Chapter 5

Potential Radiation Doses

Timothy Jannik, Patricia Lee, and Ali Simpkins
Savannah River Technology Center

To Read About . . . See Page . . .

THIS chapter presents the potential doses to offsite individuals and the surrounding population from 2001 Savannah River Site (SRS) atmospheric and liquid radioactive releases. Additionally, potential doses from special-case exposure scenarios—such as the consumption of deer meat, creek mouth fish, goat milk, and crops irrigated with Savannah River water—are documented.

Unless otherwise noted, the generic term "dose" used in this report includes both the committed effective dose equivalent (50-year committed dose) from internal deposition of radionuclides and the effective dose equivalent attributable to sources external to the body. Use of the effective dose equivalent allows doses from different types of radiation and to different parts of the body to be expressed on the same relative basis.

Many parameters—such as radioactive release quantities, population distribution, meteorological conditions, radionuclide dose factors, human consumption rates of food and water, and environmental dispersion—are considered in the dose models used to estimate offsite doses at SRS. Descriptions of the effluent monitoring and environmental surveillance programs discussed in this chapter can be found in chapter 3, "Radiological Effluent Monitoring," and chapter 4, "Radiological Environmental Surveillance." A complete description of how potential doses are calculated can be found in section 1108 of the *Savannah River Site Environmental Monitoring Section Plans and Procedures*, WSRC–3Q1–2, Volume 1 [SRS EM Program, 2001]. Tables containing all potential dose calculation results are presented in *SRS Environmental Data for 2001* (WSRC–TR–2001–00475).

Applicable dose regulations can be found in appendix A, "Applicable Guidelines, Standards, and Regulations," of this document.

Calculating Dose

Potential offsite doses from SRS effluent releases of radioactive materials (atmospheric and liquid) are calculated for the following scenarios:

- hypothetical maximally exposed individual
- 80-km (50-mile) population

Because the U.S. Department of Energy (DOE) has adopted dose factors only for adults, SRS calculates

Dose to the Hypothetical Maximally Exposed Individual

When calculating radiation doses to the public, SRS uses the concept of the maximally exposed individual; however, because of the conservative lifestyle assumptions used in the dose models, no such person is known to exist. The parameters used for the dose calculations are

For airborne releases: Someone who lives at the SRS boundary 365 days per year and consumes large amounts of milk, meat, and vegetables produced at that location

For liquid releases: Someone who lives downriver of SRS (near River Mile 118.8) 365 days per year, drinks 2 liters of untreated water per day from the Savannah River, consumes a large amount of Savannah River fish, and spends the majority of time on or near the river

To demonstrate compliance with the DOE Order 5400.5 all-pathway dose standard of 100 mrem per year, SRS conservatively combines the airborne pathway and liquid pathway dose estimates, even though the two doses are calculated for hypothetical individuals residing at different geographic locations.

maximally exposed individual and collective doses as if the entire 80-km population consisted of adults [DOE, 1988]. For the radioisotopes that constitute most of SRS's radioactive releases (i.e., tritium and cesium-137), the dose to infants would be approximately two to three times more than to adults. The dose to older children becomes progressively closer to the adult dose.

When DOE formally adopts age-specific dose factors and models, SRS will calculate doses for the various age groups.

SRS also uses adult consumption rates for food and drinking water and adult usage parameters to estimate intakes of radionuclides. These intake values and parameters were developed specifically for SRS based on an intensive regional survey [Hamby, 1991]. The survey includes data on agricultural production, consumption rates for food products, and use of the Savannah River for drinking water and recreational purposes.

Dose Calculation Models

To calculate annual offsite doses, SRS uses transport and dose models developed for the commercial nuclear industry [NRC, 1977]. The models are implemented at SRS in the following computer programs [SRS EM Program, 2001]:

- MAXDOSE–SR: calculates maximum and average doses to offsite individuals from atmospheric releases.
- POPDOSE–SR: calculates collective doses from atmospheric releases.
- LADTAP XL©: calculates maximum and average doses to offsite individuals and the population from liquid releases.
- CAP88: calculates doses to offsite individuals from atmospheric releases to demonstrate compliance with the National Emission Standards for Hazardous Air Pollutants (NESHAP) under the Clean Air Act.

The CAP88 computer code is required under the Clean Air Act to calculate offsite doses from atmospheric releases from existing and proposed facilities. SRS uses the CAP88 dose estimates to show NESHAP compliance, but not for routine dose calculations.

Meteorological Database

Meteorological data are used as input for the atmospheric transport and dose models.

For 2001, all potential offsite doses from releases of radioactivity to the atmosphere were calculated with quality-assured meteorological data for A-Area (used for A-Area and M-Area releases) and H-Area (used for releases from all other areas). The meteorological databases used were for the years 1992–1996, reflecting the most recent 5-year compilation period. Five-year average databases are used instead of the actual annual data because of the difficulty of compiling, inputting, and validating all the data in time to be used for the current-year dose calculations.

The wind rose developed from the 1992–1996 H-Area database shows that there is no prevailing wind at SRS, which is typical for the lower midlands of South Carolina. The maximum frequency that the wind blew in any one direction was 9.7 percent of the time, which occurred toward the southwest direction.

The meteorological measurements include all dispersion conditions observed during the 5-year period, ranging from unstable (considerable turbulence, which leads to rapid dispersion) to very stable (very little turbulence, which produces a narrow, undispersed plume). The data for 1992–1996 indicate that the SRS area experiences stable conditions (atmospheric stability classes E, F, G) about 18.4 percent of the time.

Population Database and Distribution

Collective, or population, doses from atmospheric releases are calculated for the population within a 80-km radius of SRS.

For 2001 dose calculations, the 2000 population database prepared by the Savannah River Technology Center (SRTC) was used. This database uses the U.S. Census Bureau population data for 2000 and distributes the population into a grid of cells one-second latitude by one-second longitude. The database is transformed by the POPDOSE–SR Code into polar coordinates of 16 compass sectors and varying radial distances out to 80 km. The POPDOSE–SR Code can prepare a polar coordinate database for any release point put into the code in polar coordinates. A separate, fixed-polar-coordinate database was prepared for use with the CAP88 Code, which does not have the capability of transforming the grid into polar coordinates. The population database generated by the POPDOSE–SR Code is centered on the geographical center of SRS.

Within the 80-km radius, the total population for 2000 was 713,500, compared to 620,100 for 1990, a 15-percent population growth in 10 years.

Some of the collective doses resulting from SRS liquid releases are calculated for the populations served by the City of Savannah Industrial and Domestic Water Supply Plant, near Port Wentworth, Georgia, and by the Beaufort-Jasper Water Treatment Plant, near Beaufort, South Carolina. According to the treatment plant operators, the population served by the Port Wentworth facility during 2001 was approximately 11,000 persons, while the population served by the Beaufort-Jasper facility (including some residents of Hilton Head Island) was approximately 97,000 persons.

River Flow Rate Data

Offsite dose from liquid effluents varies each year with the amount of radioactivity released and the amount of dilution (flow rate) in the Savannah River. Although flow rates are recorded at U.S. Geological Survey (USGS) gauging stations at the SRS boat dock and near River Mile 118.8 (U.S. Highway 301 bridge), these data are not used directly in dose calculations. This is because weekly river flow rates fluctuate widely (i.e., short-term dilution varies from week to week). Used instead are “effective” flow rates, which are based on measured concentrations of tritium in Savannah River water and measured concentrations in water used at the downstream water treatment plants. However, the USGS-measured flow rates are used for comparison to these calculated values.

For 2001, the River Mile 118.8 calculated (effective) flow rate of 4,743 cubic feet per second was used in determining doses to maximally exposed individuals, population doses from recreation and fish consumption, and potential doses from crops irrigated with river water. This flow rate was about 16 percent less than the 2000 effective flow rate of 5,640 cubic feet per second. For comparison, during 2001, the USGS-measured flow rate at River Mile 118.8 was 5,804 cubic feet per second.

The 2001 calculated (effective) flow rate for the Beaufort-Jasper facility was 5,411 cubic feet per second, which was about 19 percent less than the 2000 flow rate.

The 2001 calculated (effective) flow rate for the Port Wentworth facility was 6,047 cubic feet per second, which was about 14 percent less than the 2000 flow rate.

The 2001 calculated Savannah River estuary flow rate (6,384 cubic feet per second) was used only for calculation of dose from consumption of salt water invertebrates.

In figure 5–1, the annual average Savannah River flow rates, measured by the USGS at River Mile 118.8, are provided for the years of SRS operations (1954 to 2001). The 2001 rate of 5,804 cubic feet per second was the third lowest measured during this 48-year period.

