

# 6 RADIOLOGICAL DOSE ASSESSMENT

Department of Energy (DOE) Order 458.1, "Radiation Protection of the Public and the Environment," establishes an annual public dose standard for the public and biota dose limits for plants and animals that are at levels that would provide protection of the public and environment from the effects of radiation resulting from DOE activities. The Savannah River Site (SRS) calculates the potential doses to members of the public from atmospheric and liquid radioactive releases to verify that these releases and exposures do not exceed the DOE public dose standard of 100 mrem/yr from routine DOE operations through all reasonable exposure pathways. Also, SRS considers and quantifies rare exposure pathways that are not included in the standard calculations of the doses to the representative person. This is because they apply to unlikely scenarios such as eating fish caught only from the mouths of SRS streams or to special scenarios such as onsite volunteer hunters. In addition, DOE Order 458.1 provides for the establishment of authorized surface contamination limits, which in turn allow unconditional release of personal and real property. SRS governs the unconditional release of equipment and material by procedures and performs radiological surveys on all equipment and material considered for release.

## **2015 HIGHLIGHTS**

### **Dose to the Offsite Representative Person**

The 2015 dose to the offsite representative person from SRS liquid releases was 0.15 mrem and from SRS air releases was 0.032 mrem. To show compliance with the DOE all-pathway dose standard of 100 mrem/yr, SRS conservatively adds these two doses for a total representative person dose of 0.18 mrem, which is 0.18% of the 100 mrem/yr DOE dose standard.

### **Sportsman Doses**

**Onsite Hunter:** SRS conducts annual hunts to control onsite deer and feral hog populations. The estimated dose from the consumption of harvested deer or hog meat is determined for every onsite hunter. During 2015, the maximum dose that could have been received by an onsite hunter was estimated at 12.9 mrem, or 12.9% of the 100 mrem/yr DOE dose standard.

**Creek Mouth Fisherman:** SRS estimated the maximum potential dose from fish consumption at 0.28 mrem from bass collected at the mouth of Lower Three Runs. This dose is 0.28% of the 100 mrem/yr DOE dose standard. SRS bases this hypothetical dose on the low probability scenario that, during 2015, a fisherman consumed 53 lbs of bass caught exclusively from the mouth of Lower Three Runs.

### **Release of Material Containing Residual Radioactivity**

SRS did not release any real property (land or buildings) in 2015. SRS unconditionally released a total of 10,124 items of personal property (such as tools) from radiological areas in 2015. Most of these items did not leave the Site. However, all of these items required no additional radiological controls post-survey as they met DOE Order 458.1 release criteria.

## **2015 HIGHLIGHTS (continued)**

### **Radiation Dose to Aquatic and Terrestrial Biota**

SRS conducts evaluations of plant and animal doses for water and land systems. For 2015, all SRS water, sediment and soil locations passed this screening and no further assessments were required.

## **6.1 INTRODUCTION**

Routine SRS operations result in releases of radioactive materials to the environment by atmospheric and liquid pathways. These releases could result in a radiation exposure to people offsite. To confirm that this exposure is below public dose limits, SRS calculates annual dose estimates using environmental monitoring and surveillance data combined with relevant site-specific data (such as weather conditions, population characteristics, and river flow). SRS also confirms that the potential doses to plants and animals (biota) living onsite remain below the DOE biota dose limits. This chapter explains radiation doses, describes how doses are calculated, and presents the estimated doses from SRS activities for 2015.

All SRS dose calculation methods and results are in a report titled *Radiological Environmental Dose Assessment Methods and Compliance Dose Results for 2015 Operations at the Savannah River Site* (Jannik and Dixon 2016) found on the *SRS Environmental Report for 2015* webpage located at <http://www.srs.gov/general/pubs/ERsum/index.html>.

SRS used the data generated by the programs described in Chapter 5, “Radiological Environmental Monitoring Program” to calculate the potential doses to the public.

### **Chapter 6 Key Terms**

**Reference person** is a hypothetical person with average physical and physiological characteristics, including factors like age and gender, and is used internationally for the purpose of standardizing radiation dose calculations.

**Representative person** is a hypothetical individual receiving a dose that is representative of highly exposed individuals in the population. At SRS, the representative person equates to the 95th percentile of applicable national human usage radiation exposure data.

## **6.2 WHAT IS RADIATION DOSE?**

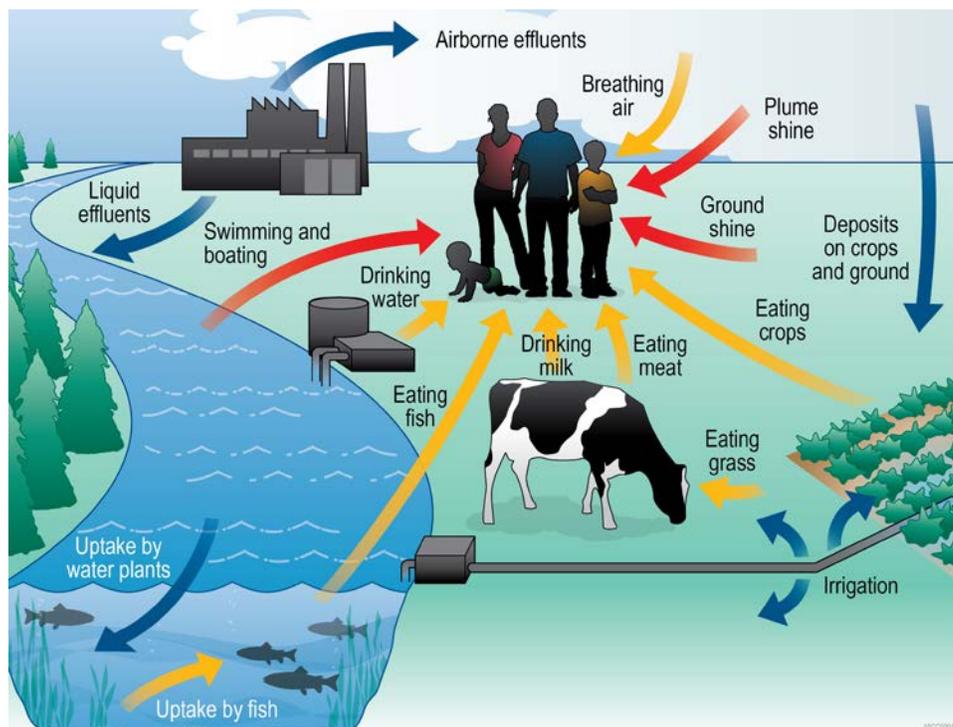
Radiation dose to a person is the amount of energy absorbed by the human body from a radioactive source, located either inside or outside of the body. SRS typically reports dose in millirem (mrem), which is one-thousandth of a rem. A rem is a standard unit used to measure the amount of radiation that is deposited in human tissue.

