tl) detector interfaces into the TRAC data acquisition computers to accumulate time and pulse-height spectra while the TRAC laboratory is traveling. This added capability improves the sensitivity for detecting a ground contamination source about five times over that of the side-log terrestrial monitors. When the TRAC laboratory travels at approximately 40 mph, the road monitor can detect a ^{137}Cs point source of about 30 mCi.



TRAC mobile laboratory

In 1989, most SRS roads were surveyed with this new detection system to determine background radioactivity levels of roadway surfaces. In November 1989, the road monitor surveyed the onsite roads after a ground contamination event was detected in K Area. No elevated levels of contamination were found.

TRAC Mobile Laboratory Dose Rate Measurement Capability

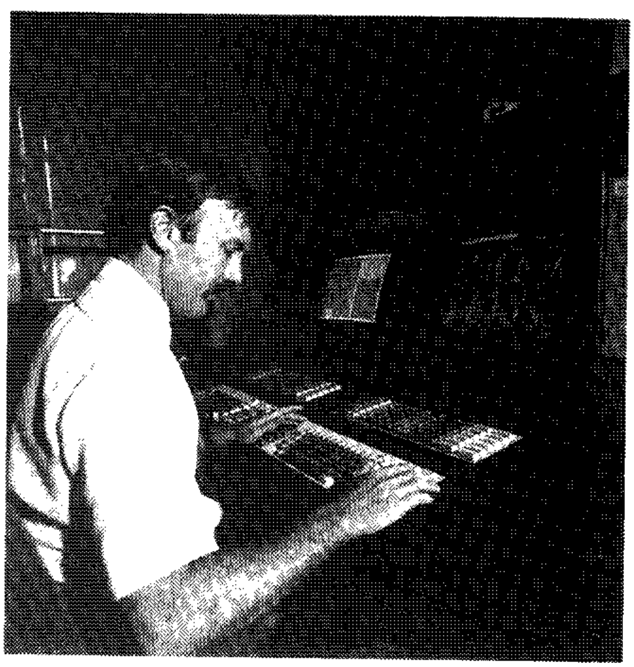
A High Pressure Ionization Chamber (HPIC) was installed on the TRAC mobile laboratory for continuous measurement of exposure rates in the field. The HPIC improves the ability to convert count-rate readings from gamma detection systems (e.g., plume monitor for atmospheric radiations, side-log terrestrial monitors for general area radiations, and road monitor for ground radiations) to exposure rates. SRL interfaced the HPIC to the Keithley data acquisition system and into the TRAC navigational computer so that time, distance, location, and exposure rates could be acquired and stored simultaneously. When the TRAC laboratory detects an elevated background condition, the exposure rate data are then communicated back to the Weather Center Analysis Laboratory (WCAL). The HPIC contains a dual-range electrometer capable of detecting area exposure rates from 10 mR/hr (with a five-second time constant) to 100 mR/hr.

Emergency Response

Weather INformation and Display System

The support provided for the Geographic Information System (GIS) and the introduction of revised emergency response codes increased the computational and memory storage loads on SRL's Weather INformation and Display (WIND) System. Increased hardware demands due to the expanding nature of the WIND System also strained the capacity of the WCAL's computer room.

To respond to these increasing system demands, SRL/ETS purchased two VAX 8550 computers to replace the two existing VAX 780/750 computers. These computers, installed in the new SRL computer room, provide a proper environment for optimum operation of the computer equipment. The VAX 8550 computers increase the available computing speed by a factor of six and the memory by a factor of five.



SRL increased the number of WIND System computers in 1989

Additional enhancements to the WIND system during 1989 are listed below:

- Telecommunication circuits were bridged to the new computer.
- Software was modified for use with the new computer systems.
- A local area network and a fiber optic cable were installed between the WCAL's computer room and the "C" Com room outside the Technical Support Center
- Network repeaters were installed at the 773-A computer room and the TSC "C" Com room.

All WIND System computers, including the TSC Micro VAXII, are integral parts of the WIND System network. The additional hardware improved the response time between the TSC and WIND System. Because of the improvements to the WCAL's computers, the WIND System has maintained a continuous operating time of greater than 99%.

SRL/ETS added laser optical disk drives and used them to back-up 10 years of meteorological data from magnetic tape. These drives provide convenient file storage onto diskettes which are compact and immune to electromagnetic contamination.

The Reactor Accident Program was added to the WIND System applications menu. This program will be used in emergency response environmental consequence assessments following a reactor fuel damage incident.

The Reactor Accident Program provides near real-time estimates of whole-body gamma radiation exposure and thyroid doses at downwind locations onsite and offsite by combining the capability to compute estimates of fuel damage and radionuclide-specific atmospheric releases with atmospheric dispersion calculations. In 1989, the program was used successfully during emergency exercises involving postulated reactor incidents at K Area.

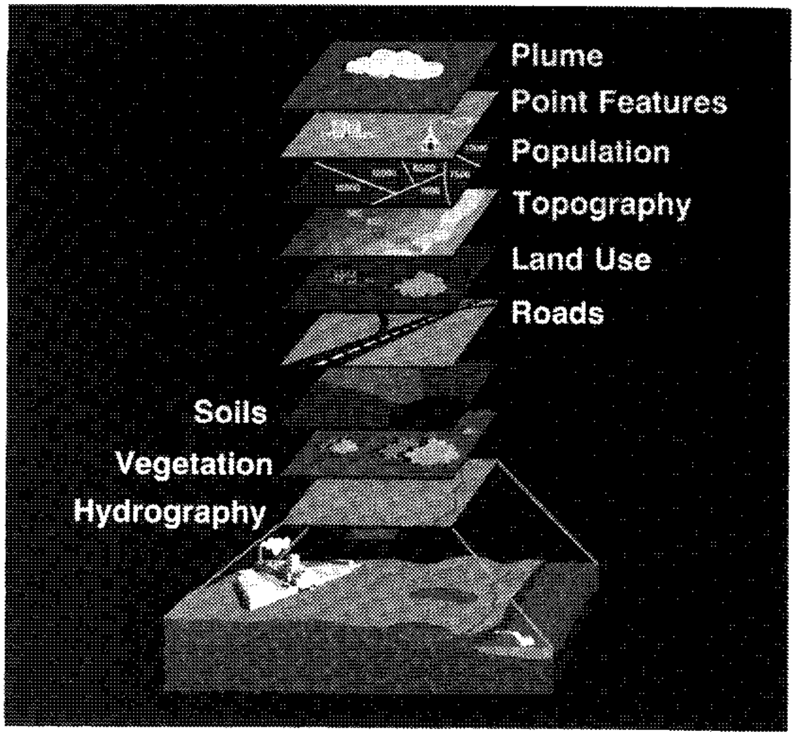


Figure 13-3. The GIS displays and analyzes geographic data

WCAL Geographic Information System
In 1989, testing began on the WCAL emergency response Geographic Information System (GIS). The GIS was installed to improve the ability to display and analyze geographic data relevant to emergency response operations.

Initial tests indicate that greater accuracy in plume positioning is obtained by overlaying plume predictions on GIS road networks, streams and rivers, and political boundaries. Figure 13-3 (above) shows the overlay capability of GIS.

