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Assessment of SRS Radiological Liquid and Airborne Contaminants and Pathways (U)

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Technical Review:

W.A. Carlton

Derivative Classifier:

A.R. Boni

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Westinghouse Savannah River Company
Savannah River Site
Aiken, SC 29808

MASTER

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Assessment of SRS Radiological Liquid and Airborne Contaminants and Pathways

INTRODUCTION

During development of the current Savannah River Site (SRS) Environmental Monitoring Plan (WSRC-3Q1-2, Vol. 1, Section 1000 Addendum, Rev. 3), which was a joint effort between WSRC and DOE-SR personnel, the following corrective action plan (CAP) item was identified:

SRS EM Plan CAP-1-1 (ESH-EMS-94-0129)

A complete critical-contaminant/critical-pathway analysis will be performed, documented in a separate report, and used as the basis for the rationale and design criteria of the SRS EM Program.

This report compiles and documents the radiological critical-contaminant/critical-pathway analysis performed for SRS.

The analysis covers radiological releases to the atmosphere and to surface water, which are the principal media that carry contaminants off site. During routine operations at SRS, limited amounts of radionuclides are released to the environment through atmospheric and/or liquid pathways. These releases potentially result in exposure to offsite people. Though the groundwater beneath an estimated 5 to 10 percent of SRS has been contaminated by radionuclides, there is no evidence that groundwater contaminated with these constituents has migrated off site (Arnett, 1996). Therefore, with the notable exception of radiological source terms originating from shallow surface water migration into site streams, onsite groundwater was not considered as a potential exposure pathway to offsite people.

DESCRIPTION

The major steps in performing public radiation dose and risk assessments are

- 1) characterization and quantification of source terms
- 2) calculation of atmospheric and surface water transport (dispersion/dilution)
- 3) characterization and quantification of environmental pathway transport to humans (exposure pathways)
- 4) calculation of radiation dose and subsequent risk

Source Terms

Environmental release data obtained from continuously monitored airborne and liquid effluent release points were used in conjunction with calculated release estimates of unmonitored radionuclides (such as noble gases, carbon-14, and fission product tritium) to quantify the annual and total amount of radioactive materials released to the environment from SRS. In addition, since 1991, an estimate of airborne radionuclide releases from unmonitored diffuse and fugitive sources is included in the atmospheric release totals. Refer to SRS EM Program, 1995 for a more complete description of the radiological effluent monitoring program at SRS.

The radiological source terms used in this analysis are presented in Appendix A and were compiled from Hetrick, 1991 and from the SRS annual environmental reports for the years 1990 through 1995 (Cummins, 1991 and Arnett 1992, 1993, 1994, 1995, and 1996).

Exposure Pathways

At SRS, the principal pathways by which offsite people may be exposed to released radionuclides are

- inhalation
- ingestion of water and food
- immersion/submersion
- ground and sediment shine

Figure 1 is a simplified representation of these principal exposure pathways.

Transport and Exposure Models

The radiological transport and dosimetry models used in this analysis were:

- MAXIGASP - used for determining dose to the maximally exposed individual (MEI) from routine atmospheric releases
- POPGASP - used for determining population dose from routine atmospheric releases
- LADTAP XL - used for determining maximally exposed individual and population doses from routine liquid releases to surface water

MAXIGASP and POPGASP are Savannah River Technology Center (SRTC)-modified versions of the U.S. Nuclear Regulatory Commission (NRC) computer programs called XOQDOQ (Sagendorf 1982) and GASPAR (Eckerman 1980). XOQDOQ calculates downwind radionuclide concentrations and GASPAR, using those concentrations, calculates doses to individuals and populations at specified locations. Modifications to the NRC codes have been made for input of specific SRS physical and biological data and to expand the amount of printed output data. The basic calculation methods used in the XOQDOQ and GASPAR programs have not been modified.

LADTAP XL (Hamby 1991a) is a Microsoft ExcelTM spreadsheet version of LADTAP II, which is an unmodified version of the NRC program of the same name (Simpson 1980). LADTAP XL incorporates dilution models described in NRC Regulatory Guide 1.113 (NRC 1977b) with improvements in the shoreline exposure and aquatic foods pathway models. Population dose predictions using LADTAP XL are slightly larger than LADTAP II because the total Savannah River commercial fish harvest is assumed to be ingested by the local 80-kilometer population and not exported out of the area.