Humans, plants, and animals potentially receive radiation doses from natural and man-made sources. The average annual “background” dose for all people living in the United States is 625 mrem; this includes an average background dose of 311 mrem from naturally occurring radionuclides found in our bodies and in the earth, and from cosmic radiation, such as from the sun. Man-made sources include medical procedures

(300 mrem), consumer products (13 mrem), and less than 1 mrem from industrial and occupational exposures.

DOE has established dose limits to the public so that DOE operations will not contribute significantly to this average annual exposure. DOE Order 458.1 (DOE 2013) establishes 100 mrem/yr (1 mSv/yr) as the annual dose limit to a member of the public. Exposure to radiation primarily occurs through the following pathways, as shown in Figure 6-1:

- Inhalation of air;
- Ingestion of water and food;
- Skin absorption; and
- Direct (external) exposure to radionuclides in soil, air, and water.



**Figure 6-1 Exposure Pathways to Humans from Atmospheric and Liquid Effluents**

### 6.3 CALCULATING DOSE

In compliance with DOE Order 458.1, dose can be calculated to the maximally exposed individual (MEI) or to a representative person. Since 2012, SRS has used the representative person concept for dose compliance.

The representative person dose is calculated using reference person criteria developed specifically for SRS. The SRS representative person falls at the 95<sup>th</sup> percentile of national and regional data. The applicable national and regional data used are from the Environmental Protection Agency's *EPA Exposure Factor Handbook*, 2011 Edition (EPA 2011).

The reference person is weighted based on gender and age and this weighting is based on the six age groups documented in International Commission on Radiation Protection Publication 89, (ICRP 2002): Infant (0 years), 1 year, 5 years, 10 years, 15 years, and Adult. The reference person accounts for the fact that younger people are, in general, more sensitive to radioactivity than older people. SRS also developed usage parameters at the 50<sup>th</sup> percentile to use in calculating dose to a “typical” person for determining population doses.

The SRS report *Site Specific Reference Person Parameters and Derived Concentration Standards for SRS* (Stone and Jannik, 2013) documents the SRS-specific reference and typical person usage parameters. All other applicable land and water use parameters used in the dose calculations are documented in the *Land and Water Use Characteristics and Human Health Input Parameters for Use in Environmental Dosimetry and Risk Assessments at the Savannah River Site* (Jannik et al. 2016). These parameters include local characteristics of food production, river recreational activities, and other human usage parameters required in the SRS models used to calculate radioactive dose exposure.

For determining compliance with DOE public dose requirements, SRS calculates the potential offsite doses from SRS effluent releases of radioactive materials (atmospheric and liquid) for the following scenarios:

- Representative person living at the SRS boundary, and
- Population living within a 50-mile (80-kilometer [km]) radius of SRS.

For all routine environmental dose calculations, SRS uses environmental transport and dose models based on codes developed by the Nuclear Regulatory Commission (NRC) (NRC 1977). The NRC-based transport models use DOE accepted methods, consider all significant exposure pathways, and permit detailed analysis of the effects of routine operations. The SRS report “Environmental Dose Assessment Manual” (Jannik 2012) describes the specific models used at SRS.

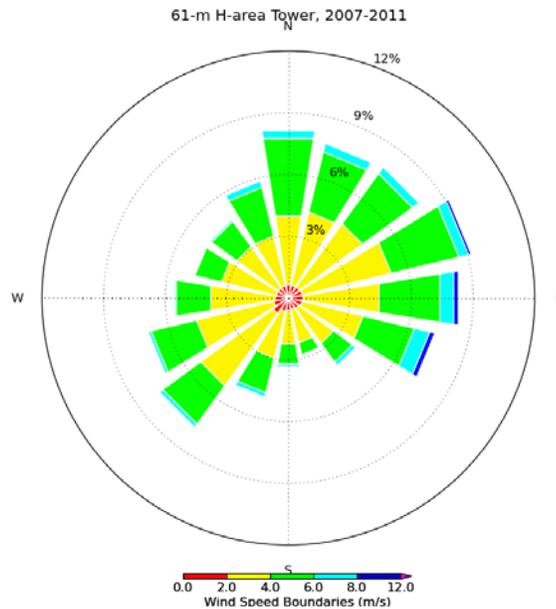
At SRS, the dose to a representative person is based on:

- 1) The SRS-specific reference person usage parameters at the 95<sup>th</sup> percentile of appropriate national or regional data, which are documented in Stone and Jannik (2013),
- 2) The reference person (gender- and age-averaged) ingestion and inhalation dose coefficients provided in *DOE Derived Concentration Technical Standard*, DOE-STD-1196-2011 (DOE 2011), and
- 3) The external dose coefficients provided in the DC\_PAK3 toolbox, which can be accessed at <http://www.epa.gov/rpdweb00/federal/techdocs.html>. Currently, there are no age-specific external dose factors available.

### 6.3.1 Weather Database

Complete and accurate weather (meteorological) data are an important part of determining the offsite contamination levels. SRS calculated potential offsite doses from releases of radioactivity to the atmosphere with quality-assured weather data from the years 2007-2011 (Viner 2013).

Figure 6-2 is the H-Area wind rose for 2007-2011, with the directions shown being toward which the wind blows. As shown, the wind blows towards the East Northeast the highest percentage time (about 9%), but there is no strongly prevalent wind direction.



**Figure 6-2 2007-2011 Wind Rose for H Area  
(Direction is toward which the wind blows)**

**6.3.2 Population Database and Distribution**

SRS calculates the collective (population) doses from atmospheric releases for the population within a 50-mile radius of the Site. Based on the U.S. Census Bureau’s 2010 data, the population within a 50-mile radius of the center of SRS is 781,060. This translates to about 104 people per square mile outside the SRS boundary, with the largest concentration in the Augusta metropolitan area.

Some of the collective doses from SRS liquid releases are calculated for the populations served by the water supply plants shown in Table 6-1.

**Table 6-1 Regional Water Supply Service**

Water Supply Plant	Nearest City	Population Served
City of Savannah Industrial and Domestic Water Supply Plant (City of Savannah I&D)	Port Wentworth, Georgia	35,000 people
Beaufort-Jasper Water and Sewer Authority’s (BJWSA) Chelsea Water Treatment Plant	Beaufort, South Carolina	82,900 people
Beaufort-Jasper Water and Sewer Authority’s (BJWSA) Purrysburg Water Treatment Plant	Beaufort, South Carolina	64,200 people

The total population dose resulting from routine SRS liquid releases is the sum of five contributing categories:

- 1) BJWSA water consumers,
- 2) City of Savannah I&D water consumers,
- 3) Consumption of fish and invertebrates of Savannah River origin,
- 4) Recreational activities on the Savannah River, and
- 5) Irrigation of foodstuffs using river water near River Mile (RM) 118.8 (U.S. Highway 301 bridge).