The GIS will also be used to extract map data for upgrading background maps on emergency response terminals in SRS operating areas and the Technical Support Center. These improvements resulted from installing the 1:2000000 U.S. Geologic System (USGS) map database into the GIS database and from changing the puff/plume code to provide data files compatible with the WCAL GIS. Special 1:100000 USGS map data files are being installed to provide detailed road information around SRS.

772-F Replacement Stack Studies
SRL/ETS completed a study in March 1989 to determine the location and height required for constructing the 772-F replacement stack in F Area. This study was conducted to ensure that the cavity and wake zones of the 221-F building do not affect effluent from the stack.

As originally planned, the stack might allow a plume to enter the cavity and wake zones of the 221-F building when the wind is from easterly sectors (Figure 13-4, below). Under these conditions, personnel on the ground near 772-F would be exposed to minimally diluted effluent if an unplanned release occurred.

The study showed that the stack height should either be raised 2.5 times the height of 221-F or moved a distance of five times the height of 221-F to the northwest of the presently planned location. By selecting the latter alternative, the planned stack height or a lesser stack height would be adequate to avoid the cavity and wake effects of 221-F.

The study also showed that a nozzle could be added to the 772-F stack to gain additional momentum rise of the plume. A 4-ft-diameter nozzle would result in an additional plume rise of 19 to 51 ft, depending on wind speed. However, the nozzle might be noisy.

This study indicates that moving the new 772-F replacement stack to the west side of 772-F or extending the height to at least 187.5 ft would satisfy standard engineering practice stack design.

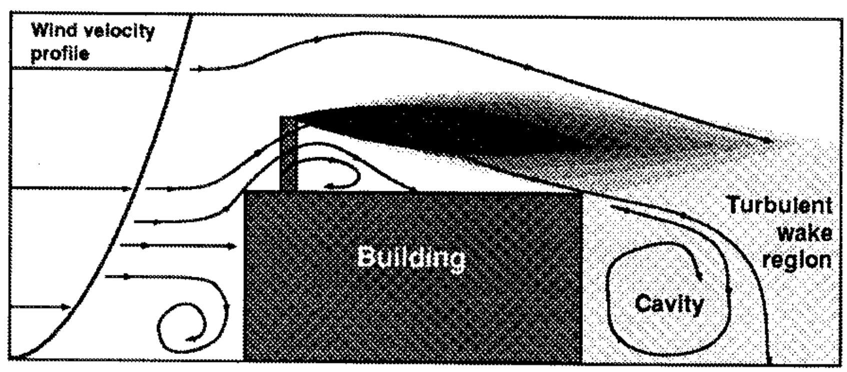


Figure 13-4. Diagram of a potential plume from F stack

Atmospheric Transport Research

Acoustic Sounders

SRL currently uses an acoustic sounder (sound radar) network for atmospheric boundary layer research. These sounders will eventually be added to SRS's meteorological sensor network. Acoustic sounders have several advantages over conventional meteorological towers. The sounders are portable, they provide data to higher altitudes with greater resolution than towers, and they can operate under adverse weather conditions such as icing. On the other hand, sounders require careful siting and do not measure low turbulence levels as well as bivanes on meteorological towers.

Comparison tests completed in 1989 between the sounders and SRL meteorological towers showed that wind speed and direction measurements agreed within 2% during daytime measurements. However, the sounders did not determine nighttime turbulence as accurately. A new method was developed to determine nighttime turbulence with the sounders. This method uses fluctuations in the horizontal wind, which can be accurately measured with the sounders, and a digital filter to determine the turbulent component.

Aqueous Research

Estimate of Cesium-137 Contribution from SRS Streams to the Savannah River

An estimate of the percent contribution from ^{137}Cs remobilization for K-, L-, and P-Reactor operations was needed for the Reactor Operation EIS. SRL/ETS provided support by estimating ^{137}Cs contribution from SRS streams to the Savannah River. During the time of this study, the primary source of ^{137}Cs to the river from SRS operations was ^{137}Cs remobilized from sediments in the SRS stream system.

The ^{137}Cs contribution from each SRS stream to the Savannah River was estimated using ^{137}Cs concentration measurements and flows for SRS streams and the Savannah River. The percent ^{137}Cs contribution to the Savannah River from each area is summarized in Figure 13-5 (right).

SRL/ETS used ^{137}Cs concentrating methods and low-level counting techniques to measure the ^{137}Cs concentrations in SRS streams and the Savannah River. Results revealed that the concentrations of ^{137}Cs in the Savannah River were less than 0.2 pCi/L or about 0.2% of EPA ^{137}Cs drinking water guide of 100 pCi/L.

Tritium Surface Water Transport

Studies are underway to determine the pathway of tritium released to Upper Three Runs Creek from the Effluent Treatment Facility (ETF). The ETF processes effluent previously discharged from F- and H-Area operations to seepage basins in F and H Areas. ETF removes radioactivity from the process effluent except tritium. The effluent is then released to Upper Three Runs Creek.

After discharge into the Savannah River, water from Upper Three Runs Creek can be entrained by the 1G river pumphouse canal and pumped to reactor areas. The canal is located about 100 yards downstream of the mouth of Upper Three Runs Creek. River water containing discharged Upper Three Runs Creek water can also be entrained by the 400-D pumphouse, located about one mile downstream from the mouth of Upper Three Runs Creek. The 400-D Area obtains its drinking water from the Savannah River.

The concentration of tritium increased in the 1G river pumphouse header water after ETF startup. This increase indicated that some Upper Three Runs Creek water was entrained by the canal, even at reduced pumping rates due to shut down of the reactors. Tritium concentrations in the 400-D Area drinking water also increased from 0.4 to 1.4 pCi/mL, but remained below the EPA drinking water standard of 20 pCi/mL.

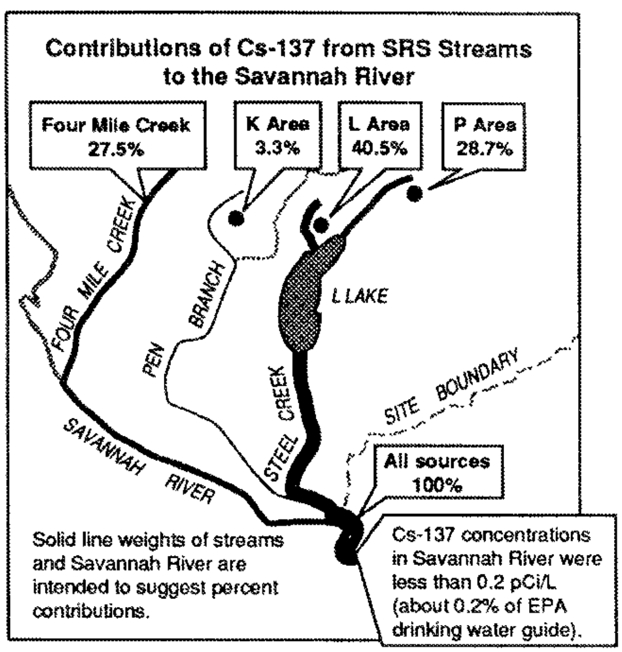


Figure 13-5. Contributions of ^{137}C to the Savannah River from SRS streams

ENVIRONMENTAL SCIENCES SECTION

Activities to Meet Permit or Environmental Impact Requirements

Impact Assessment Expert System

IMPACT is a computer program developed to improve the quality of SRS environmental assessments. It encodes basic information about various SRS ecological features (e.g., wetlands and wildlife habitat), along with data on the sensitivity of these areas to various types of disturbances. This information is encoded into a series of rules. Proposed projects are evaluated against these rules to identify potential problems. During 1989, SRL/ESS delivered the Alpha test release to the National Environmental Policy Act group of the Environmental Protection Section for evaluation and feedback. Further work will involve access to site databases.