Uncertainty in Dose Calculations

Radiation doses are calculated using the best available data. If adequate data are unavailable, then site-specific parameters are selected that would result in a conservative estimate of the maximum dose.

All radiation data and input parameters have an uncertainty associated with them, which causes uncertainty in the dose determinations. For example, there is uncertainty in the assumed maximum meat consumption rate of 81 kg (179 pounds) per year for an individual. Some people will eat more than 81 kg, but most probably will eat less. Uncertainties can be combined mathematically to create a distribution of doses rather than a single number. While the concept is simple, the calculation is quite difficult. A detailed technical discussion of the method of estimating uncertainty at SRS was published in the July 1993 issue of *Health Physics* [Hamby, 1993].

Dose Calculation Results

Liquid and air pathway doses are calculated for the maximally exposed individual and for the surrounding population. In addition, a sportsman dose is calculated separately for consumption of fish, deer, and feral hogs, which are nontypical exposure pathways. Finally, a dose is calculated for the aquatic biota found in SRS streams.

Liquid Pathway

This section contains information on liquid release quantities used as source terms in SRS dose calculations, including a discussion about radionuclide concentrations in Savannah River fish. The calculated dose to the maximally exposed individual, the calculated collective (population) dose, and the potential dose from agricultural irrigation are presented.

Liquid Release Source Terms

The 2001 radioactive liquid release quantities used as source terms in SRS dose calculations are presented in chapter 3 and summarized by radionuclide in table 5–1.

As discussed in chapters 3 and 4, SRS measures tritium releases to the Savannah River using three methods. In calculating doses from tritium, the stream transport value is used instead of the the river transport value or the direct-plus-migration value

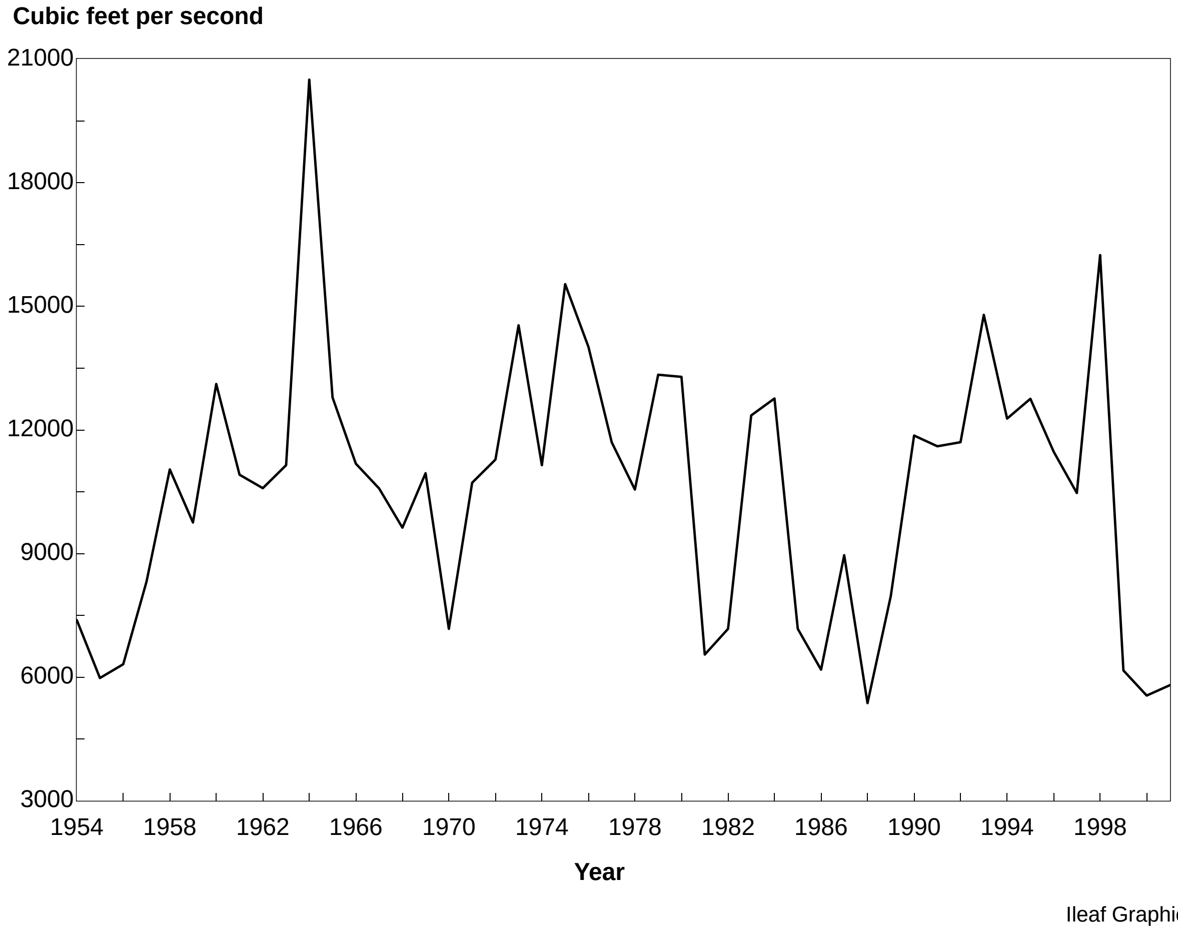

Figure 5–1 Savannah River Mile 118.8 Annual Average Flow Rates, 1954–2001

The 2001 River Mile 118.8 flow rate of 5,804 cubic feet per second was the third lowest measured during the 48-year operating history of SRS. River Mile 118.8 flow rates were not measured for the years 1971–1981; mean flow rates for those years are based on rates measured near Augusta, Georgia.

(chapter 4). This is because the stream transport value—measured in site streams just prior to their discharge to the Savannah River—most accurately reflects the actual amount of aqueous tritium leaving the site. During 2001, the total tritium transport in SRS streams decreased by approximately 28 percent (from 5,960 Ci in 2000 to 4,320 Ci in 2001). Most of this decrease is attributed to the Four Mile Creek phytoremediation project.

Releases of unspecified alpha emitters and nonvolatile beta emitters are listed separately in the source term. Prior to 1999, these alpha and beta emitters were included in plutonium-239 and strontium-89,90 releases, respectively.

For dose calculations, unspecified alpha releases were assigned the plutonium-239 dose factor, and unspecified nonvolatile beta releases were assigned the strontium-90 factor. Accounting for the alpha and beta emitters in this way generates an overestimated dose attributed to releases from SRS because

- plutonium-239 and strontium-90 have the highest dose factors among the common alpha- and beta-emitting radionuclides
- a part of the unidentified activity probably is not from SRS operations but from naturally occurring radionuclides, such as potassium-40 and radon progeny

Radionuclide Concentrations in Savannah River Water and Fish

For use in dose determinations and model comparisons, the concentrations of tritium in Savannah River water and cesium-137 in Savannah River fish are measured at several locations along the river. The amounts of all other radionuclides released from SRS are so small that they usually cannot be detected in the Savannah River using standard analytical techniques.

Radionuclide Concentrations in River Water and Treated Drinking Water The measured concentrations of tritium in the Savannah River near River Mile 118.8 and at the Beaufort-Jasper and Port Wentworth water treatment facilities are shown in table 5–1, as are the LADTAP XL©-determined concentrations for the other released radionuclides.

The 12-month average tritium concentrations measured in the Savannah River near River Mile 118.8 (1.02 pCi/mL), and at the Beaufort-Jasper (0.894 pCi/mL) and Port Wentworth (0.800 pCi/mL) water treatment plants, remained below the U.S. Environmental Protection Agency (EPA) maximum contaminant level (MCL) of 20 pCi/mL.

The 2001 River Mile 118.8 concentration was slightly less than the 2000 concentration of 1.18 pCi/mL.

Annual average tritium concentrations measured during the period 1992–2001 at River Mile 118.8 and at the Beaufort-Jasper and Port Wentworth facilities are compared to the EPA MCL in figure 5–2. The data for Beaufort-Jasper and Port Wentworth are the tritium concentrations measured in the finished drinking water at each facility.

Compliance With EPA's Maximum Contaminant Levels for Radionuclides in Drinking Water

In 2001, the EPA promulgated 40 CFR, Parts 9, 141, and 142, "National Primary Drinking Water Regulations; Radionuclides; Final Rule." This rule, applicable only to community drinking water systems, finalized maximum contaminant levels for radionuclides, including uranium [EPA, 2000].

The MCL for each radionuclide released from SRS during 2001 is provided in table 5–1. The table indicates that all individual radionuclide concentrations at the two downriver community drinking water systems, as well as at River Mile 118.8, were below the MCLs.