### **6.3.3 River Flow Rate Data**

The annual rate of flow in the Savannah River, which varies greatly from year to year, is an important criterion for determining down river concentrations of contaminants released from SRS. SRS uses the Savannah River flow rate measured by the U.S. Geological Survey (USGS) at their River Mile 118.8 gauging station, located near the US Hwy 301 Bridge. Figure 6-3 provides the river flow rates measured at this location from 1954 through 2015 and it shows that the average river-flow-rate for these years is about 10,000 cubic feet per second (cfs). However, recently, there has been a downward trend in these data with an average measured flow rate of just 7,237 cfs during the past 10 years.

For 2015, SRS used an estimated Savannah River flow rate of 5,972 cfs in the dose calculations. The 2015 estimated flow rate is 30% less than the 2014 estimated flow rate of 8,531 cfs. This estimated flow rate (based on actual measured tritium concentrations in the river) is more conservative than the 2015 USGS measured flow rate of 8,833 cfs. By using a conservative method, the estimates assume a lower dilution of radioactive material, and therefore over-estimate the potential impact. This is done to reflect the public health risks under a worst case scenario.

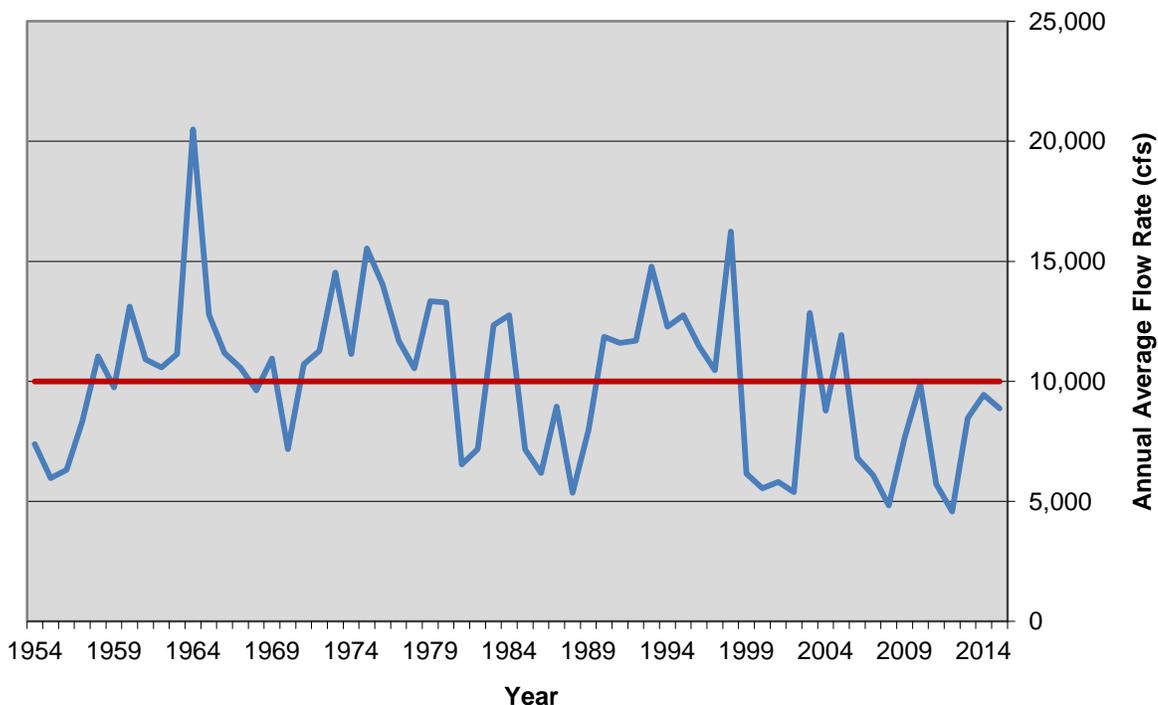


Figure 6-3 Savannah River Annual Average Flow Rates at River Mile 118.8

## 6.4 OFFSITE REPRESENTATIVE PERSON DOSE CALCULATION RESULTS

### 6.4.1 Liquid Pathway

#### 6.4.1.1 Liquid Release Source Terms

Table 6-2 shows, by radionuclide, the amount of radioactive liquid released in 2015. This is used as the source of the type and amount of radioactive material released in SRS dose calculations. Discussions of the sources of these data are in Chapter 5, "Radiological Environmental Monitoring Program."

Tritium accounts for more than 99% of the total amount of radioactivity released from the Site to the Savannah River. In 2015, SRS released a total of 786 curies of tritium to the river, a 12% increase from the 2014 amount of 699 curies.

In 2015, the Georgia Power Company's Vogtle Electric Generating Plant (VEGP) released 1,709 curies of tritium to the Savannah River and 70 curies migrated from the Barnwell Low-Level Disposal Facility (BLLDF) for an overall total of 2,565 curies of tritium (SRS plus VEGP plus BLLDF). This is a 13% decrease from the combined total of 2,933 curies in 2014.

#### 6.4.1.2 Radionuclide Concentrations in Savannah River Water, Drinking Water, and Fish

At several locations along the Savannah River, SRS measures the concentrations of tritium in the river water and cesium-137 in fish. SRS uses these measurements to make dose determinations. The amounts of all other radionuclides released from SRS are so small that their concentration in the Savannah River usually cannot be detected using conventional analytical techniques. SRS calculates their concentrations in the river based on the annual release amounts and river flow rates.

**Radionuclide Concentrations in River Water and Treated Drinking Water** —Table 6-2 shows the measured concentrations of tritium in the Savannah River near RM 118.8 and at the BJWSA Purrysburg water treatment facility, which is representative of the BJWSA Chelsea and the City of Savannah I&D water treatment plants. These downriver tritium concentrations include tritium releases from SRS and the VEGP and BLLDF. Also provided in Table 6-2 are the calculated concentrations for the other released radionuclides and a comparison of these concentrations to the Safe Drinking Water Act, 40 CFR 141 (EPA, 2000) maximum contaminant level (MCL) for each radionuclide.