Environmental Impact Detection

Because existing statistical methods are inadequate for evaluating some environmental issues at SRS, SRL/ESS initiated a study in 1989 to develop statistical methods to handle complex environmental situations. For example, when researchers try to compare the biota on a site at SRS with those at other locations, the differences in successional stages (e.g., new reservoir versus mature reservoir) at the two sites may completely confound the statistical analysis. This new process may help to simplify these types of problems.

First, methods were developed to establish the expected behavior of the system over time in the no-disturbance case, taking into account random effects. Then, statistical methods were defined for comparing a test site with a control. Trends and other effects may also be tested. Appropriate monitoring designs were also discussed for such problems. In 1989, two peer-reviewed papers on the results were accepted in *Environmental Management*.

Reactor Operation Environmental Information Document

SRL/ESS and SRL/ETS jointly produced the three-volume Reactor Operation Environmental Information Document (RO-EID) in 1989. The document covers a wide range of environmental conditions and concerns in support of the Environmental Impact Statement (RO-EIS) currently being prepared for continued operation of K, L, and P reactors at SRS. Each volume of the RO-EID covers the specific areas listed below:

Volume I	- Geology, Seismology, and Subsurface Hydrology
Volume II	- Ecology
Volume III	- Meteorology, Surface Hydrology, and Transport and Impacts

The draft of each volume was completed on August 31, 1989 and has since undergone internal and external technical review and revision. The RO-EID will be issued in February 1990 before issuing the draft RO-EIS. It is anticipated that portions of the RO-EID will be routinely updated as new information becomes available.

K-Reactor Predictive 316(a) Demonstration

Section 316(a) of the Clean Water Act requires that cooling water discharge temperatures neither exceed 90°F nor cause temperatures in receiving waters to rise by more than 5°F. To satisfy these regulations, SRS implemented a thermal mitigation plan using cooling towers for K-Reactor discharges into Indian Grave Branch and Pen Branch. A once-through, gravity-fed, natural-draft, hyperbolic cooling tower and a recirculating cooling tower were two design alternatives evaluated in the Alternative Cooling Water Systems EIS.

The recirculating cooling tower was selected because it maintains near-ambient temperatures and moderates flows in Pen Branch. To demonstrate the effectiveness of the recirculating cooling tower mitigation option, SRL/ESS compiled a Predictive 316(a) Demonstration Report containing information on the biological communities and physical conditions likely to occur in Pen Branch and Indian Grave Branch when K Reactor is operated with a recirculating cooling tower.

A computer model predicted temperatures in Pen Branch after constructing the cooling tower. SRL/ESS compared these temperatures with results from laboratory studies on the temperature tolerances of local fishes, ecological data collected by field and remote sensing surveys on SRS, and information from the scientific literature to assess the probable impacts resulting from the cooling tower discharge. The results of these analyses indicate that mitigation with the recirculating cooling tower will permit Pen Branch biota to recover from previous thermal impacts and ultimately return it to natural or near-natural conditions.

After review by DOE, the Predictive 316(a) Demonstration for K-Reactor operation following mitigation with a recirculating cooling tower was submitted to the South Carolina Department of Health and Environmental Control (SCDHEC) in mid-March 1989.

F- and H-Area ETF Biological Monitoring Program

A biological monitoring program was initiated in 1987 to assess the effects of the H-016 outfall (F- and H-Area ETF) on the biota of Upper Three Runs Creek. Data collected following ETF startup in October 1988 indicated no measurable adverse impacts on the stream community during the first six months of operation. However, ETF was operating at less than 25% of design capacity during that period.

Further studies will determine if the ETF effluents will impact the stream under normal operating conditions. Toxicity tests indicate that the ETF effluent should not be toxic after mixing with Upper Three Runs Creek.

316(a) Biological Monitoring Program for Beaver Dam Creek

In 1988, an 18-month-long biological monitoring program was initiated to determine if thermal mitigation in D Area was adequate to protect the biota in Beaver Dam Creek. Thermal mitigation consists of increasing the water discharged from the Savannah River to the D-001 outfall during the summer months to prevent stream temperatures from exceeding 90°F.

Data collected during the first 12 months of the program indicate that the stream maintains a diverse biological community. Due to reduced steam production in D Area, no thermal mitigation was required during the study. SRL/ESS may extend the monitoring program to encompass a normal operating period in D Area.

Status of L-Lake/Steel Creek Monitoring Program

The L-Lake/Steel Creek monitoring program began in November 1985 for compliance with Section 316(a) of the Clean Water Act, which regulates thermal discharges into surface waters. This monitoring program will provide information to satisfy provisions of this law. L Lake, which has an NPDES discharge permit (outfall L-007), is the once-through cooling reservoir for L Reactor. Under the NPDES permit specifications, DOE must demonstrate that the L-Reactor effluent will not significantly alter ecosystem components in the lower half of L Lake and lower reaches of Steel Creek.

Results of this program will provide data to facilitate decisions regarding "balanced biological communities" (BBCs) within the compliance zone of L Lake. BBCs are communities that:

- are not dominated by pollution (i.e., thermal) tolerant organisms
- have diversity and productivity characteristic of lakes and streams of the region
- contain representatives of all feeding groups expected in a lake or stream of this region
- contain self-maintaining (i.e., successfully reproducing) biotic communities and are not maintained by continual reseeding, stocking, and immigration

Completed in November 1985, L Lake is relatively young compared to other regional impoundments. Both young and old reservoirs experience eutrophication, a type of community-level succession.

Eutrophication is defined as the structural and functional changes occurring within the lake's communities and the ecosystem as a whole. In artificial lakes such as L Lake, eutrophication is often named "reservoir aging."

Reservoir aging in L Lake responds to several external physical, chemical, and biological forces including water quality of the Savannah River, thermal loads from L Reactor, the depth of withdrawal at the lake's outlet dam, weather conditions including rainfall, cloud cover, and temperature, and physical and chemical conditions of the lake's drainage basin.

To a large extent, the rate and intensity of eutrophication will determine the development of BBCs in the basin and in Steel Creek. Based on results of the current four-year monitoring program, community development in the lake and creek towards BBC communities has progressed in an expected and satisfactory manner.

The initial monitoring program for L Lake and Steel Creek ended December 31, 1989 with a new program beginning on January 1, 1990. The 1990 program, approved by SCDHEC, improves sampling designs and program efficiency, while maintaining continuity with key parts of the initial program.