The dose conversion factors used in the codes are based on International Commission on Radiological Protection (ICRP) 30 (ICRP 1979) and have been provided by DOE (DOE, 1988a and 1988b). Some usage factors contained in Regulatory Guide 1.109 (NRC, 1977a) are included as standard assumptions, but many have been replaced with SRS-specific parameters (Hamby, 1991b). Refer to SRS EM Program (1995), for a more complete description of the radiological dose assessment program at SRS.

Figure 1. Exposure Pathways to Man from SRS Atmospheric and Aqueous Releases

CALCULATIONS

Many parameters—such as source terms, population distribution, meteorological conditions, radionuclide dose factors, dose-to-risk factors, human consumption rates, and environmental dispersion—are considered in the models used to calculate offsite doses and risks at SRS.

In this analysis, in order to maintain consistency in year-to-year comparisons, the potential offsite doses and risks from each year (1954-1995) were all calculated using the most current population, meteorological, consumption, transport, and dispersion parameters (Arnett, 1996).

Potential offsite doses and risks were calculated for the following scenarios:

- maximally exposed individual
- 80-kilometer radius population

Because the U.S. Department of Energy (DOE) has adopted dose factors only for adults, MEI and collective doses were calculated as if the entire 80-km population consisted of adults. Refer to SRS EM Program (1995) for a more complete description of radiological dose calculations at SRS.

Atmospheric Dose Calculations

Maximally exposed individual (MEI) and 80-km population airborne pathway doses were calculated using the MAXIGASP and POPGASP codes for the following pathways:

• plume shine	• ground shine
• inhalation	• vegetation consumption
• cow milk consumption	• meat (beef) consumption

MAXIGASP

The MAXIGASP code was used to calculate annual average air and ground deposition concentrations per unit release for the site boundary distances in 16 compass sectors. Site-specific meteorological data was used to generate joint-frequency distributions of windspeed, stability, and direction for input to the MAXIGASP code. Plume rise, induced by momentum or thermal effects, was not considered. The meteorological dispersion parameters obtained and the user-specified source term were used to estimate radiation dose to the MEI from atmospheric exposure pathways. The MEI was assumed to reside continuously at the offsite location where the largest dose would be expected to occur. Major parameters used in calculating doses to the MEI are summarized in Table 1.

POPGASP

The POPGASP code was used to calculate annual air and ground deposition concentrations per unit release for each of 160 segments (16 wind direction sectors at 10 distances) within an 80-km radius. Meteorological dispersion parameters, source terms, population density, terrain elevations, and food production estimates were input to the POPGASP code and used to generate population doses from atmospheric exposure pathways. Major physical and usage parameters used in the POPGASP code for population dose calculations are summarized in Table 2.

Table 1. Parameters Used in MAXIGASP

Parameter	Value
Inhalation (m ³ /yr)*	8,000
Ingestion**	
Cow's milk (L/yr)	230
Meat (kg/yr)	81
Leafy vegetables, (kg/yr)	43
Fruits, vegetables, and grains (kg/yr)	276
Release Location and Height	58000E, 62000N; Height = 61m
Meteorological data***	H-Area Met Tower (1987-1991)

* From Regulatory Guide 1.109 (NRC 1977a)

** From Hamby (1991)

*** Parker (1992)

Table 2. Parameters Used in POPGASP

Parameter	Value
Inhalation(m ³ /yr)*	8,000
Ingestion**	
Cow's milk (L/yr)	120
Meat (kg/yr)	43
Leafy vegetables (kg/yr)	21
Fruits, vegetables, and grains (kg/yr)	163
Release Location and Height	58000E, 62000N; Height = 61m
Meteorological data***	H-Area Met Tower (1987-1991)
80-km Population****	620,100

* From Regulatory Guide 1.109 (NRC 1977a).