In 2015, the 12-month average tritium concentration measured in Savannah River water near RM 118.8 was 481 picocuries per liter (pCi/L). This reflects a 25% increase from the 385 pCi/L measured in 2014. SRS attributes this increase to the 30% decrease in the estimated 2015 Savannah River flow, which caused less dilution to occur in the river.

**Radionuclide Concentrations in Fish** — At SRS, an important dose pathway for the representative person is from the consumption of fish. Fish exhibit a high degree of bioaccumulation for certain elements. For cesium (including radioactive isotopes of cesium, such as cesium-137), the bioaccumulation factor for Savannah River fish is 3,000, meaning that the concentration of cesium in fish flesh is about 3,000 times the concentration of cesium found in the water in which the fish live (Carlton et al., 1994).

Because of this high bioaccumulation factor, SRS can detect cesium-137 more easily in fish flesh than in river water. Therefore, when conservative to do so, SRS will base the fish pathway dose from cesium-137 directly on the analysis of the fish collected near RM 118.8, the assumed location of the hypothetical representative person. In 2015, the cesium-137 release value of 0.0468 Ci is based on analysis of fish in the river.

**Table 6-2 2015 Radioactive Liquid Release Source Term and 12-Month Average Downriver Radionuclide Concentrations Compared to the EPA's Drinking Water Maximum Contaminant Levels (MCL)**

Nuclide	Curies Released	12-Month Average Concentration (pCi/L)		
		Below SRS <sup>(a)</sup>	at BJWSA Purrysburg Plant <sup>(b)</sup>	EPA MCL <sup>(d)</sup>
H-3 <sup>(c)</sup>	7.86E+02	4.81E+02	4.03E+02	2.00E+04
C-14	5.33E-03	9.99E-04	8.37E-04	2.00E+03
Sr-90	2.43E-02	4.56E-03	3.82E-03	8.00E+00
Tc-99	1.30E-02	2.44E-03	2.04E-03	9.00E+02
I-129	1.44E-02	2.70E-03	2.26E-03	1.00E+00
Cs-137	4.68E-02	8.77E-03	7.35E-03	2.00E+02
U-234	6.77E-02	1.27E-02	1.06E-02	1.03E+01
U-235	2.50E-03	4.69E-04	3.93E-04	4.67E-01
U-238	7.55E-02	1.42E-02	1.19E-02	1.00E+01
Np-237	3.21E-07	6.02E-08	5.04E-08	1.50E+01
Pu-238	5.13E-04	9.62E-05	8.06E-05	1.50E+01
Pu-239	1.10E-04	2.06E-05	1.73E-05	1.50E+01
Am-241	1.79E-04	3.36E-05	2.81E-05	1.50E+01
Cm-244	1.21E-04	2.27E-05	1.90E-05	1.50E+01
Alpha	8.60E-03	1.61E-03	1.35E-03	1.50E+01
Beta	9.53E-02	1.79E-02	1.50E-02	8.00E+00

a. Near Savannah River Mile 118.8, downriver of SRS at the U.S. Highway 301 bridge

b. Beaufort-Jasper Water and Sewer Authority, drinking water at the Purrysburg Plant

c. The tritium concentrations and source term are based on actual measurements of the Savannah River water at the various locations. They include contributions from VEGP and the Barnwell Low-Level Disposal Facility. All other radionuclide concentrations are calculated based on the effective or measured river flow rate.

d. MCLs for Uranium based on radioisotope specific activity X 30 µg/L X isotopic abundance

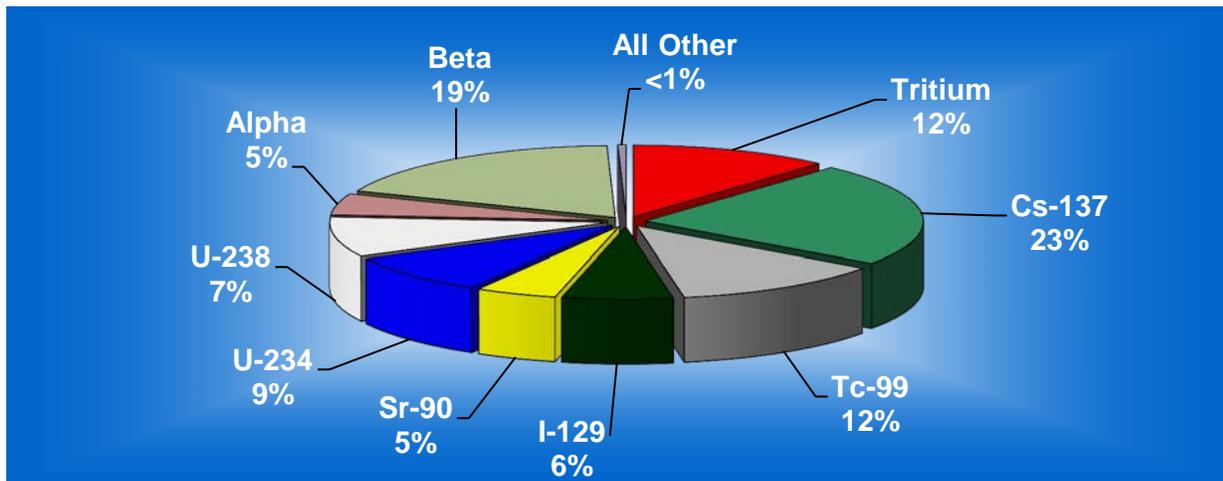
6.4.1.3 Dose to the Representative Person

The 2015 dose to the representative person from all liquid pathways including irrigation was estimated at 0.15 mrem (0.0015 mSv), which was 25% more than the comparable dose in 2014 of 0.12 mrem (0.0012 mSv). SRS attributes this increase to the 30% decrease in estimated Savannah River flow rate during 2015. Table 6-3 shows that this total dose is 0.15% of DOE’s public dose standard of 100 mrem/yr (1 mSv/yr).

**Table 6-3 Potential Dose to the Representative Person from SRS Liquid Releases in 2015**

	Committed Dose (mrem)	Applicable Standard (mrem)	Percent of Standard (%)
<b>Near Site Boundary (All Liquid Pathways)</b>			
All Liquid Pathways Except Irrigation	0.053		
Irrigation Pathways	0.093		
<b>Total Liquid Pathways</b>	<b>0.15</b>	<b>100<sup>a</sup></b>	<b>0.15%</b>
<sup>a</sup> DOE dose standard: 100 mrem/yr (DOE Order 458.1)			

Over 64% of the 2015 total dose to the representative person resulted from consuming meat, milk, and vegetables. The fish consumption pathway accounted for 23% and the drinking water pathway accounted for 13%. As shown in Figure 6-4, cesium-137 (23%) and unidentified beta emitters (19%) were the major contributors to the total dose.