Because more than one radionuclide is released from SRS, the sum of the ratios of the observed concentration of each radionuclide to its corresponding MCL must not exceed 1.0.

As shown in table 5–1, the sum of the ratios was 0.0574 at the Port Wentworth facility and 0.0641 at

Table 5–1
2001 Radioactive Liquid Release Source Term and 12-Month Average Downriver Radionuclide Concentrations Compared to EPA's Drinking Water Maximum Contaminant Levels (MCLs)

		12-Month Average Concentration (pCi/mL)			
Nuclide	**Curies Released**	**Below SRS[a]**	**Beaufort-Jasper[b]**	**Port Wentworth[c]**	**EPA MCL**
H-3[d]	4.32E+03	1.02E+00	8.94E–01	8.00E–01	2.00E+01
Sr-90	2.05E–02	4.84E–06	4.24E–06	3.80E–06	8.00E–03
Tc-99	4.56E–02	1.08E–05	9.44E–06	8.44E–06	9.00E–01
I-129	7.82E–02	1.85E–05	1.62E–05	1.45E–05	1.00E–03
Cs-137[e]	6.58E–02	1.55E–05	1.36E–05	1.22E–05	2.00E–01
U-234	9.47E–05	2.24E–08	1.96E–08	1.75E–08	1.87E+02
U-235	1.70E–06	4.01E–10	3.52E–10	3.15E–10	6.48E–01
U-238	1.24E–04	2.93E–08	2.57E–08	2.30E–08	1.01E–02
Pu-238	4.50E–05	1.06E–08	9.31E–09	8.33E–09	1.50E–02
Pu-239	7.43E–06	1.75E–09	1.54E–09	1.38E–09	1.50E–02
Am-241	7.07E–06	1.67E–09	1.46E–09	1.31E–09	1.50E–02
Cm-244	7.09E–06	1.67E–09	1.47E–09	1.31E–09	1.50E–02
Alpha	2.87E–02	6.78E–06	5.94E–06	5.31E–06	1.50E–02
Nonvolatile Beta	8.51E–02	2.01E–05	1.76E–05	1.58E–05	8.00E–03
Sum of the Ratios =		7.32E–02	6.41E–02	5.74E–02	

a Near Savannah River Mile 118.8, downriver of SRS at the U.S. Highway 301 bridge
b Beaufort-Jasper, South Carolina, drinking water
c Port Wentworth, Georgia, drinking water
d Measured concentrations; all other concentrations calculated using models verified with tritium measurements
e Curies released based on measured cesium-137 levels in Savannah River fish

the Beaufort-Jasper facility. These are below the 1.0 requirement.

For 2001, the sum of the ratios at the River Mile 118.8 location was 0.0732. This is provided here only for comparison because River Mile 118.8 is not a community water system location.

Radionuclide Concentrations in River Fish At SRS, an important dose pathway for the maximally exposed individual is from the consumption of fish.

Fish exhibit a high degree of bioaccumulation for certain elements. For the element cesium (including radioactive isotopes of cesium), the bioaccumulation factor for Savannah River fish is approximately 3,000. That is, the concentration of cesium found in fish flesh is about 3,000 times more than the concentration of cesium found in the water in which the fish live.

Because of this high bioaccumulation factor, cesium-137 is more easily detected in fish flesh than in river water. Therefore, the fish pathway dose from cesium-137 is based directly on the radioanalysis of the fish collected near Savannah River Mile 118.8, which is the assumed location of the hypothetical maximally exposed individual. The fish pathway dose from all other radionuclides is based on the calculated concentrations determined by the LADTAP XL© code. A consumption rate of 19 kg (42 pounds) of fish per year is used in the maximally exposed individual dose calculation [Hamby, 1991]. Some fraction of this estimated dose is due to cesium-137 from worldwide fallout and from neighboring Vogtle Electric Generating Plant; however, that amount is difficult to determine and is not subtracted from the total.

The dose determinations are accomplished in the LADTAP XL© code by substituting a cesium-137 release value that would result in the measured concentration in river fish, assuming the site-specific bioaccumulation factor of 3,000. A weighted average concentration (based on the number of fish in each composite analyzed) of cesium-137 in River Mile 118.8 fish was used for maximally exposed individual and population dose determinations.

Dose to the Maximally Exposed Individual

The potential liquid pathway dose to the hypothetical maximally exposed individual living downriver of

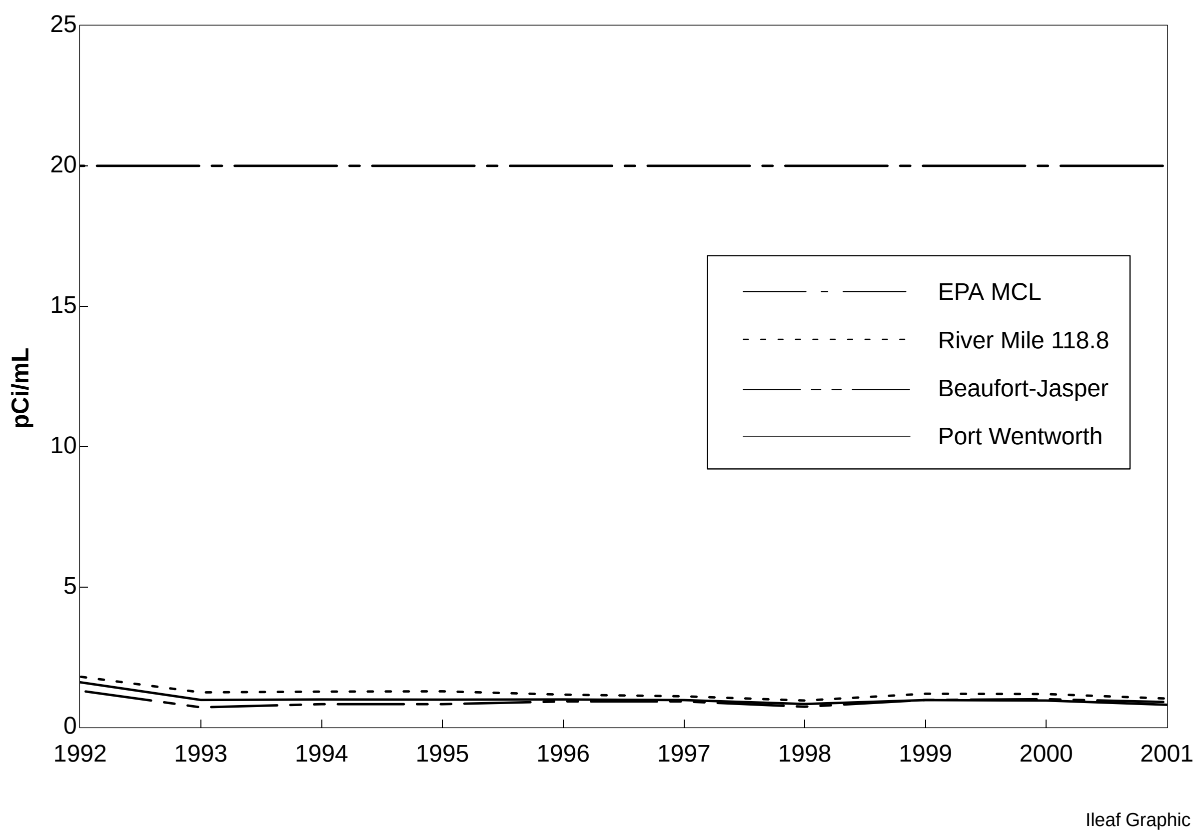

Figure 5–2 Annual Average Tritium Concentrations at River Mile 118.8, Beaufort-Jasper, and Port Wentworth (1992–2001) Compared to the EPA MCL for tritium of 20 pCi/mL.

Table 5–2
Potential Dose to the Maximally Exposed Individual from SRS Liquid Releases in 2001

	Committed Dose (mrem)	Applicable Standard (mrem)	Percent of Standard
Maximally Exposed Individual			
Near Site Boundary (all liquid pathways)	0.13	100[a]	0.13
At Port Wentworth (public water supply only)	0.06	4[b]	1.50
At Beaufort-Jasper (public water supply only)	0.07	4[b]	1.75

a All-pathway dose standard: 100 mrem per year (DOE Order 5400.5)
b Drinking water pathway standard: 4 mrem per year (DOE Order 5400.5)

SRS, near River Mile 118.8, was determined based on adult intake and usage parameters discussed earlier in this chapter and on other site-specific physical parameters.

As shown in table 5–2, the highest potential dose to the maximally exposed individual from liquid releases in 2001 was estimated at 0.13 mrem (0.0013 mSv). This dose is 0.13 percent of DOE's 100-mrem all-pathway dose standard for annual exposure.