** From Hamby (1991) Foodstuff obtained at large from the 80-km agricultural production of man's foods; any insufficiency is assumed to be imported (uncontaminated).

*** Parker (1992)

**** 1990 U.S. Census, from Arnett (1996)

Liquid Dose Calculations

LADTAP XL

The LADTAP XL spreadsheet calculates radiation dose due to exposure via liquid effluent pathways for several individual and population receptors: 1) SRS boundary maximally exposed individual, 2) 80-km population, 3) treated drinking water maximally exposed individual, and 4) treated drinking water population.

The offsite individual (MEI) who receives the maximum dose from SRS routine liquid releases is assumed to be a hypothetical person who lives on the shore of the Savannah River, just beyond the SRS boundary, near River Mile 120. Complete mixing of all SRS liquid effluents into the river water is assumed to have occurred. It is conservatively assumed that this individual uses untreated river water for drinking, consumes river fish, and receives external exposure from the shoreline, swimming, and boating. Consumption and usage parameters used as inputs to LADTAP XL for calculating the MEI dose are summarized in Table 3.

The total population dose resulting from routine SRS releases is the sum of four contributing categories: 1) Beaufort-Jasper water consumers, 2) Port Wentworth water consumers, 3) consumption of fish and saltwater invertebrates of Savannah River origin, and 4) recreational activities on the Savannah River.

Water from the Savannah River is processed for consumption at two facilities approximately 160 km downstream of SRS. The Beaufort-Jasper Water Treatment Plant, a facility supplying Beaufort and Jasper Counties in South Carolina, utilizes river water for service to water consumers. Several miles further downstream, the City of Savannah Industrial and Domestic Water Supply Plant (formally Cherokee Hill Water Treatment Plant), located near Port Wentworth, GA, withdraws water from the river to supply a business-industrial complex near Savannah, Georgia.

The Beaufort-Jasper water treatment authority estimates that its consumer population in 1996 was 60,000. The Port Wentworth commercial and industrial consumers of Savannah River water are estimated to be 10,000 for 1996. The average transit time from the Savannah River at Steel Creek to the water treatment river intakes is 72 hours. The raw river water is assumed to have an average system retention time of 24 hours before distribution to water consumers. Therefore, a total holdup time of 96 hours is used in the calculation of drinking water dose. This holdup time is only significant for nuclides with very short half-lives.

Dose from the consumption of aquatic foods is calculated assuming the concentration of radionuclides in edible tissues are under equilibrium or steady-state conditions with that in the surrounding water. In LADTAP XL, it is conservatively assumed that all fish and invertebrates harvested commercially from the Savannah River are consumed by the population within 80 km of SRS.

The 80-km population receives no river water downstream of SRS for domestic purposes. However, this population is assumed to use the river for the harvesting of fish and invertebrates and for recreational purposes.

The major consumption and usage parameters used as inputs to LADTAP XL for calculating the offsite population doses are summarized in Table 3.

Table 3. Input Parameter Values Used for LADTAP XL Calculations *

Parameter	Value
80-km Population (1990 census)	620,100 adults
Maximum Usage Rates	
Fish	19 kg/yr
Drinking Water	730 L/yr
Shoreline	23 hrs
Swimming	8.9 hrs
Boating	21 hrs
Average (Population) Usage Rates	
Fish	9 kg/yr
Invertebrates	2 kg/yr
Drinking Water	370 L/yr
Shoreline	960,000 person-hrs
Swimming	160,000 person-hrs
Boating	1,100,000 person-hrs
Beaufort-Jasper User Population	60,000 adults
Port Wentworth User Population	10,000 adults
Sport fish harvest	35,000 kg/yr
Commercial fish harvest	2,700 kg/yr
Commercial invertebrate harvest	390,000 kg/yr
Estuary dilution factor	3
Transport Times (max individual)	
Discharge to recreation	24 hrs
Discharge to drinking water	36 hrs
Fish/invertebrate harvest	48 hrs
Transport Times (population)	
Discharge to customers of treatment facility	96 hrs
Sport fish harvest	240 hrs
Commercial fish & shellfish harvest	312 hrs
River Flow Rate at River Mile 120	10,500 cfs
River Flow Rate at Water Treatment Plants	13,000 cfs
River Flow Rate at Estuary	11,550 cfs

* From Hamby (1991a and 1991b)

Atmospheric and Liquid Risk Calculations

The total, lifetime, stochastic risks from SRS radiological atmospheric and liquid releases were estimated using the total risk coefficient developed by the ICRP in its Publication 60 (ICRP, 1990).