**Figure 6-4 Radionuclide Contributions to the 2015 SRS Total Liquid Pathway Dose of 0.15 mrem (0.0015 mSv)**

#### 6.4.1.4 Drinking Water Pathway Dose

People living downriver of SRS may receive some dose by consuming drinking water that contains radioactive releases from the Site. Tritium in downriver drinking water represented the highest percentage of the dose (about 49%) received by customers of the three downriver water treatment plants.

In 2015 SRS-only releases were responsible for a maximum potential drinking water dose of 0.016 mrem (0.00016 mSv). This dose is 45% more than the 2014 dose of 0.011 mrem (0.00011 mSv). Again, this increase is mainly attributed to the decrease in the estimated Savannah River flow rate during 2015. There is not a separate drinking water dose standard, but the EPA Maximum Contamination Level (MCL), defined in 40 CFR 141 (EPA 2000), assume a potential dose of about 4 mrem/yr for beta and gamma emitters.

#### 6.4.1.5 Collective (Population) Dose

SRS calculates the collective drinking water consumption dose for the separate population groups served by the BJWSA and City of Savannah I&D water treatment plants. Calculations of collective doses from agricultural irrigation assume that 1,000 acres of land are used for each of the major food types grown in the SRS area (vegetables, milk, and meat), with the population within 50 miles of SRS consuming all the food produced on these 1,000-acre parcels.

In 2015, the collective dose from all liquid pathways was 2.6 person-rem (0.026 person-Sv). Person-rem is calculated as the average dose per person multiplied by the number of people exposed. This is 30% more than the comparable 2014 collective dose of 2.0 person-rem (0.020 person-Sv). SRS attributes this increase to the 30% decrease in in the estimated Savannah River flow rate during 2015.

### 6.4.2 **Air Pathway**

#### 6.4.2.1 Atmospheric Release Source Terms

Chapter 5 (“Radiological Environmental Monitoring Program”) documents the 2015 radioactive atmospheric release quantities used as the source term in SRS dose calculations. Tritium accounts for a majority of the dose from SRS atmospheric releases. As discussed in Chapter 5, tritium releases decreased about 30% from 2014 to 2015, which caused a decrease in the 2015 SRS air pathway doses.

#### 6.4.2.2 Atmospheric Concentrations

SRS uses calculated radionuclide concentrations instead of measured concentrations for dose determinations because most radionuclides released from SRS were not detected (using conventional analytical methods) in the air samples collected at the Site perimeter and offsite locations. However, SRS can routinely measure the concentrations of tritium at locations along the site perimeter and compares these results with the calculated concentrations to confirm the dose models. In 2015, this comparison showed that the dose models used at SRS were about 1.5 to 2 times more conservative than the actual measured tritium concentrations.

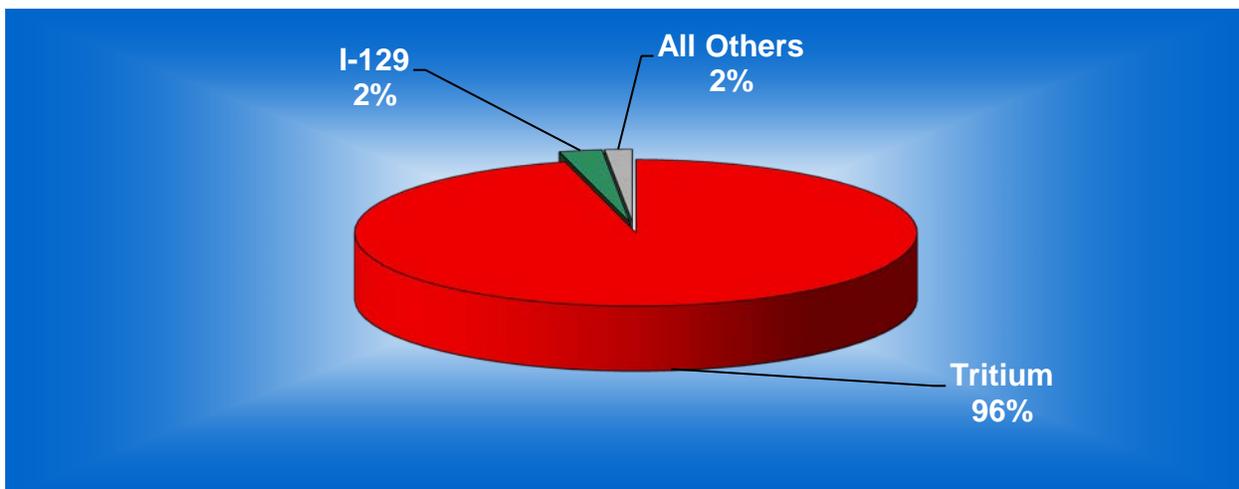
### 6.4.2.3 Dose to the Representative Person

The 2015 estimated dose from atmospheric releases to the representative person was 0.032 mrem (0.00032 mSv), 0.32% of the EPA 40 CFR 61 air pathway standard of 10 mrem per year. Table 6-4 compares the representative person dose with the EPA standard. The 2015 dose was about 27% less than the 2014 dose of 0.044 mrem (0.00044 mSv). SRS attributes this decrease to the 30% decrease in tritium releases during 2015 (see Chapter 5, “Radiological Environmental Monitoring Program”).

**Table 6-4 Potential Doses to the Representative Person and to the MEI from SRS Atmospheric Releases in 2015 and Comparison to the Applicable Dose Standard**

	MAXDOSE-SR	CAP88-PC (EPA NESHAP)
Calculated dose (mrem)	0.032	0.022
Applicable Standard (mrem)	10 <sup>a</sup>	10 <sup>b</sup>
Percent of Standard (%)	0.32	0.22
<sup>a</sup> DOE: DOE Order 458.1		
<sup>b</sup> EPA: (NESHAP) 40 CFR 61, Subpart H		

As shown in Figure 6-5, tritium releases accounted for nearly 96% of the dose to the representative person. Iodine-129 accounted for about 2%. No other individual radionuclide accounted for more than 1% of the representative person dose.



**Figure 6-5 Radionuclide Contributions to the 2015 SRS Air Pathway Dose of 0.032 mrem (0.00032 mSv)**

The major ways a representative person received radioactivity from atmospheric releases were inhalation (38%), vegetable consumption (37%), and cow milk consumption (25%).

### 6.4.2.4 Collective (Population) Dose

SRS calculates the air-pathway collective dose for the entire 781,060 population living within 50 miles of the center of the Site. In 2015, SRS estimated the airborne-pathway collective dose at 1.1 person-rem

(0.011 person-Sv), less than 0.01% of the annual collective dose received from natural sources of radiation (about 234,000 person-rem).