The 1990 program will incorporate the following details:

- retain nearly all measured ecological variables
- use many of the same sampling stations from the initial program
- employ the same field and laboratory methods as the initial program
- provide for all modes of L-Reactor operation (thermal loading) in the suggested temporal and spatial sampling designs
- incorporate new methods that meet or exceed those often employed by EPA, National Oceanic and Atmospheric Agency, and National Science Foundation designs for biological sampling for taxa richness and seasonal characteristics of each community
- incorporate recommendations of a biostatistician consulted on field sampling programs to ensure proper application of statistical procedures and sampling designs

Evaluating L-Lake and Steel Creek biotic populations regarding BBC criteria is difficult because many of the criteria were developed for aquatic systems located at more northern latitudes where temperature conditions are significantly different than those at SRS. SRL/ESS conducted a Regional Lakes Study during the summers of 1988 and 1989 to compare the water quality and biological populations in L Lake, Pond B, and Par Pond at SRS and seven other reservoirs in South Carolina. SRL/ESS will compare the data collected in these reservoirs and final reports will be completed in 1990.

Mitigation Options for Fish Kills in L Lake and Pond C

If fish enter reactor discharge areas during reactor outages and the reactor is restarted, these fish die because of rapid rises in water temperature following restart of the reactor. Factors that influence the severity of fish kills include the length of the outage, season during which the outage occurs, reactor power level, and fish size in the discharge area.

Fish kills will continue in L Lake and Pond C following the start-up of L and P Reactor unless some form of mitigation is employed. Without mitigation and assuming a return to past schedules of reactor operation, fish kills will likely occur in Pond C at approximately the same frequency and severity as in the past. However, even without mitigation, it is unlikely that future fish kills in L Lake will be as large as past kills because fish abundance near the L-Reactor outfall has declined due to natural factors associated with reservoir aging.

To minimize future kills, eight mitigation options that vary in approach, scope, likelihood of success, and cost were developed for L Lake and Pond C. These options fall into the following three general categories:

- changes in reactor operations
- methods to exclude fish from the discharge area
- methods to promote the escapement of fish from the discharge area

An appropriate option or combination of options will be implemented in L Lake and Pond C following additional research and evaluation.

Waste Management and Groundwater Protection

<u>Groundwater Cleanup Using Horizontal Wells</u>

Vacuum extraction, biotechnology, chemical fixation and other treatment technologies are under development to remediate subsurface (i.e., groundwater and vadose) systems contaminated with hazardous or radioactive contaminants. The *in situ* processes also minimize surface discharges or disposal of treated effluent or waste and they also reduce the costs associated with groundwater interception and pumping to surface treatment systems.

Horizontal wells offer an improved geometry for delivering reactants to or recovering contaminants from subsurface systems for the reasons listed on the following page:

- Contaminants are often confined to relatively thin water-bearing zones.
- Horizontal wells installed parallel to the source can remediate linear sources such as pipelines and streams.
- Horizontal wells would be more efficient in protecting the site boundaries (or other legal spatial limits)
- Remediation systems can be installed under existing facilities using horizontal wells.

Technical staff at SRS actively studied the possible applications of horizontal wells for *in situ* hazardous waste site and groundwater remediation. In one study, two horizontal wells were installed under an abandoned process sewer line that leaked chlorinated solvents to the subsurface.

Figure 13-6 (shown below) details these wells and the process used to remove the contaminants. In a second study, a laboratory scale "horizontal well" test system was constructed. A full scale field test involving vacuum extraction from the vadose zone and simultaneous purging of volatile contaminants from the saturated zone is planned for 1990.

Future research and technology transfer will include collaboration with various DOE national laboratories, other government agencies, private industry, and universities. Technical task teams will focus on the following phases of research: drilling technology; monitoring technology; remediation technology (e.g., which remediation technologies could benefit from the use of horizontal wells); site characterization; and system modeling.

Study of Wetland Vegetation Mortality

In 1989, studies were conducted to assess the causes of death of wetland vegetation adjoining Four Mile Creek near the F- and H-Area seepage basins. Soil and vegetation samples were collected and chemically analyzed for concentrations of toxic metals as well as for nonhazardous but potentially toxic compounds such as sodium.

Although field and laboratory studies were completed in 1989, literature surveys to assess the toxic levels relative to those observed continue.

In 1989, tree ring analyses were completed to assess the timing and nature of stresses. A laboratory study, conducted to evaluate the ability of rainfall to leach toxic constituents from the soils, will provide information to evaluate the need for remedial action in these wetlands.

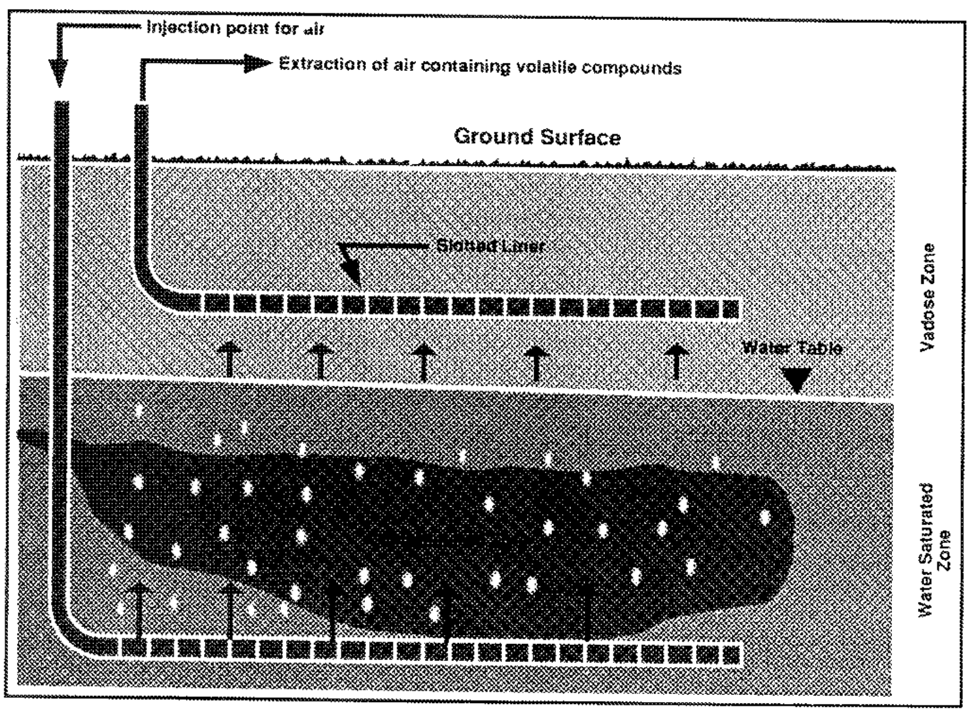


Figure 13-6. Horizontal well installation and contaminant removal

Groundwater Modeling Program

Several groundwater modeling projects were completed during 1989. In one project, SRL/ESS completed a saturated flow and transport groundwater computer code (FTWORK). The FTWORK code simulated SRS groundwater movement to provide required regulatory information for the NPR EIS. The computer code will be distributed to the public through Argonne National Laboratory.

SRL/ESS also developed a variably saturated code (VAM3D) for applications at SRS. VAM3D simulated the effectiveness of the Z-Area Saltstone facility. An impacts assessment of K-, L-, and P-Reactor operations on groundwater was also simulated with VAM3D to fulfill RO-EIS requirements.

Other groundwater modeling projects completed for SRS support facilities included A/M-Area groundwater modeling to assess the extent and movement of trichloroethylene contamination, F- and H-Area modeling to assess closure of the seepage basins, and modeling at TNX Area to develop a groundwater remediation strategy.