The ICRP-60 total risk coefficient, which is $7.3E-07$ per mrem, includes factors for

- fatal cancers ($5.0E-07$ per mrem)
- non-fatal cancers ($1.0E-07$ per mrem)
- hereditary effects ($1.3E-07$ per mrem)

According to risk assessment guidance provided by the U.S. Environmental Protection Agency (EPA) (EPA, 1991), the upper bound value of 30 years was used to determine and compare projected lifetime risks.

For the projected 30-year lifetime risks, an average of the liquid and airborne effluent releases during the most recent 5-year period (1991-1995) was used as the source term.

The annual cumulative risks were determined using the following equation:

$$Risk_{cumulative} = 7.3E-07/mrem \cdot \sum Dose_i$$

where:

$Risk_{cumulative}$	=	cumulative risk for the years 1954-1995
$7.3E-07/mrem$	=	ICRP-60 total risk factor
$Dose_i$	=	annual MEI or population dose from radionuclide i (mrem or person-mrem)

The projected 30-year risks were determined using the following equation:

$$Risk_{projected} = 30years \cdot 7.3E-07/mrem \cdot \sum \overline{Dose}_i$$

where:

$Risk_{projected}$	=	projected 30-year risks
$7.3E-07/mrem$	=	ICRP-60 total risk factor
$\overline{Dose}_i$	=	average MEI or population dose from radionuclide i for the years 1991-1995 (mrem/year or person-mrem/yr)

RESULTS

In Appendix A, the annual and cumulative radiological airborne and liquid source terms and associated MEI and population doses are presented by radionuclide for the years 1954-1995. A breakdown of the doses by applicable exposure pathways also is provided. In addition, the annual source terms and doses are graphically presented by radionuclide.

For each radionuclide, a summary sheet is provided in Appendix A that includes the total curies released, the cumulative and projected risks, the critical exposure pathways, and a discussion of the past and projected importance of the radionuclide at SRS.

In Appendix B, charts are provided, by airborne and liquid pathways, that show the relative percentage importance of individual and similarly grouped (e.g. activation products) radionuclides for 5-year time periods dating back to 1954 (the first time period was 1954-1960).

In Appendix C, charts are provided, by airborne and liquid pathways, that show the relative percentage importance of individual exposure pathways for 5-year time periods dating back to 1954. For the liquid pathway comparisons, the swimming, boating, and shoreline exposure pathways were combined into a single "recreation" pathway.

Critical Airborne Radionuclides

In Table 4, cumulative (1954-1995) and projected (30-year) MEI risk comparisons are provided and show the relative importance of each radionuclide measured and/or calculated to have been released to the atmosphere from SRS. In Table 5, similar comparisons are made for cumulative and projected population airborne pathway risks. To maintain consistency with other tables, three significant figures are provided for the risk values. However, because of the large uncertainties associated with risk calculations, it should not be implied that the risk values are that precise.

MEI Airborne Pathway Risk Comparison

In the early years of operations at SRS, because of the urgency to obtain special nuclear materials, short-cooled (about 100 days) fuel and target rods were processed in the separations areas (Kantelo, 1993). As shown in Appendix B, iodine-131 was the most critical radionuclide, on a MEI risk basis, from 1954 to 1960. Also, as shown in Table 4, iodine-131 was the most critical radionuclide on an overall cumulative risk basis (1954-1995). In the 1960's, physical and administrative controls (e.g. increasing cooling time to a minimum of 200 days) were implemented and served to lessen the offsite impact of iodine-131 releases. During subsequent years, as shown in Appendix B, tritium, iodine-129, plutonium-239, argon-41, and fission products increased in relative importance. Their percentage of importance varied depending on operational missions and accidental releases. In the most current 5-year period (1991-1995), because of the shut down of all SRS reactors and the limited operations performed in the separations areas, tritium dominates the airborne pathway MEI risk, accounting for over 90% of the risk. As shown in table 4, tritium is projected to remain the critical airborne pathway radionuclide at SRS, unless there are unforeseen changes in operations or new missions added.