#### 6.4.2.5 National Emission Standards for Hazardous Air Pollutants (NESHAP) Compliance

To demonstrate compliance with NESHAP regulations (EPA 2002), SRS calculated Maximally Exposed Individual (MEI) and collective doses using:

- 1) The CAP88 PC version 4.0.1.17 computer code,
- 2) The 2015 airborne-release source term, and
- 3) Site-specific input parameters.

EPA requires the use of the MEI concept and does not allow use of the reference person concept at this time. EPA specifies most of the input parameters in the CAP88 PC program and they cannot be changed without specific EPA approval.

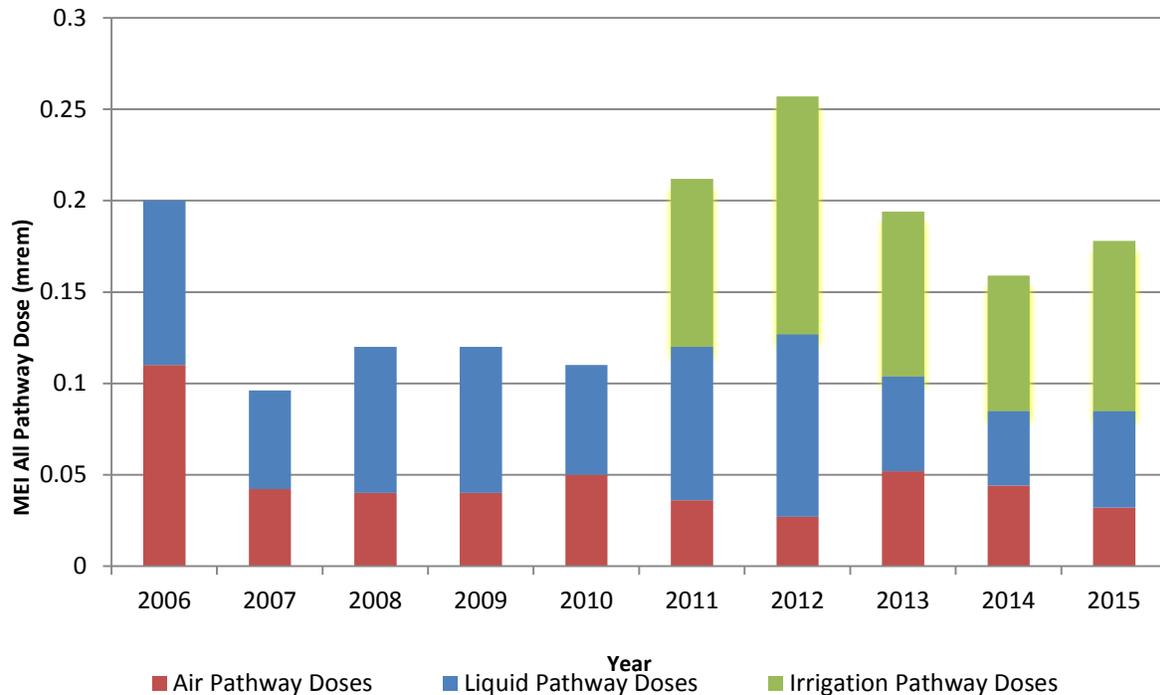
For 2015, SRS used CAP88 PC (version 4.0.1.17, dated September 2014) to demonstrate compliance with EPA's 10 mrem/yr (0.1 mSv/yr) public dose standard for airborne emissions from DOE sites. For 2015, the MEI dose was estimated at 0.022 mrem (0.00022 mSv), or 0.22% of the 10-mrem/yr EPA standard, as shown in Table 6-4.

Tritium oxide releases accounted for about 87% of the MEI dose and elemental tritium accounted for 11%. The 2015 NESHAP compliance dose (MEI dose) was about 27% less than the 2014 dose of 0.031 mrem (0.00031 mSv). Again, SRS attributes this decrease to the 30% decrease in tritium oxide releases during 2015 (see Chapter 5, "Radiological Environmental Monitoring Program").

#### 6.4.3 All-Pathway Dose

As stated in DOE Order 458.1, the all-pathway dose standard is 100 mrem/yr. SRS ensures a conservative estimate by combining the representative person airborne all-pathway and liquid all-pathway dose estimates, even though the two estimated doses are for hypothetical individuals residing at different geographic locations.

For 2015, the potential representative person all-pathway dose was 0.18 mrem (0.0018 mSv), calculated as 0.032 mrem from air pathways plus 0.15 mrem from liquid pathways. The all-pathway dose is 0.18% of the 100 mrem/yr (1 mSv/yr) DOE dose standard. The 2015 all-pathway dose is about 13% more than the 2014 total dose of 0.16 mrem (0.0016 mSv). SRS attributes this increase to the 30% decrease in in the estimated Savannah River flow rate during 2015.



**Figure 6-6 Ten-Year History of SRS Maximum Potential All-Pathway Doses**

1. Beginning in 2011, the irrigation pathway dose is included in the liquid pathway dose. Previous years do not include the irrigation pathway dose.
2. Beginning in 2012, SRS began using the representative person dose instead of the MEI dose.

Figure 6-6 shows a ten-year history of SRS's all-pathway (airborne pathways plus liquid pathways) doses to the MEI/representative person. Figure 6-7 graphically shows a comparison of SRS's 2015 all pathway dose to the DOE dose standard of 100 mrem/yr by equating 1 mrem to 1 yard on a football field.

## 6.5 SPORTSMAN DOSE CALCULATION RESULTS

DOE Order 458.1 specifies radiation dose standards for individual members of the public. The dose standard of 100 mrem/yr includes the dose a person receives from routine DOE operations through all exposure pathways. Additionally, SRS considers and quantifies rare exposure pathways that are not included in the standard calculations of the doses to the representative person. This is because they apply to unlikely scenarios such as eating fish caught only from the mouths of SRS streams ("creek-mouth fish") or to special scenarios such as onsite volunteer hunters.

In addition to deer, hog, fish, and turkey consumption, SRS considered the following exposure pathways for an offsite hunter and an offsite fisherman on Creek Plantation, a privately-owned portion of the Savannah River Swamp.

- External exposure to contaminated soil,
- Incidental ingestion of contaminated soil, and
- Incidental inhalation of renewed suspension of contaminated soil.