The 2001 potential maximally exposed individual dose was slightly less than the 2000 dose of 0.14 mrem (0.0022 mSv).

Approximately 36 percent of the dose to the maximally exposed individual resulted from the ingestion of cesium-137, mainly from the consumption of fish, and about 38 percent resulted from the ingestion (via drinking water) of tritium. About 18 percent of the liquid pathway maximally exposed individual dose was attributed to unspecified alpha emitters, which are conservatively assigned the dose factor for plutonium-239 in the dose calculations (chapter 3).

Drinking Water Pathway Persons downriver of SRS may receive a radiation dose by consuming drinking water that contains radioactivity as a result of liquid releases from the site. In 2001, tritium in downriver drinking water represented the majority of the dose (about 63 percent) received by persons at downriver water treatment plants.

The calculated doses to maximally exposed individuals whose entire daily intake of water is supplied by the Beaufort-Jasper and Port Wentworth water treatment facilities, located downriver of SRS, were determined for maximum (2 liters per day for a year) water consumption rates.

The maximum potential drinking water doses during 2001 were 0.07 mrem (0.0007 mSv) at the Beaufort-Jasper Water Treatment Plant and 0.06 mrem (0.0006 mSv) at the City of Savannah Industrial and Domestic Water Supply Plant (Port Wentworth).

As shown in table 5–2, the maximum dose of 0.07 mrem (0.0007 mSv) is 1.75 percent of the DOE standard of 4 mrem per year for public water supplies. The 2001 maximum potential drinking water dose was slightly more than the 2000 maximum dose of 0.06 mrem (0.0006 mSv).

The "Potential Dose" section of appendix A, "Applicable Guidelines, Standards, and Regulations," explains the differences between the DOE and EPA drinking water standards.

Collective (Population) Dose

The collective drinking water consumption dose is calculated for the discrete population groups at Beaufort-Jasper and Port Wentworth. The collective dose from other pathways is calculated for a diffuse population that makes use of the Savannah River. However, this population cannot be described as being in a specific geographical location.

Potential collective doses were calculated, by pathway and radionuclide, using the LADTAP XL©

computer code. In 2001, the collective dose from SRS liquid releases was estimated at 4.3 person-rem (0.043 person-Sv). This was 10 percent more than the 2000 collective dose of 3.9 person-rem (0.039 person-Sv).

Potential Dose from Agricultural Irrigation

The 1990 update of land- and water-use parameters [Hamby, 1991] revealed that there is no known use of river water downstream of SRS for agricultural irrigation purposes. However, in response to public concerns, potential doses from this pathway are calculated for information purposes only and are not included in calculations of the official maximally exposed individual or collective doses.

For 2001, a potential offsite dose of 0.13 mrem (0.0013 mSv) to the maximally exposed individual and a collective dose of 8.9 person-rem (0.089 person-Sv) were estimated for this exposure pathway.

As in previous years, collective doses from agricultural irrigation were calculated for 1,000 acres of land devoted to each of four major food types—vegetation, leafy vegetation, milk, and meat. It is assumed that all the food produced on the 1,000-acre parcels is consumed by the 80-km population of 713,500.

Air Pathway

This section describes the atmospheric source term and concentrations used for dose determinations and presents the calculated dose to the maximally exposed individual, as well as the calculated collective (population) dose. Also included is a discussion about how SRS demonstrates NESHAP compliance.

Atmospheric Source Terms

The 2001 radioactive atmospheric release quantities used as the source term in SRS dose calculations are presented in chapter 3. Releases of unspecified alpha emitters and nonvolatile beta emitters were listed separately in the source term. Prior to 1999, these alpha and beta emitters were included in the plutonium-239 and strontium-89,90 releases, respectively.

For air pathway dose calculations—as in liquid dose calculations—unspecified alpha releases were assigned the plutonium-239 dose factor, and unspecified nonvolatile beta releases were assigned the strontium-90 dose factor.

In 2001, krypton-85 accounted for more than half of the radioactivity released to the atmosphere from SRS. Because krypton is an inert noble gas, which means it is chemically and biologically inactive, it is not readily assimilated or absorbed by the human body and it quickly disperses in the atmosphere. Therefore, it causes a relatively small amount of dose to humans (less than 1 percent of the maximally exposed individual dose in 2001).

Estimates of unmonitored diffuse and fugitive sources were considered, as required for demonstrating compliance with NESHAP regulations.

Airborne effluents are grouped by major release points for dose calculations. For the MAXDOSE–SR code, five release locations (center of site, H-Area, K-Area, M-Area, and SRTC) with specific release heights were used.

The CAP88 code can calculate doses from collocated release heights but cannot combine calculations for releases at different geographical locations. Therefore, for CAP88 calculations, airborne effluents were grouped for elevated releases (61 meters) and ground-level releases (0 meters), and the geographical center of the site was used as the release location for both.

Atmospheric Concentrations

The MAXDOSE–SR and CAP88 codes calculate average and maximum concentrations of all released radionuclides at the site perimeter. These calculated concentrations are used for dose determinations instead of measured concentrations. This is because most radionuclides released from SRS cannot be measured, using standard methods, in the air samples collected at the site perimeter and offsite locations. However, the concentrations of tritium oxide at the site perimeter locations usually can be measured and are compared with calculated concentrations as a verification of the dose models.

In table 5–3, the average 1992–2001 tritium oxide concentrations in air—measured near the center of the site and at locations along the site perimeter—are compared to the average concentrations calculated for the site perimeter, using the MAXDOSE–SR code.

These data show that the calculated site-perimeter tritium oxide concentrations have consistently and reasonably approximated the measured values and therefore are appropriate for use in dose determinations.

The average tritium-in-air concentration at the site boundary calculated using the MAXDOSE–SR code was 9 pCi/m^3. The maximum concentration was

Table 5–3
Ten-Year History of SRS Atmospheric Tritium and Tritium Oxide Releases and Average Measured Tritium Oxide Concentrations in Air Compared to Calculated Concentrations in Air

			Average Tritium Oxide Concentrations in Air		
	Total Tritium Released	Tritium Oxide Released[a]	Center of Site (measured)	Site Perimeter (measured)	Site Perimeter (calculated by dose model)[b]
Year	(Ci)	(Ci)	(pCi/m^3)	(pCi/m^3)	(pCi/m^3)
1992[c]	156,000	100,000	420	27	30
1993	191,000	133,000	450	30	37
1994[d]	160,000	107,000	350	23	30
1995	97,000	55,000	300	16	16
1996	55,300	40,100	123	11	11
1997	58,000	39,100	162	12	10
1998	82,700	58,600	147[e]	12[e]	15
1999	51,600	33,900	148[f]	14[f]	9
2000	44,800	32,400	[g]	[g]	8
2001	47,400	33,000	293	15	9

a Tritium oxide releases are included with elemental tritium releases in the “Total Tritium Released” column.

b MAXDOSE–SR

c During May 1992, the method for determining tritium oxide concentrations in air was changed to the use of measured humidity values (averaged biweekly) instead of a single generic value. The listed concentrations are for May to December 1992.

d During 1994, because of problems with measuring location-specific humidity values, a single generic value of 11.4 g/m^3 was used for absolute humidity.

e In 1998, the number of monitoring stations near the center of the site was reduced to one, and the number of monitoring stations at the site perimeter was reduced to 12.

f In 1999, the Environmental Monitoring Section changed the way that the tritium concentration in air is determined at SRS by incorporating a factor to correct for the dilution of tritium-in-air samples by intrinsic water in the silica gel sampling media.

g During 2000, because of problems with the analysis of silica gel sampling material, the uncertainty in the measured tritium-in-air concentrations was too high to allow a comparison.

calculated to be 18 pCi/m^3 in the north-northwest sector.

These concentrations compare favorably with the CAP88 code, which calculates an average concentration of 8 pCi/m^3 and a maximum site perimeter concentration of 12 pCi/m^3. This value is less than the MAXDOSE–SR code value because the CAP88 code assumes that all releases occurred from only one point, which is located at the center of the site.

Dose to the Maximally Exposed Individual

The potential air pathway dose to a hypothetical maximally exposed individual located at the site perimeter was determined using the MAXDOSE–SR computer code. The adult consumption and usage parameters used for the calculations were discussed earlier in this chapter.

In 2001, the estimated dose to the maximally exposed individual was 0.05 mrem (0.0005 mSv), which is 0.5 percent of the DOE Order 5400.5 (“Radiation Protection of the Public and the Environment”) standard of 10 mrem per year. This dose is slightly more than the 2000 dose of 0.04 mrem (0.0004 mSv); the change is attributed to increases in releases of tritium and iodine-129 from SRS (chapter 3). Table 5–4 compares the maximally exposed individual’s dose with the DOE standard.