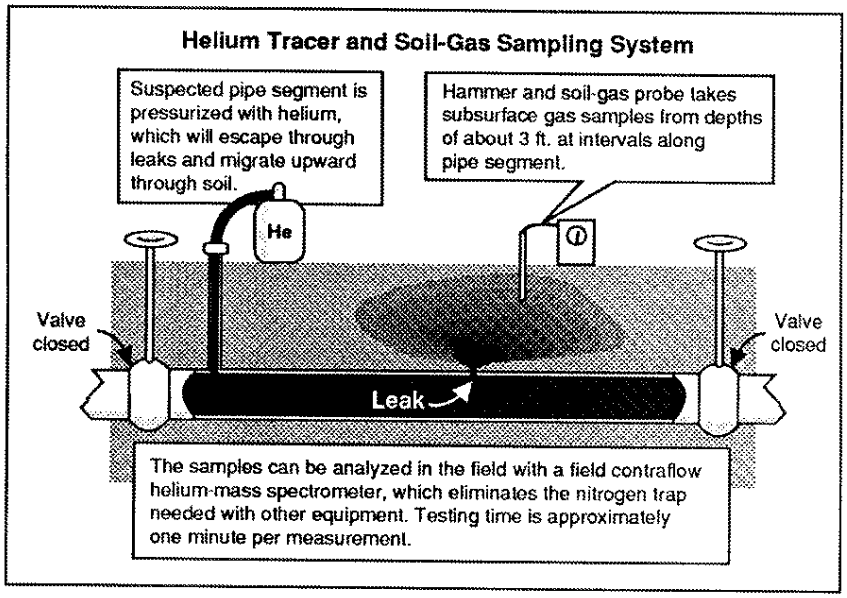


Figure 13-7. SRL developed a system to detect leaks in piping

Underground Leak Detection

SRL/ESS developed and implemented a system for rapidly tracing the location of leaks in underground piping systems using helium tracer and soil-gas sampling followed by field mass spectrometry. Several leak studies were performed at the F- and H-Area tank farms where high-level radioactive wastes are stored. In most of the studies, leaks in pipes up to 20 ft deep were located in less than one day. Use of this system will reduce the employees' radiation exposure and will also reduce the cost of locating and repairing leaks.

To perform a test on an underground system, the system is pressurized with helium, which escapes through any leaks and migrates up through the soil. A specially designed hammer and soil-gas probe withdraws subsurface gas samples from about 3 ft deep at intervals along the buried line. The samples are then analyzed in the field using a field contraflow helium mass spectrometer. Figure 13-7 (above) illustrates the soil-gas sampling system.

The mass spectrometer design eliminates the liquid nitrogen trap normally needed. The design also enables rapid testing (approximately one minute) and allows immediate follow-up in areas having possible leaks. SRL/ESS developed a similar technique using sulfur hexafluoride and gas chromatography for situations requiring greater sensitivity.

In 1989, SRL/ESS began a sitewide program to transfer the developed technology so that the large number of tests anticipated in the F- and H-Area tank farms over the next few years can be performed.

Fate and Effects of Pollutants from SRS

Remote Sensing Development

Development of remote sensing techniques continued in 1989 as a cost-effective means of monitoring large areas, such as L Lake, Par Pond, the Savannah River swamp, and the F- and H-Area seepage basins. Airborne multispectral scanner (MSS) surveys, airborne (helicopter) gamma radiation surveys, and vertical and oblique aerial photograph surveys collected primarily by EG&G are remote sensing techniques currently used. The French Satellite, Pour l'Observation (SPOT), also collected seasonal satellite data.

Data analysis provided information on environmental impact to wetlands and the distribution of radionuclides onsite. Techniques to determine the water quality and algal distributions in Par Pond and L Lake were also developed. Photographic and MSS data provided valuable information in mapping potential outcrop areas from the F- and H-Area seepage basins to the upper Four Mile Creek watershed. Information gathered by remote sensing supported the L-Lake 316(a) Demonstration, the RO-EIS, and the NPR site-selection processes.

Lower cost remote sensing systems, which primarily include seasonal SPOT satellite data, are currently under evaluation in the SRL remote sensing analysis laboratory. SRL/ESS is comparing SPOT data collected nearly concurrently with the airborne MSS data to determine if these data can provide a low-cost supplement for landcover characterization of environmental, wetlands, and habitat assessments for project support and documentation required for regulatory issues. The SPOT satellite sensor system may provide detailed seasonal and regional coverage in a readily usable format for application at SRS.