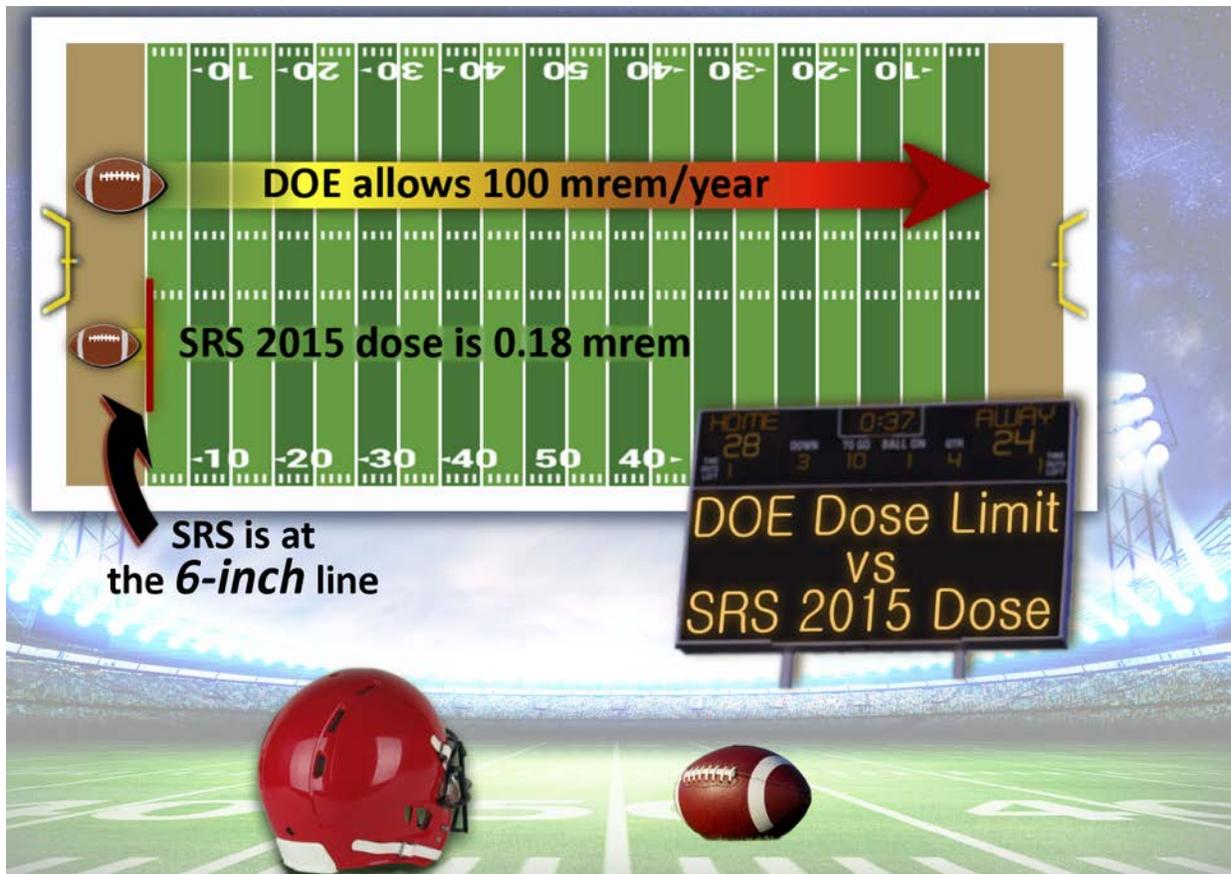


Figure 6-7 Comparison of DOE's 100 mrem/yr Dose Standard to SRS's 2015 All-Pathway Dose of 0.18 mrem

### 6.5.1 Onsite Hunter Dose

**Deer and Hog Consumption Pathway** — Annual hunts, which are open to the public, are conducted at SRS to control the Site's deer and feral hog populations and to reduce animal-vehicle accidents. The estimated dose from the consumption of harvested deer or hog meat is determined for every onsite hunter. During 2015, the maximum dose that could have been received by an onsite hunter was estimated at 12.9 mrem (0.129 mSv), or 12.9% of DOE's 100 mrem/yr dose standard (Table 6-5). This dose was determined for an actual hunter who harvested 1 hog during the 2015 hunts. For the hunter-dose calculation, SRS conservatively assumes that this hunter individually consumed the entire edible portion, about 45 kilogram (kg) (99 pounds).

**Turkey Consumption Pathway** — SRS hosts a special turkey hunt during April for hunters with mobility impairments. Hunters harvested 27 turkeys in 2015. SRS measured all of the turkeys for radiation. Since none of them measured above background, no dose was assigned to these hunters.

### 6.5.2 Hypothetical Offsite Hunter Dose

**Deer and Hog Consumption Pathway** — The deer and hog consumption pathways considered were for hypothetical offsite individuals whose entire intake of meat (81 kg) during the year was either deer or hog meat. SRS assumes that these individuals harvest deer or hogs that had resided on SRS during the year but then moved offsite prior to hunting season.

Based on these unlikely assumptions and on the measured average concentration of cesium-137 in all deer (1.71 pCi/g) and hogs (0.91 pCi/g) harvested from SRS during 2015, the potential maximum doses from this pathway were estimated at 4.9 mrem (0.049 mSv) for the offsite deer hunter and 1.7 mrem (0.017 mSv) for the offsite hog hunter.

**Savannah River Swamp Hunter Soil Exposure Pathway** — SRS estimated the potential dose to a recreational hunter exposed to SRS legacy contamination on the privately-owned Creek Plantation. SRS assumes 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.

As shown in Table 6-5, 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 7.8 mrem (0.078 mSv). This potential dose is 7.8% of the DOE 100 mrem/yr dose standard.

### 6.5.3 Hypothetical Offsite Fisherman Dose

**Creek-Mouth Fish Consumption Pathway** — For 2015, analyses were conducted on three species of fish (panfish, catfish, and bass) taken from the mouths of four SRS streams. Using these concentrations, SRS estimated the maximum potential dose from fish consumption at 0.28 mrem (0.0028 mSv) from bass collected at the mouth of Lower Three Runs. SRS bases this hypothetical dose on the low probability scenario that, during 2015, a fisherman consumed 24 kg (53 lb) of bass caught exclusively from the mouth of Lower Three Runs. About 65% of this potential dose was from cesium-137.

**Savannah River Swamp Fisherman Soil Exposure Pathway** — SRS calculated the potential dose to a recreational fisherman exposed to SRS legacy contamination in Savannah River Swamp soil on the privately-owned Creek Plantation using the RESRAD code (Yu et al., 2001). SRS assumes 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.

Using the radionuclide concentrations measured at this location, SRS estimated 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 renewed suspension soil to be 0.67 mrem (0.0067 mSv).