Tritium oxide releases accounted for about 51 percent of the dose to the maximally exposed individual.

Iodine-129 and plutonium-239 emissions each accounted for about 16 percent of the maximally exposed individual dose. More than 90 percent of the plutonium-239 releases were estimated to be from diffuse and fugitive sources (chapter 3).

For 2001, the MAXDOSE–SR code determined that the north-northwest sector of the site was the location

Table 5–4
Potential Dose to the Maximally Exposed Individual from SRS Atmospheric Releases in 2001

	MAXDOSE–SR	CAP88 (NESHAP)
Calculated dose (mrem)	0.05	0.05
Applicable standard (mrem)	10[a]	10[b]
Percent of standard	0.5	0.5

a DOE: DOE Order 5400.5, February 8, 1990
b EPA: (NESHAP) 40 CFR 61 Subpart H, December 15, 1989

of the highest maximally exposed individual dose. Figure 5–3 shows the potential dose to the maximally exposed individual residing at the site boundary for each of the 16 major compass point directions around SRS.

The major pathways contributing to the dose to the maximally exposed individual from atmospheric releases were inhalation (43 percent) and the consumption of vegetation (44 percent), cow milk (9 percent), and meat (3 percent).

Additional calculations of the dose to the maximally exposed individual were performed substituting goat milk for the customary cow milk pathway. The potential dose using the goat milk pathway was estimated at 0.06 mrem (0.0006 mSv).

Collective (Population) Dose

Potential doses also were calculated, by pathway and radionuclide, using the POPDOSE–SR computer code for the population (713,500 people) residing within 80 km of the center of SRS.

In 2001, the collective dose was estimated at 2.9 person-rem (0.029 person-Sv)—less than 0.01 percent of the collective dose received from natural sources of radiation (about 214,000 person-rem).

Tritium oxide releases accounted for 59 percent of the collective dose. The 2001 collective dose was 26 percent more than the 2000 collective dose of 2.3 person-rem (0.023 person-Sv). The increase is attributed primarily to the use of the U.S. Census Bureau population data for 2000 (see earlier section, "Population Database and Distribution," page 72).

NESHAP Compliance

To demonstrate compliance with NESHAP (Clean Air Act, 40 CFR 61, Subpart H) regulations, maximally exposed individual and collective doses were calculated, and a percentage of dose contribution from each radionuclide was determined using the CAP88 computer code.

The dose to the maximally exposed individual, calculated with CAP88, was estimated at 0.05 mrem (0.0005 mSv), which is 0.5 percent of the 10-mrem-per-year EPA standard, as shown in table 5–4. Tritium oxide releases accounted for about 85 percent of this dose.

The CAP88 collective dose was estimated at 5.6 person-rem (0.056 person-Sv). Tritium oxide releases accounted for about 86 percent of this dose.

The CAP88 code estimates a higher dose for tritium oxide than do the MAXDOSE–SR and POPDOSE–SR codes. Most of the differences occur in the tritium dose estimated from food consumption. The major cause of this difference is the CAP88 code's use of 100-percent equilibrium between tritium in air moisture and tritium in food moisture, whereas the MAXDOSE–SR and POPDOSE–SR codes use 50-percent equilibrium values, as recommended by the Nuclear Regulatory Commission [NRC, 1977]. A site-specific study indicated that the 50-percent value is correct for the atmospheric conditions at SRS [Hamby and Bauer, 1994].

Because tritium oxide dominates the doses determined using the CAP88 code, and because the CAP88 code is limited to a single, center-of-site release location, other radionuclides (such as plutonium-239) are less important—on a percentage-of-dose basis—for the CAP88 doses than for the MAXDOSE–SR and POPDOSE–SR doses.

All-Pathway Dose

To demonstrate compliance with the DOE Order 5400.5 all-pathway dose standard of 100 mrem per year (1.0 mSv per year), SRS conservatively combines the maximally exposed individual airborne pathway and liquid pathway dose estimates, even

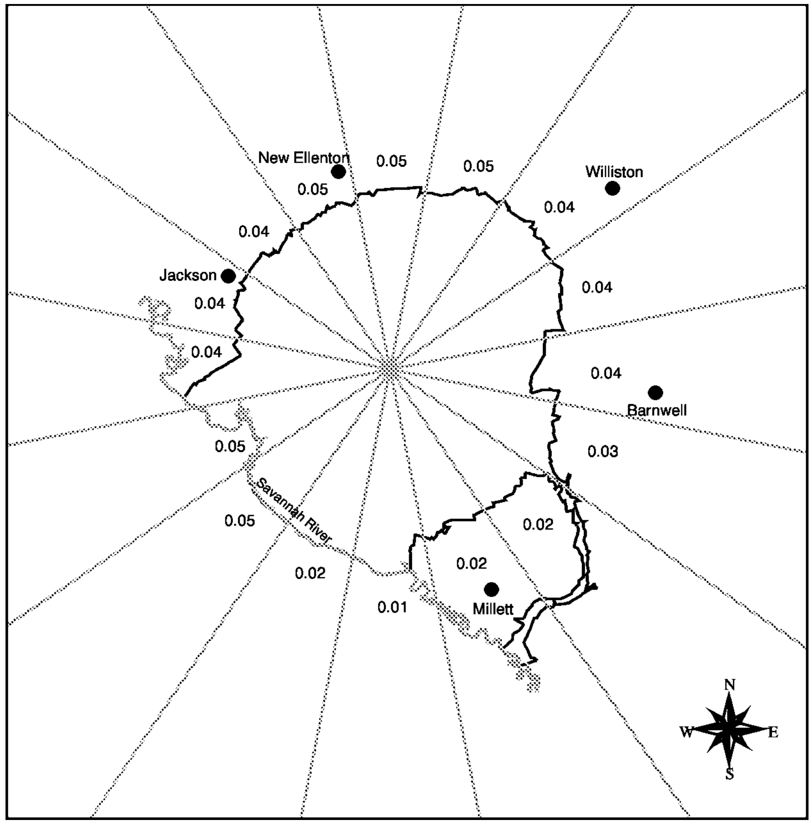

Figure 5–3 Sector-Specific Adult Maximally Exposed Individual Air Pathway Doses (in mrem) for 2001

Maximally exposed individual site boundary doses from airborne releases are shown for each of the 16 major compass point directions surrounding SRS. For 2001, five sectors (NNW, N, NNE, SW, WSW) had essentially the same maximally exposed individual dose of 0.05 mrem. However, when the third decimal point was considered, the NNW sector was slightly higher than the other four sectors.

EPD/GIS Map

though the two doses are calculated for hypothetical individuals residing at different geographic locations.

For 2001, the potential maximally exposed individual all-pathway dose was 0.18 mrem (0.0018 mSv)—0.05 mrem from airborne pathway plus 0.13 mrem from liquid pathway. This dose is the same as the 2000 all-pathway dose.

Figure 5–4 shows a 10-year history of SRS's all-pathway doses (airborne pathway plus liquid pathway doses to the maximally exposed individual).

As shown in table 5–5, the 2001 potential all-pathway dose of 0.18 mrem (0.0018 mSv) is 0.18 percent of the 100-mrem-per-year DOE dose standard.

Figure 5–5 shows a comparison of the 2001 maximum potential all-pathway dose attributable to SRS operations (0.18 mrem) with the average annual radiation dose received by a typical Central Savannah River Area (CSRA) resident from natural and manmade sources of radiation (360 mrem).

Sportsman Dose

DOE Order 5400.5 specifies radiation dose standards for individual members of the public. The dose standard of 100 mrem per year includes doses a person receives from routine DOE operations through all exposure pathways. Nontypical exposure pathways, not included in the standard calculations of the doses to the maximally exposed individual, are considered and quantified separately. This is because they apply to low-probability scenarios, such as consumption of fish caught exclusively from the mouths of SRS streams, or to unique scenarios, such as volunteer deer hunters.