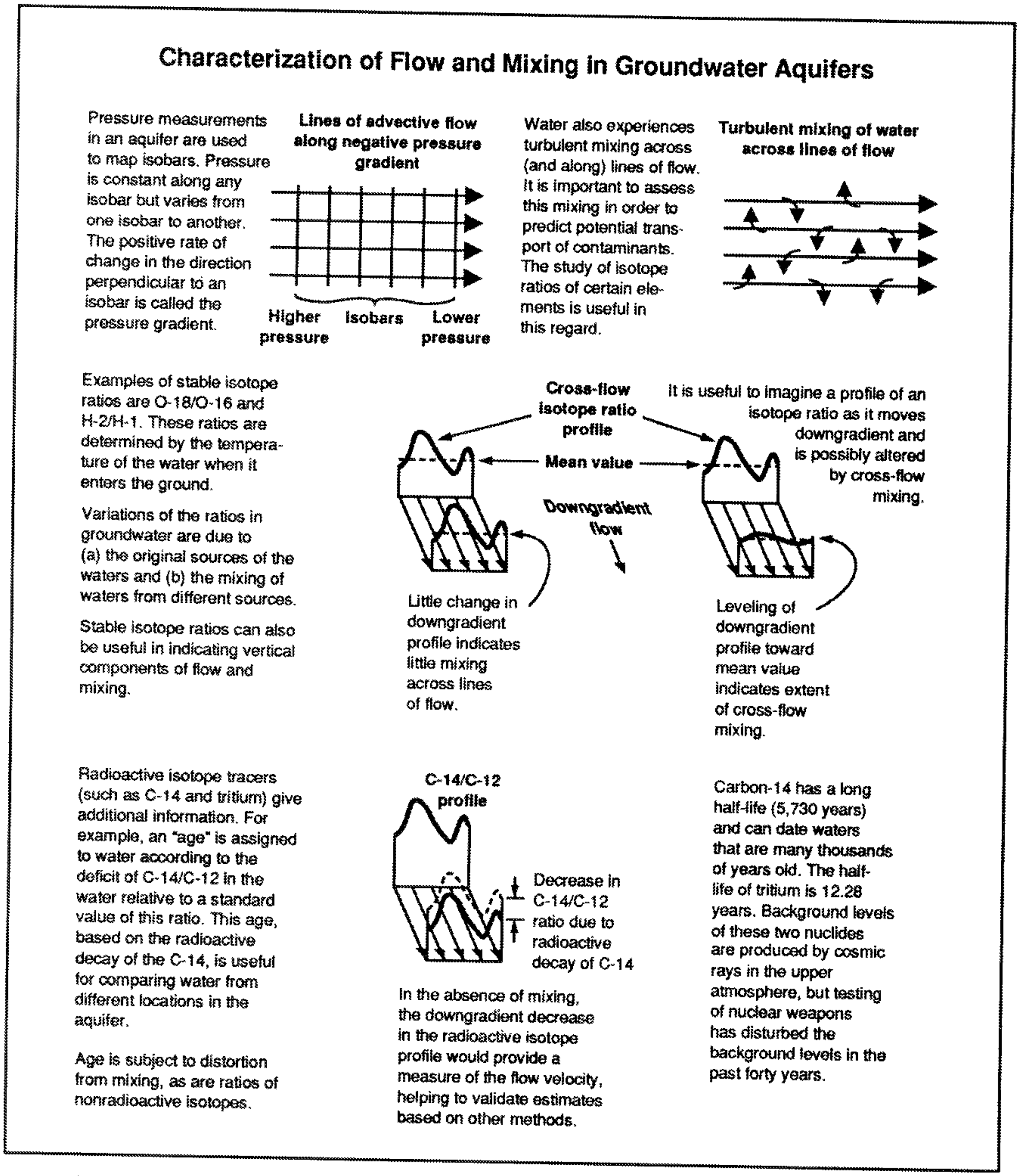


Figure 13-8. A number of aquifer characterization studies will be conducted in 1990

Aquifer Characterization Program

Detailed geochemical and physical characterizations of the aquifers underlying SRS were initiated using the wells installed and the cores obtained during the Baseline Hydrogeologic Investigation Program. The Aquifer Characterization Program, summarized in Figure 13-8 (left), will provide information for water resources utilization and contaminant transport modeling by describing the hydrogeologic systems that underlie the site.

The program includes the following objectives:

- determining the nature and distribution of chemical species in groundwater from the various aquifers underlying the site
- determining the relationship between groundwater and sediment chemistries
- modeling groundwater chemistry
- determining flow paths and rates for each aquifer system
- mapping the transmissivities for each aquifer system across the site

Eghteen well clusters were installed at key locations across the site. Each cluster consisted of approximately eight wells screened in different aquifers. Continuous geologic cores were obtained at each of the 18 cluster locations.

Groundwater samples collected from most of the cluster wells and from offsite wells both up- and downgradient of SRS were analyzed for major cations, major anions, trace metals, pH, conductivity, temperature, Eh, dissolved oxygen, gross alpha, nonvolatile beta, tritium, ^{14}C, and stable isotopes of oxygen, carbon, and hydrogen.

The radioactive isotopes of carbon and hydrogen analyses will be used to determine the age of the waters at various locations and depths across the site. The stable isotopes of carbon, oxygen, and hydrogen may provide information on groundwater flow paths.

Figure 13-8 provides additional information on the characterization of flow and mixing in groundwater aquifers. Core samples were analyzed for mineralogy and chemistry (i.e., major oxides, trace elements, and total organic carbon). Many of the chemical analyses are complete and data interpretation is under way.

In 1990, aquifer tests will be conducted at each of the well clusters. Researchers will use these data to determine aquifer properties such as transmissivity across the site.

Sitewide Hydrogeologic Study

SRL/ESS conducted a hydrogeologic study on SRS and surrounding areas in 1989 to define and describe the aquifers and confining systems underlying the site. Geophysical and core data derived from deep wells (those penetrating to basement rock) drilled on and near SRS were analyzed to determine the thickness, lateral extent, and quality of the aquifer units.

A series of cross sections illustrating the geographic and stratigraphic distribution of the aquifer units was also completed. Isopach maps and structural maps are currently being developed for this study. The research findings will provide a clear, concise three-dimensional representation of the hydrological units that underlie SRS.

Pen Branch Fault Program

Pen Branch Fault (PBF), shown in Figure 13-9 (following page), was identified and described in the fall of 1988. This fault, located in the middle of SRS from the southwest to northeast, displaces Coastal Plain sedimentary rock about 75 ft. PBF is thought to have been actively moving from the Cretaceous through Tertiary time (90 to 35 million years ago).

Because PBF is located near operating nuclear facilities, a thorough investigation of the fault was necessary to determine if any seismic hazard exists. The PBF program will characterize the nature of the fault and address regulatory issues concerning the placement of nuclear reactors near any faults (e.g., Appendix A, 10 CFR 100).

Regulation 10 CFR 100 identifies several criteria used to determine if a fault is capable of generating earthquake-type ground motion during the lifetime of the reactor operation. The criteria to detemine a fault's earthquake capability include:

- the possibility of recent or continual movement of the fault
- any relation of the fault to recorded earthquakes

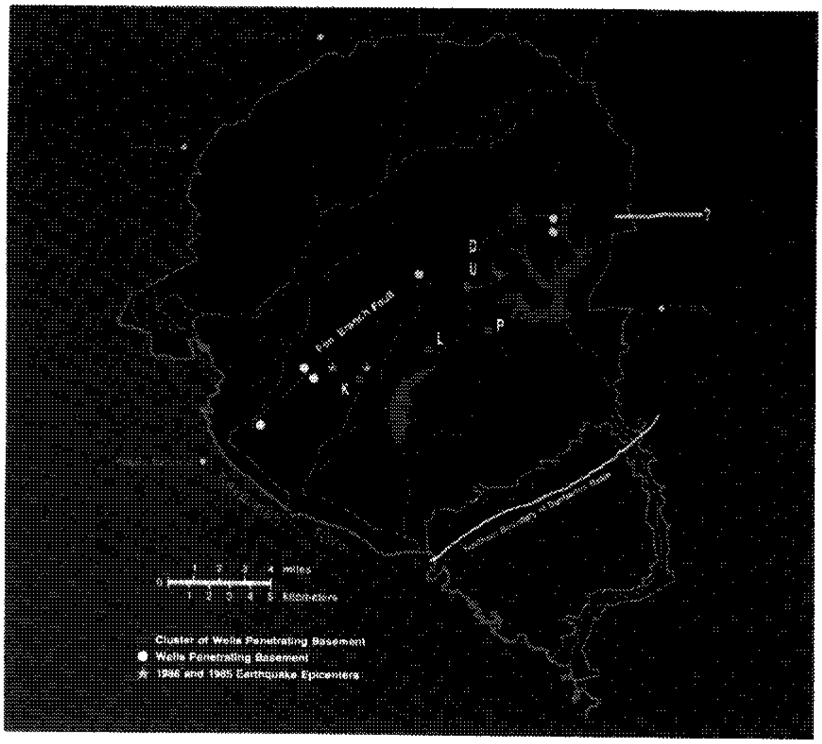


Figure 13-9. Pen Branch Fault is located in the middle of SRS

- a direct connection to a known capable fault

- a direct connection to another geologically very old fault or structure

If the last criterion is satisfied, then the fault is probably not capable of producing earthquake-type ground motion.

An outside technical advisory group, the Earth Science Advisory Committee, will be formed in 1990 to provide independent review and oversight for the PBF program. This outside group will consist of experts in seismology, tectonics, structural geology, sedimentology, and geohydrology.

Phase 1 of the PBF drilling program was completed during 1989. Initial observations indicate that several wells penetrated different types of basement rock. Detailed stratigraphic analysis of the cores is underway to locate the PBF in the Coastal Plain section.

SRL/ESS plans to conduct a high-resolution, shallow seismic reflection survey for the PBF program in 1990. The survey will detail the structure of the fault from 50 to 200 ft below the earth's surface.