As shown in Table 6-5, the maximum Steel Creek fish consumption dose (0.28 mrem) and the Savannah River Swamp fisherman soil exposure pathway were conservatively added together to obtain a total offsite fisherman dose of 0.95 mrem (0.0095 mSv). This potential dose is 0.95% of the DOE 100 mrem/yr dose standard.

Table 6-5 2015 Sportsman Doses Compared to the DOE Dose Standard

	Committed Dose (mrem)	Applicable Standard (mrem) <sup>a</sup>	Percent of Standard (%)
<b>Sportsman Dose</b>			
Onsite Hunter	12.9	100	12.9
Creek-Mouth Fisherman <sup>b</sup>	0.28	100	0.28
<b>Savannah River Swamp Hunter</b>			
Offsite Hog Consumption	1.67		
Offsite Deer Consumption	4.93		
Soil Exposure <sup>c</sup>	2.90		
Total Offsite Deer Hunter Dose	7.83	100	7.83
<b>Savannah River Swamp Fisherman</b>			
Steel Creek Fish Consumption	0.28		
Soil Exposure <sup>d</sup>	0.67		
Total Offsite Fisherman Dose	0.95	100	0.95
<sup>a</sup> DOE dose standard; 100 mrem/yr (DOE Order 458.1) <sup>b</sup> In 2015, the maximum dose to a hypothetical fisherman resulted from the consumption of bass from the mouth of Lower Three Runs <sup>c</sup> Includes the dose from a combination of external exposure to and incidental ingestion and inhalation of the worst-case Savannah River swamp soil <sup>d</sup> Includes the dose from a combination of external exposure and incidental ingestion and inhalation of Savannah River swamp soil near the mouth of Steel Creek			

#### 6.5.4 Potential Risk from Consumption of SRS Creek-Mouth Fish

During 1991 and 1992, in response to a U.S. House of Representatives Appropriations Committee request for a plan to evaluate risk to the public from fish collected from the Savannah River, SRS developed a fish monitoring plan in conjunction with EPA, the Georgia Department of Natural Resources (GDNR), and SCDHEC. This plan includes the assessment of radiological risk from the consumption of Savannah River fish, and requires that SRS present a summary of the results in the Annual SRS Environmental Report. For 2015, SRS estimated the maximum potential lifetime risk of developing fatal and non-fatal cancer from the consumption of SRS creek-mouth fish to be 1.9E-07. That is, if 10 million people each received a dose of 0.28 mrem, there is a potential for 1.9 excess cancer incidents.

## 6.6 RELEASE OF MATERIAL CONTAINING RESIDUAL RADIOACTIVITY

DOE Order 458.1 provides for the establishment of authorized surface contamination limits, which in turn allow unconditional release of personal and real property. This order defines personal property as “property of any kind, except for real property” and defines real property as “land and anything permanently affixed to the land such as buildings, fences and those things attached to the buildings, such as light fixtures, plumbing and heating fixtures, or other such items, that would be personal property if not attached.” SRS handles unconditional release of real property on a case-by-case basis, which requires specific approval from DOE. SRS did not release any real property in 2015, so the following discussion is associated with release of personal property from SRS. DOE Order 458.1 specifies that an annual summary of cleared property must be prepared and submitted to the Field Element Manager (i.e., DOE-SR Manager).

### 6.6.1 Property Release Methodology

SRS governs the unconditional release of equipment and material by procedures. Following a radiological survey, SRS can unconditionally release an item if it meets specific documented limits. For items meeting unconditional release criteria, SRS generates a form and electronically attaches it to the applicable radiological survey via the Visual Survey Data System. SRS subsequently compiled these electronic forms and coordinated a site-wide review to determine the amount of material and equipment released from SRS facilities in 2015. These measures ensure that radiological releases of material from SRS are consistent with the requirements of DOE Order 458.1.

SRS unconditionally released a total of 10,124 items of personal property from radiological areas in 2015. Most of these items did not leave the Site. However, all of these items required no additional radiological controls post-survey as they met DOE Order 458.1 release criteria (the recently implemented DOE Order 458.1 allows the use of DOE Order 5400.5 derived supplemental limits for unconditional release of equipment and materials).

In 2003, DOE approved a SRS request to use supplemental limits for releasing material from the Site with no further DOE controls. These supplemental release limits, provided in Table 31 of *Radiological Environmental Dose Assessment Methods and Compliance Dose Results for 2015 Operations at the Savannah River Site* (Jannik and Dixon 2016), are dose-based, and are such that if any member of the public received any exposure, it would be less than 1 mrem/yr. The supplemental limits include both surface and volume concentration criteria. The surface criteria are very similar to those used in previous years. The volume criteria allow SRS the option to dispose of potentially volume-contaminated material in Three Rivers Landfill, an onsite sanitary waste facility. In 2015, SRS did not release any material from the Site using the supplemental release limits volume concentration criteria.

## 6.7 RADIATION DOSE TO AQUATIC AND TERRESTRIAL BIOTA

DOE Order 458.1 requires that SRS conduct Site operations in a manner that protects the local biota from adverse effects due to radiation and radioactive material releases. To demonstrate compliance with this requirement, SRS uses the approved DOE Standard, DOE-STD-1153-2002, "A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota" (DOE 2002).

The biota dose rate limits specified in this standard are:

- Aquatic Animals 1.0 rad/day (0.01 gray/day),
- Riparian Animals 0.1 rad/day (0.001 gray/day),
- Terrestrial Plants 1.0 rad/day (0.01 gray/day), and
- Terrestrial Animals 0.1 rad/day (0.001 gray/day).

### 6.7.1 DOE Biota Concentration Guides

SRS conducts evaluations of plant and animal doses for water and land systems using the RESRAD Biota model (version 1.5) (SRS EDAM 2012), which directly implements the DOE (2002) guidance.

For water systems (animals who live in the water or along river banks), the RESRAD Biota model performs a combined water-plus-sediment evaluation. SRS performed initial screenings in 2015 using maximum radionuclide concentration data from SRS's 13 stream and sediment sampling locations that are located

within SRS. These screenings determine the biota concentration guide by adding the fractions for each of the 13 assessed aquatic systems. A sum of the fractions less than 1.0 indicates the sampling site has passed its initial pathway screening, which means that the biota dose rate limits were not exceeded and no further assessments are needed. For 2015, all SRS aquatic system locations passed the initial screening and no further assessments were required.

For the land based systems evaluation, SRS performed initial screenings using concentration data from the five onsite radiological soil sampling locations. Typically, SRS collects and analyzes only one soil sample per year from each location. For 2015, all land based locations passed their initial pathway screenings.

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