For 2001, in addition to deer and fish consumption, the following exposure pathways were considered for an offsite hunter and an offsite fisherman—both on a privately owned portion of the Savannah River Swamp (Creek Plantation):

- External exposure to contaminated soil
- Incidental ingestion of contaminated soil
- Incidental inhalation of resuspended contaminated soil

The Creek Plantation, a privately owned land area located along the Savannah River, borders the southeast portion of SRS. The land is primarily undeveloped and agricultural; it is used in equestrian-related operations and as a recreational hunt club. A portion of Creek Plantation along the Savannah River includes part of the Savannah River

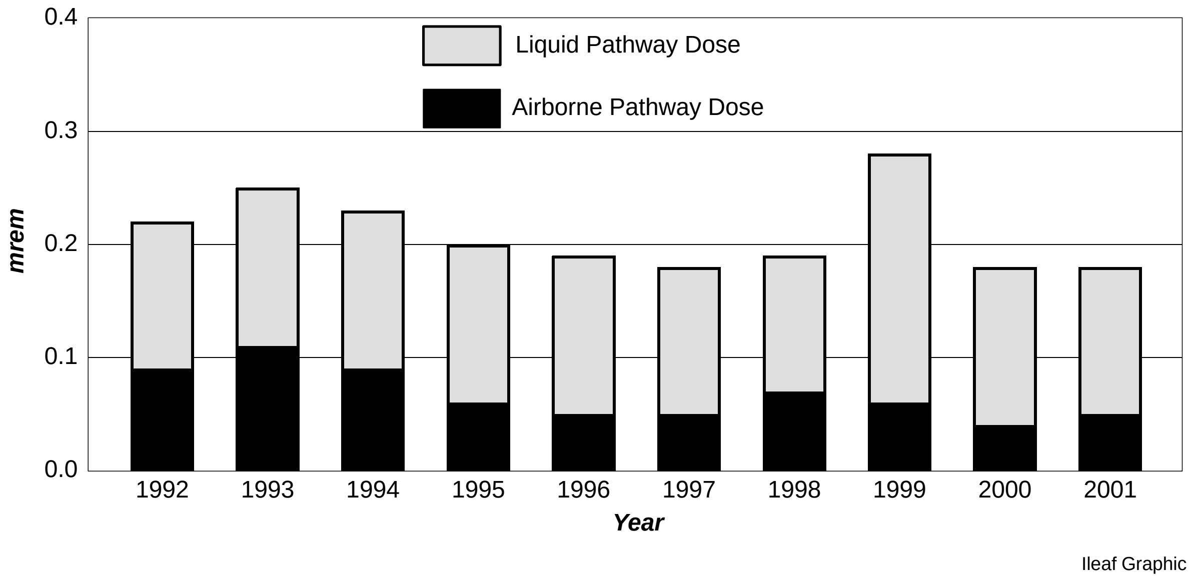

Figure 5–4 Ten-Year History of SRS Potential All-Pathway Doses to the Maximally Exposed Individual (Airborne plus Liquid Pathways)

Swamp, a low-lying swamp that is uninhabited and not easily accessible.

In the 1960s, an area of the Savannah River Swamp on Creek Plantation—specifically, the area between Steel Creek Landing and Little Hell Landing—was contaminated by SRS operations.

Comprehensive and cursory surveys of the swamp have been conducted periodically since 1974. These surveys measure radioactivity levels to determine changes in the amount and/or distribution of radioactivity in the swamp. The last comprehensive survey was conducted in 2000; a cursory survey was performed in 2001 (chapter 10, “Special Surveys and Projects”).

Onsite Hunter Dose

Controlled hunts of deer and feral hogs are conducted at SRS every year for approximately 6 weeks. Hunt participants are volunteers. Before any harvested deer or hog is released to a hunter, SRS personnel perform a field analysis for cesium-137 on the animal at the hunt site, using a portable sodium iodide detector.

Because of heightened security concerns in the wake of the terrorist attacks of September 11, the number and locations of the hunts were restricted. As a result, the number of animals harvested in 2001 was greatly reduced.

Deer and Hog Consumption Pathway The estimated dose from consumption of the harvested deer or hog meat is determined for each onsite hunter. During 2001, the maximum potential dose that could have been received by an actual onsite hunter was estimated at 14 mrem (0.14 mSv), or 14 percent of DOE’s 100-mrem all-pathway dose standard (table 5–5). This dose was determined for a prolific hunter who in fact harvested 11 hogs during the 2001 hunts.

The hunter-dose calculation is based on the conservative assumption that the hunter individually consumed the entire edible portion—approximately 279 kg (616 pounds)—of the hogs he harvested from SRS.

Offsite Hunter Dose

The potential doses to a hypothetical offsite hunter from deer consumption and contaminated soil exposure were calculated for 2001.

Deer Consumption Pathway The deer consumption pathway considered was for a hypothetical offsite individual whose entire intake of meat during the year was deer meat. It was assumed that this individual harvested deer that had resided on SRS, but then moved off site. The estimated dose was based on the assumed maximum annual meat consumption rate for an adult of 81 kg per year [Hamby, 1991].

Based on these low-probability assumptions and on the average concentration of cesium-137 (1.13 pCi/g) in deer harvested from SRS during 2001, the potential maximum dose from this pathway was estimated at 0.53 mrem (0.0053 mSv). A background cesium-137 concentration of 1 pCi/g is subtracted from the onsite average concentration before calculating the dose.

The background concentration is based on previous analyses of deer harvested 80 km from SRS (table 33, *SRS Environmental Data for 1994*, WSRC–TR–95–077).

Savannah River Swamp Hunter Soil Exposure Pathway The potential dose to a recreational hunter exposed to SRS legacy contamination in Savannah River Swamp soil on the privately owned Creek Plantation in 2001 was estimated using the RESRAD dosimetry code (DOE Order 5400.5). It was assumed that this recreational sportsman hunted for 120 hours during the year (8 hours per day for 15 days) at the location of maximum radionuclide contamination.

During the comprehensive survey of the Savannah River Swamp conducted in 2000, the location with the worst-case combination of cesium-137, cobalt-60, and strontium-90 concentrations was on trail 2, at a distance of 3,100 feet from the Savannah River (table 60, *SRS Environmental Data for 2000*, WSRC–TR–2000–00329).

Using these radionuclide concentrations, the potential dose to a hunter from a combination of 1) external exposure to the contaminated soil, 2) incidental ingestion of the soil, and 3) incidental inhalation of resuspended soil was estimated to be 4.4 mrem (0.044 mSv).

As shown in table 5–5, the offsite deer consumption pathway and the Savannah River Swamp hunter soil exposure pathway were conservatively added together to obtain a total offsite hunter dose of 4.93 mrem (0.0493 mSv). This potential dose is 4.9 percent of the DOE 100-mrem all-pathway dose standard.

Offsite Fisherman Dose

The potential doses to a hypothetical offsite fisherman from fish consumption and contaminated soil exposure were calculated for 2001.

Table 5–5
2001 Maximum Potential All-Pathway and Sportsman Doses Compared to the DOE All-Pathway Dose Standard

	Committed Dose (mrem)	Applicable Standard[a] (mrem)	Percent of Standard
Maximally Exposed Individual Dose			
All-Pathway (Liquid Plus Airborne Pathway)	0.18	100	0.18
Sportsman Doses			
Onsite Hunter	14	100	14
Creek Mouth Fisherman[b]	0.26	100	0.26
Savannah River Swamp Hunter			
Offsite Deer Consumption	0.53		
Soil Exposure[c]	4.4		
Total Offsite Hunter Dose	4.93	100	4.9
Savannah River Swamp Fisherman			
Steel Creek Fish Consumption	0.1		
Soil Exposure[d]	0.54		
Total Offsite Fisherman Dose	0.64	100	0.64

a All-pathway dose standard: 100 mrem per year (DOE Order 5400.5)

b In 2001, the maximum fisherman dose was caused by the consumption of bass from the mouth of Upper Three Runs.

c Includes the dose from a combination of external exposure to—and incidental ingestion and inhalation of—the worst-case Savannah River Swamp soil

d Includes the dose from a combination of external exposure to—and incidental ingestion and inhalation of—Savannah River Swamp soil near the mouth of Steel Creek