Seismic Program

During 1989, activities in this project focused on seismic issues and concerns related to present site operations and future facilities. The SRS Seismic Advisory Committee held two meetings onsite during 1989 to discuss concerns related to seismic hazard analysis at SRS and to review seismic programs.

As a result, new programs were initiated to review the seismic hazard assessments developed for the site, and to purchase strong-motion instrumentation for the reactors.

The existing SRS seismic network continued operation, while plans to purchase additional instrumentation were completed. When this instrumentation is operational, SRL/ESS will calibrate the network by simulating earthquakes using high explosives. The network will be connected to the SRL WIND System to provide information for the site in a timely manner in the event of an earthquake.

Subsurface Microbiology 'Deep Probe' Program at SRS

SRL/ESS completed the deepest of four holes drilled for microbiological analysis in the OHER-DOE Subsurface Science Program "Deep Probe" in October 1988. This borehole, located just off SRS near Allendale, SC, was drilled in cooperation with the South Carolina Water Resources Commission and the South Carolina Forestry Commission. It reached a depth of 1,700 ft before reaching basement rock.

Analysis of samples from this hole revealed that physiologically active microorganisms can be found at high concentrations at any depth, even in fractured bedrock. However, depth is not an important variable in determining a soil microbe's niche.

Molecular analysis of isolates from these samples revealed that these organisms are unlike any organisms common to surface soils. Standard taxonomic keys failed to identify 95% of the microorganisms, and another 4% were misidentified. These microbes have unusual abilities in their breadth of assimilation of organic compounds and a unique movement behavior towards organic compounds.

This research shows potential for defining and controlling environmental transport, and it suggests that even the deepest aquifers can be bioremediated.

Bioremediation Research and Development at SRS

This program focuses on using the natural ability of microbes to degrade toxic wastes by examining both *in situ* and "pump and treat" strategies. Studies show that certain vegetation can promote degradation of toxic substances like trichloroethylene by encouraging growth and physiological activity of bacteria and fungi associated with their roots. This technique may prove to be a cost-effective and aesthetically pleasing way to restore contaminated soil in areas of heavy clay content where contamination is confined to the soil's surface.

Contaminated groundwater is conventionally treated by aeration, a technique that removes volatile compounds but does not degrade them. Instead, aeration transfers the volatile compounds to the atmosphere. SRL/ESS scientists demonstrated in the laboratory that if contaminated groundwater passes through a bioreactor (i.e., a large vessel used to grow bacteria), the bacteria degrade nearly all organic compounds present in groundwater. Thus, bioreactors may completely decontaminate groundwater without transferring the contaminants to another environment. The bioreactor technology is also less expensive than conventional aeration technologies, which require high-energy expenditures.

SRL scientists are currently making larger bioreactors so they can be tested under field conditions at flow rates as high as 10 gpm. Studies have shown that bacteria capable of degrading organic contaminants such as diesel fuel or gasoline are present in SRS soil. These microbes can be encouraged to degrade these compounds at very high rates by adding simple limiting compounds like those found in fertilizers (e.g., phosphorus and nitrogen). Studies are underway to determine how to control soil fertilization and the optimal mix required to clean up petroleum-contaminated areas at SRS.

Biobarrier Testing

Vegetation is commonly used to stabilize the ground covering buried waste sites. However, if the plant roots penetrate the waste, constituents of the buried waste can be brought to the surface. An ideal waste burial system would allow vegetation to stabilize the soil above the buried waste but would exclude roots from the waste. SRL/ESS is testing a biobarrier technology which uses a slow-release encapsulation of Trifluralin, a root growth inhibitor. The capsules are bonded to a geotextile which provides an easy means of distributing the capsule evenly over the area to be protected. The projected lifetime of the biobarrier capsule is approximately 100 years.

Tests have been conducted in a rhizotron, in glass-walled field trenches, in established forest vegetation, and in large pots. In all cases, the Trifluralin excluded roots from the soil zone below and immediately surrounding the biobarrier. Concentrations of Trifluralin near the biobarrier were greater than 5 $\mu g/cm^3$. At this concentration, the roots of virtually all species of vegetation should stop growing. The concentration of Trifluralin was below detection at distances greater than 10 in. above the biobarrier.

Vegetation grown in the soil above the barrier provided good ground cover, although some decreased growth was found in some species. Of the species tested, the sensitivity to the biobarrier, as measured by the distance that roots stop near the barrier, is bamboo > Bahia grass> Bermuda grass> soybean, where bamboo is the most sensitive.

Potential uses for the biobarrier at SRS include the protection of clay caps over buried, low-level saltstone and the protection of gravel drains and clay caps over decommissioned seepage basins. Trials of the biobarrier as part of waste site caps will begin in 1990.

Uptake of Transuranic Elements in Burial Ground Trenches by Vegetation

The uptake of buried, low-level transuranic waste from unlined earthen trenches by forest vegetation is under study as part of an evaluation of the potential radiological consequences of reinhabiting the SRS burial ground. Two tree plots were established in 1979. One plot was located over a trench containing transuranic waste and the other was located in an area without trenches.

Tree seedlings were sampled in 1979 and 1980 and analyzed for ^{239}Pu and ^{238}Pu activity. The results indicated a small difference in radionuclide activity between trees planted over the trench and those planted on the control plot. The small difference occurred because root intrusion of the seedlings into the trench was limited. However, when trees were sampled in 1986, 1987, and 1988 and analyzed for ^{241}Am, ^{238}Pu, ^{239}Pu, and ^{237}Np activity, the average activity of all isotopes was significantly higher over the trenches than in the control plot.

These measurements indicate that tree roots will extract transuranic isotopes from buried, low-level waste. The amount of radioisotopes migrating from the trenches to the surface is small and the level in the trees is low enough that dose from exposure will be small.

SRL/ESS evaluated the long-term transport effects of radioisotopes from the trenches to the surface soil by estimating the accumulation in the surface soil. Transuranic activity in selected food crops was calculated using the soil activity and literature-derived concentration factors. In all cases, the results indicated low activity of the transuranic isotopes in the edible portion of the plants. The activity in the leaf tissue was much higher than in the seed. In one case, the transuranic activity was higher than the naturally-occurring ^{40}K activity in the pine foliage.

Lysimeter Study of Vegetation Uptake from Buried SRS Saltstone

A lysimeter study is underway to determine uptake of radionuclides by vegetation from buried saltstone. An auxiliary objective of this study is to determine the relationship between the burial depth and amount of uptake.

Figure 13-10 illustrates a typical lysimeter setup used in this study. The experiment consists of 29 6-ft-diameter lysimeters (devices used to determine the solubility of substances) with depths varying from 6 to 10 ft. . Nine saltstone blocks, 2 ft × 2 ft × 4 in., were buried at depths varying from 0.5 to 5.5 ft. Pine trees, Bermuda grass, and row crops were grown in the lysimeters.

Tree and grass samples grown in the lysimeters are collected annually. Row crops are collected throughout the year as each crop matures. These samples are analyzed for ^{99}Tc, ^{90}Sr, ^{129}I, ^{137}Cs, ^{125}Sb, ^{106}Ru, ^{238}Pu, ^{3}H, and $^{239,240}Pu$. The water collected in the lysimeter sumps is analyzed for the same radionuclides as well as for pH, nitrate, nitrite, organic nitrogen, sulfate, chromium, mercury, boron, and aluminum. Radioactive water analysis is performed annually and nonradioactive water analysis, quarterly.