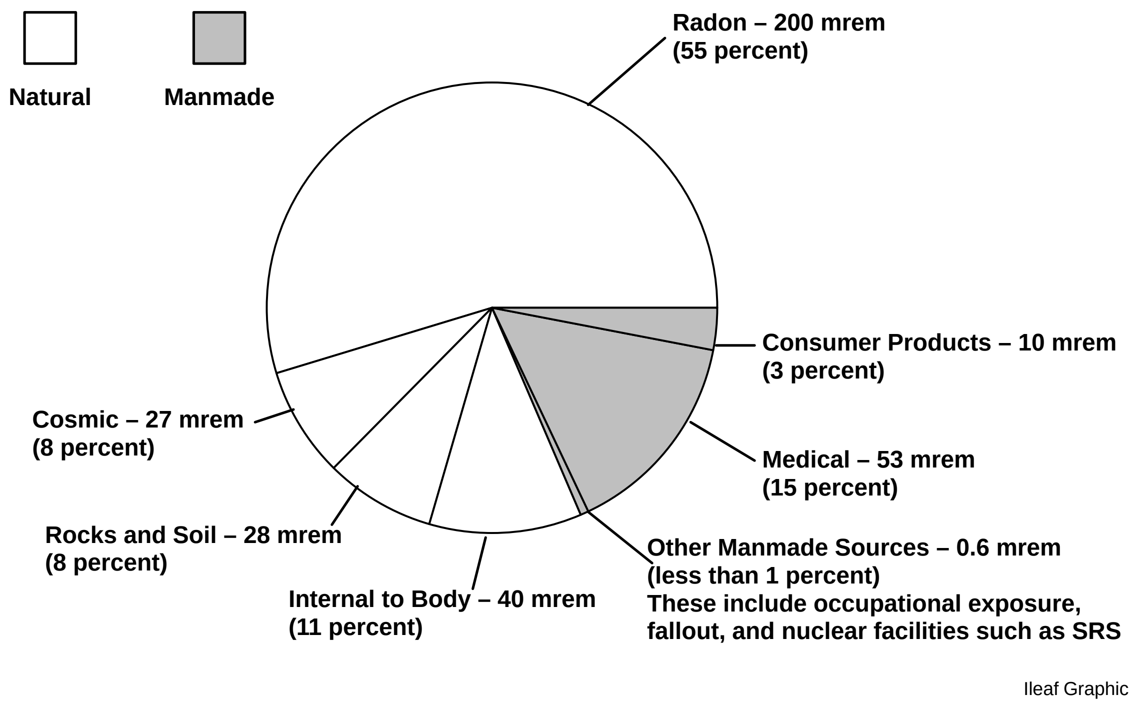

Figure 5–5 Contributions to the U.S. Average Individual Dose
The major contributor to the annual average individual dose in the United States, including residents of the CSRA, is naturally occurring radiation (about 300 mrem) [NCRP, 1987]. During 2001, SRS operations potentially contributed a maximum individual dose of 0.18 mrem, which is 0.05 percent of the 360-mrem total annual average dose (natural plus manmade sources of radiation).

Creek Mouth Fish Consumption Pathway For 2001, analyses were conducted of fish taken from the mouths of five SRS streams, and the subsequent estimated doses from the maximum consumption of 19 kg (42 pounds) per year [Hamby, 1991] of these fish were determined. Fish flesh was composited by species for each location and analyzed for tritium, strontium-89,90, cesium-137, plutonium-238, and plutonium-239.

As shown in table 5–5, the maximum potential dose from this pathway was estimated at 0.26 mrem (0.0026 mSv) from the consumption of bass collected at the mouth of Upper Three Runs. This hypothetical dose is based on the low-probability scenario that, during 2001, a fisherman consumed 19 kg of bass caught exclusively from the mouth of Upper Three Runs. About 74 percent of this potential dose was from strontium-90.

Savannah River Swamp Fisherman Soil Exposure Pathway The potential dose to a recreational fisherman exposed to SRS legacy contamination in Savannah River Swamp soil on the privately owned Creek Plantation in 2001 was estimated using the RESRAD dosimetry code (DOE Order 5400.5). It was assumed that this recreational sportsman fished on the South Carolina bank of the Savannah River near the mouth of Steel Creek for 250 hours during the year.

During the comprehensive survey of the Savannah River Swamp conducted in 2000, the location on Creek Plantation that was closest to the South Carolina bank of the Savannah River and the mouth of Steel Creek was on trail 1, at a distance of 0 feet from the Savannah River (table 60, *SRS Environmental Data for 2000*).

Using the radionuclide concentrations measured at this location, the potential dose to a fisherman from a combination of 1) external exposure to the contaminated soil, 2) incidental ingestion of the soil, and 3) incidental inhalation of resuspended soil was estimated to be 0.54 mrem (0.0054 mSv).

As shown in table 5–5, the Steel Creek mouth fish consumption dose (0.1 mrem) and the Savannah River Swamp fisherman soil exposure pathway were conservatively added together to obtain a total offsite creek mouth fisherman dose of 0.64 mrem (0.0064 mSv). This potential dose is 0.64 percent of the DOE 100-mrem all-pathway dose standard.

Potential Risk from Consumption of SRS Creek Mouth Fish

During 1991 and 1992, in response to a U.S. House of Representative Appropriations Committee request for a plan to evaluate risk to the public from fish collected from the Savannah River, SRS developed—in conjunction with EPA, the Georgia Department of Natural Resources (GDNR), and the South Carolina Department of Health and Environmental Control (SCDHEC)—the *Westinghouse Savannah River Company/Environmental Monitoring Section Fish Monitoring Plan*, which is summarized in SRS EM Program, 2001. Part of the reporting requirements of this plan are to perform an assessment of radiological risk from the consumption of Savannah River fish, and to summarize the results in the annual *SRS Environmental Report*. The following sections discuss the potential radiological risks from the consumption of Savannah River fish. Potential radiological risks are determined using both the ICRP–60 [ICRP, 1991] and the EPA [EPA, 1991] methods.

Exposure Scenario In EPA's risk assessment guidance document [EPA, 1991], two fish consumption pathways are considered—the recreational fisherman scenario and the subsistence fisherman scenario. Because of SRS's relatively remote location, the recreational fisherman scenario—as opposed to the subsistence fisherman scenario—is considered the more reasonable exposure scenario and is used in this assessment.

It is assumed that a recreational fisherman fishes for a single species of fish—either panfish, such as bream; predators, such as bass; or bottom dwellers, such as catfish—from the mouth of the worst-case SRS stream. Access to upstream portions of SRS streams is prohibited by postings, fencing (where possible), and periodic patrols.

Per EPA guidance [EPA, 1991], the maximum consumption rate that should be used for determining risk to the recreational fisherman is 19 kg (42 pounds) per year. This is the same as the consumption rate used by SRS for demonstrating maximally exposed individual dose compliance [Hamby, 1991].

The EPA guidance document requires that critical subpopulations and fish species be considered in risk assessments. Currently, there are no known sensitive subpopulations (e.g., Native Americans) in the immediate SRS region who are known to regularly consume whole fish (edible and nonedible portions) as part of their typical diet. Also, there are no known species of fish, such as smelt, in the SRS region of the Savannah River that are commonly eaten whole. Therefore, it is reasonably assumed that the recreational fisherman consumes only the edible (fillet only) portion of the fish caught.

Risk Factors For the EPA method, estimates of potential risk are calculated directly by multiplying the amount of each radionuclide ingested by the appropriate risk (slope) factors provided in EPA's *Health Effects Assessment Summary Tables* (HEAST) [EPA, 2001]. The HEAST ingestion slope factors are best estimates of potential, age-averaged, lifetime excess cancer incidence (fatal and nonfatal) risk per unit of activity ingested.

For the ICRP–60 method, estimates of potential risk are determined first by calculating a radiation dose attributable to the amount of radionuclides ingested and then multiplying that dose by the ICRP–60 coefficient of risk of severe detriment of 7.3E–07 per mrem [ICRP, 1991]. Stated another way, if 10,000,000 people each received a radiation dose of 1 mrem, there would theoretically be—during their collective lifetimes—7.3 additional severe detrimental incidences (fatal/nonfatal cancer or severe hereditary effects), which is small compared to the 2,000,000 or more expected fatal cancer incidences from other causes during their lifetimes [NRC, 1990].

The ICRP–60 risk coefficient includes factors for

- fatal cancers (5.0E–07 per mrem)
- nonfatal cancers (1.0E–07 per mrem)
- hereditary effects (1.3E–07 per mrem)

It should be noted that all radiological risk factors are based on observed and documented health effects to actual people who have received high doses (more than 10,000 mrem) of radiation, such as the Japanese atomic bomb survivors. Radiological risks at low doses (less than 10,000 mrem) are theoretical and are estimated by extrapolating the observed health effects at high doses to the low-dose region by using a linear, no-threshold model. However, cancer and other health effects have not been observed consistently at low radiation doses because the health risks either do not exist or are so low that they are undetectable by current scientific methods.

Exposure Duration According to EPA guidance, the upper bound value of 30 years can be used for exposure duration when calculating reasonable maximum residential exposures. This assessment compares the potential risks of exposure durations of 1 year, 30 years, and 50 years. The 30-year and 50-year exposure duration risks are simply 30 times and 50 times the 1-year exposure duration risk, respectively.

Risk Comparisons The maximum potential radiation doses and lifetime risks from the consumption of SRS creek mouth fish for 1-year, 30-year, and 50-year exposure durations are shown in table 5–6 and are compared to the radiation risks associated with the DOE Order 5400.5 all-pathway dose standard of 100 mrem (1.0 mSv) per year.