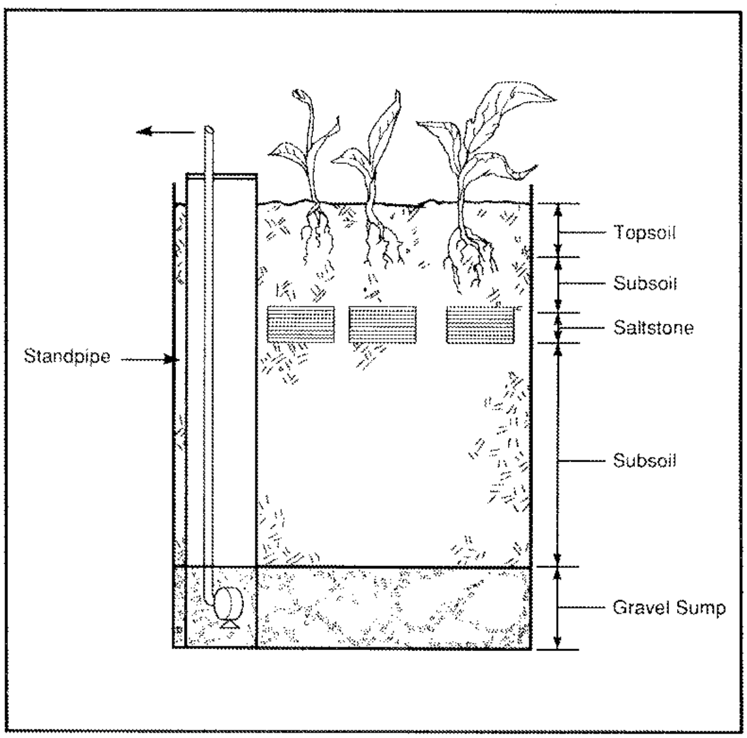


Figure 13-10. Typical soil study using a lysimeter

Results indicate that ^{99}Tc is the only radionuclide at elevated levels in the vegetation and in the sump water. The first increase in ^{99}Tc and nitrate in the water and in ^{99}Tc in the vegetation suggests that the other radionuclides and nonradioactive constituents do not leave the saltstone in measurable quantities. The release of ^{99}Tc and nitrate to the sump water peaked two years after the lysimeter was established and is now slowing. Additional data collected in 1990 should establish the rate of decrease.

The results of the crop analysis indicate that the smallest concentration of ^{99}Tc is present in the grain of corn and soybeans. This observation is important from a dose perspective. SRL/ESS planted another corn crop in 1989 to continue the ^{99}Tc studies. The vegetation will be analyzed in 1990. SRL/ESS will document the results of this study in a WSRC report in the spring of 1990.

Transport and Cycling of Tritium in the Environment

The largest contributing radionuclide to the offsite radiation dose from site operations is tritium. Since tritium is an important radionuclide in calculating offsite dose, the transport of tritium in the environment and its implications for health protection are important to SRS operations. The following tritium dispersion measurements in the environment around SRS were emphasized in the tritium transport and cycling project:

- determining the rate of tritiated hydrogen (HT) uptake in vegetation and soils and the effect of environmental factors controlling uptake
- determining the partitioning of tritium absorbed from atmospheric HT into plant organic material
- estimating the transport of organically bound tritium through food chains using tritium uptake and partitioning data
- determining the contribution of organically bound tritium to the radiation dose to man from atmospheric releases of HT
- determining the relationship between tritiated water and organically bound tritium in aquatic organisms, particularly under conditions of changing water tritium concentrations

SRL/ESS is meeting these program objectives through field and laboratory experiments and through cooperation with other groups interested in environmental tritium. Assessing the transport of tritium to vegetation and soils following inadvertent atmospheric or liquid tritium releases continued with the cooperation of the Meteorology and Environmental Measurements Groups of SRL/ETS.

In another project, tritium analyses were performed on fish collected in Par Pond and Upper Three Runs Creek to determine the organic tritium concentration in aquatic organisms. Continued analysis of fish from Upper Three Runs Creek will provide data on the dynamics of incorporating tritium into organic forms following an increase in tritium exposure.

The results of the tritium program were included in the tritium dose assessment document in the SRS Radionuclide Assessment Series. The tritium dispersion and cycling model, TRITMOD, is being used to evaluate the long-term consequences of reactor operation at SRS for the Reactor Operations EIS. In addition, SRL/ESS will review tritium cycling and transport, based in part on work from this program, for the NPR EIS.

Algaculture and Algal Bioaccumulation

Algaculture, a type of biotechnology that involves growing and harvesting algae, can be performed in a way that improves existing aquatic systems. Beneficial uses of waste heat and excess nutrients—two inherent and currently undesirable components of SRS reactor cooling water effluents—can also be derived using algaculture. In addition, algaculture may be effective in innovative heavy metal/radionuclide reclamation processes which utilize bioaccumulation.

Two preliminary feasibility studies of algaculture at SRS were completed in 1989. One study was a collaborative effort between SRL/ESS and Georgia Institute of Technology; the University of South Carolina performed the second study. Each study concluded that algaculture at SRS appears technically sound and highly desirable from environmental and economic standpoints.

Culturing activities conducted at SRS since the summer of 1988 have focused on algae in L Lake and the P-Reactor cooling system. In these experiments, indigenous algal strains of non-toxic, high-temperature-tolerant, filamentous, nitrogen-fixing blue-green algae were isolated from L Lake and the P-Reactor cooling system and grown in laboratory culture. Sterile SRS cooling water was used for media.

A two-phase research plan to evaluate the bioaccumulation of algae was developed. The first phase of this research will evaluate the ability of algae to accumulate or concentrate materials from the environment at SRS. If suitable potential is identified, the second research phase would determine practical applications at the site.

1989 HIGHLIGHTS

- The Environmental Dosimetry Group estimated doses from normal operation of the New Production Reactor to be less than 1% of the annual Central Savannah River Area natural background radiation level of 295 mrem.
- Cesium-137 was the only significant radionuclide detected in air particulate samples collected at the Aiken airport, with levels ranging from 0.01 fCi/m^3 to 0.10 fCi/m^3. These values can be compared to the DOE DCG of 400,000 fCi/m^3.
- The Reactor Accident Program, used with the WIND System to provide emergency response environmental consequence assessments for emergency response, can provide real-time estimates of whole body gamma exposure and thyroid doses at downwind locations onsite and offsite.
- Cesium-137 concentrations in the Savannah River were less than 0.2 pCi/L or about 0.2% of the EPA ^{137}Cs drinking water guide of 100 pCi/L.
- Development of a saturated flow and transport groundwater computer code (FTWORK) was completed in 1989 and will provide required regulatory information for the New Production Reactor EIS.
- In the aquifer characterization program, 18 well clusters were installed at key locations across the site. Each cluster consists of approximately eight wells screened in different aquifers.
- In a study of the uptake of transuranic elements by vegetation over burial-ground trenches, the average activity of ^{241}Am, ^{238}Pu, ^{239}Pu, and ^{237}Np was significantly higher in trees over the trenches than in the control plot.