The maximum recreational fisherman dose was caused by the consumption of bass collected at the mouth of Upper Three Runs. About 74 percent of the dose was attributed to strontium-90, and about 26 percent was attributed to cesium-137.

Figure 5–6 shows a 9-year history of the annual potential radiation doses from consumption of Savannah River fish. No apparent trends can be discerned from these data. This is because there is large variability in the annual strontium-90 and cesium-137 concentrations measured in fish from the same location due to differences in

- the size of the fish collected each year
- their mobility and location within the stream mouth from which they are collected
- the time of year they are collected.

Also, it should be noted that most of the strontium-90 and cesium-137 that exists in SRS stream watersheds is legacy contamination left from relatively large releases that occurred during the early years of operations at SRS (1954–1963) and is not from current direct operational releases [Carlton et al., 1994]. Therefore, there is large annual variability in the amount of strontium-90 and cesium-137 available in the water and sediments at the site stream mouths; this is caused by annual changes in stream flow rates (turbulence) and water chemistry.

As indicated in figure 5–6, the 50-year maximum potential lifetime risks from consumption of SRS creek mouth fish range between 9.5E–06 and 6.2E–05, which are below the 50-year risk (3.2E–03) associated with the 100-mrem-per-year dose standard.

According to EPA practice, if a potential risk is calculated to be less than 1.0E–06 (i.e., one additional case of cancer over what would be expected in a group of 1,000,000 people), then the risk is considered minimal and the corresponding contaminant concentrations are considered negligible. If a calculated risk is more than 1.0E–04 (one additional case of cancer in a population of 10,000), then some form of corrective action or remediation usually is required. However, if a calculated risk falls between 1.0E–04 and 1.0E–06, which is the case with the maximum potential lifetime risks from the consumption of Savannah River fish, then the risks are considered acceptable if they are kept as low as reasonably achievable (ALARA).

At SRS, the following programs are in place to ensure that the potential risk from site radioactive liquid effluents (and, therefore, from consumption of Savannah River fish) are kept ALARA:

- radiological liquid effluent monitoring program (chapter 3)
- radiological environmental surveillance program (chapter 4)
- environmental ALARA program [SRS EM Program, 2001]

Table 5–6
Potential Lifetime Risks from the Consumption of Savannah River Fish Compared to Dose Standards

	Committed Dose (mrem)	ICRP–60 Risk Method	EPA/CERCLA Risk Method
2001 Savannah River Fish			
1-Year Exposure	0.26	1.9E–07	1.9E–07
30-Year Exposure	8	5.7E–06	5.8E–06
50-Year Exposure	13	9.5E–06	9.7E–06
Dose Standard			
100-mrem/year All Pathway			
1-Year Exposure	100	7.3E–05	6.3E–05
30-Year Exposure	3,000	2.2E–03	1.9E–03
50-Year Exposure	5,000	3.7E–03	3.2E–03

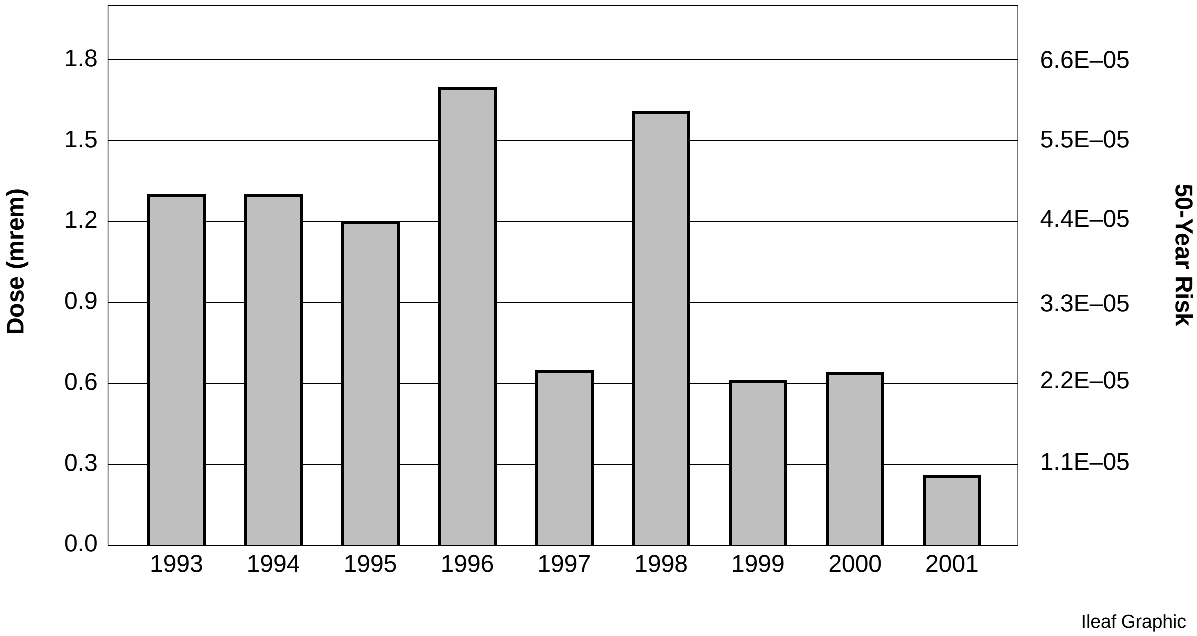

Figure 5–6 Annual Potential Radiation Doses and 50-Year Potential Risks from Consumption of Savannah River Creek Mouth Fish, 1993–2001

Dose to Aquatic Animal Organisms

DOE Order 5400.5 establishes an interim dose standard for protection of native aquatic animal organisms. The absorbed dose limit to these organisms is 1 rad per day (0.01 Gy per day) from exposure to radioactive material in liquid effluents released to natural waterways.

Hypothetical doses to various aquatic biota (fish, shellfish, algae, raccoon, and duck) in SRS streams are calculated annually to demonstrate compliance with this 1-rad-per-day dose standard. Upper-limit doses are calculated with measured radioactivity transport and minimum flow rates for each surface stream. Flow rates are chosen to maximize the biota dose. Source terms (stream transport) are provided by the site's Environmental Monitoring Section.

The CRITR computer code [Soldat et al., 1974], incorporated as part of the LADTAPII code, calculates internal and external doses to aquatic biota and to higher trophic levels that depend on aquatic biota for food. The CRITR Code is one of the three aquatic biota dose codes currently recommended by DOE [DOE, 1991].

External doses are calculated with the same external dose factors used for man [DOE, 1988]. Internal doses are based on the physical size (effective radius) of the biota and on effective energies provided for each radionuclide for each radius. Because of their size and eating habits, ducks usually are the aquatic biota that receive the largest dose.

In 2001, the maximum dose to aquatic biota was estimated at 0.004 rad per day (0.00004 Gy per day), which potentially occurred in ducks inhabiting Four Mile Creek. This is 0.4 percent of the 1-rad-per-day DOE dose limit.

Initial Screening of Biota Doses Using DOE Biota Concentration Guides

For 2001, a screening of biota doses at SRS was performed using the DOE Biota Concentration Guides (BCGs) listed in the proposed DOE standard entitled *A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota* [DOE, 2000].

The aquatic systems evaluation includes exposures to primary (herbivores) and secondary (predators) aquatic animals. Aquatic plants are not considered. The terrestrial systems evaluation includes exposures to terrestrial plants and animals.

For the aquatic systems evaluation portion of the BCGs, an initial screening was performed using maximum radionuclide concentration data for the 12 EMS stream sampling locations from which co-located water and sediment samples are collected. An exception was location FM–2B because of its historically high cesium and tritium concentration levels. This location was included in the initial screening even though no co-located sediment sample was collected there.

For water samples, the unidentified alpha and beta concentrations were conservatively added to the identified plutonium-239 and cesium-137 concentrations, respectively. Gross alpha and beta analyses are not performed on sediment or soil samples.

The combined water-plus-sediment BCG sum of the fractions was used for the aquatic systems evaluation. A sum-of-the-fractions value less than one indicates the sampling site has passed the initial pathway screen.

For the terrestrial systems evaluation portion of the BCGs, an initial screening was performed using concentration data from the five EMS onsite radiological soil sampling locations. Only one soil sample per year is collected from each location.

For 2001, stream sampling locations FM–A7, FM–2B, and R–1 failed the initial aquatic systems screen. All other locations, including the five soil sampling locations, passed.

For the three locations that failed, an additional assessment was performed using annual average radionuclide concentrations. All three locations passed this secondary screen (the sum of the fractions of each was less than 1.0).