Using current, 5-year average meteorology, the cumulative airborne pathway MEI risks attributable to iodine-131, tritium, plutonium-239 (including unidentified alpha emitters), argon-41, ruthenium-103/106, iodine-129, strontium-89/90 (including unidentified beta

Table 4. Airborne Pathway MEI Risk Comparisons
(Blank spaces indicate that the radionuclide was not, or is not projected to be, released)

Radionuclide (Historical)	Cumulative Risk (1954 - 1995)		Radionuclide (Recent 5-Yr)	Projected 30-Yr Risk (Recent 5-yr Avg Basis)
I-131	1.56E-05	1	H-3	1.41E-06
H-3	1.07E-05	2	I-129	8.01E-08
Pu-239	7.01E-06	3	Pu-239	5.08E-08
Ar-41	5.11E-06	4	Pu-238	5.06E-08
Ru-103/106	3.23E-06	5	U-235/238	2.10E-08
I-129	2.82E-06	6	Cs-137	9.90E-09
Sr-89/90	2.13E-06	7	Am-241/243	6.94E-09
Pu-238	1.44E-06	8	Sr-89/90	4.15E-09
C-14	5.86E-07	9	Ar-41	1.21E-09
Cs-137	3.55E-07	10	C-14	1.02E-09
U-235/238	3.36E-07	11	Cm-242/244	9.99E-10
Kr-88	1.99E-07	12	I-131	7.75E-10
Cm-242/244	1.11E-07	13	Kr-85	1.32E-10
Kr-85	4.49E-08	14	I-133/135	1.21E-10
Xe-135	3.51E-08	15	Ru-103/106	8.79E-11
Ru-103	3.13E-08	16	Co-60	3.82E-11
Ce-141/144	2.52E-08	17	Cs-134	1.16E-11
Xe-133	1.62E-08	18	Ce-141/144	1.03E-11
Kr-85m	1.54E-08	19	Zr-95/Nb-95	7.31E-13
Am-241/243	1.43E-08	20	Eu-154/155	4.80E-13
Co-60	8.79E-09	21	Ru-103	3.67E-13
Zr-95/Nb-95	8.43E-09	22	Xe-135	1.15E-13
Kr-87	8.29E-09	23	Sb-125	5.26E-15
Cs-134	2.35E-09	24	Ba-La-140	
Nb-95	1.35E-09	25	Cr-51	
Xe-131m	2.90E-10	26	Kr-85m	
I-133/135	2.13E-11	27	Kr-87	
Eu-154/155	5.00E-12	28	Kr-88	
Sb-125	6.81E-15	29	Mn-54	
Ba-La-140		30	Mo-99	
Cr-51		31	Nb-95	
Mn-54		32	Np-239	
Mo-99		33	P-32	
Np-239		34	Pm-147	
P-32		35	S-35	
Pm-147		36	Sb-124/125	
S-35		37	Sr-89	
Sb-124/125		38	Tc-99	
Sr-89		39	Xe-131m	
Tc-99		40	Xe-133	
Y-91		41	Y-91	
Zn-65		42	Zn-65	
Total	4.98E-05		Totals	1.64E-06

Table 5. Airborne Pathway Population Risk Comparisons

(Blank spaces indicate that the radionuclide was not, or is not projected to be, released)

Radionuclide (Historical)	Cumulative Risk (1954 - 1995)		Radionuclide (Recent 5-Yr)	Projected 30-Yr Risk (5-yr Avg Basis)
H-3	9.18E-01	1	H-3	1.21E-01
I-131	6.15E-01	2	Pu-239	3.52E-03
Pu-239	4.72E-01	3	Pu-238	3.32E-03
Ar-41	1.67E-01	4	I-129	2.19E-03
Pu-238	9.44E-02	5	U-235/238	2.14E-03
Ru-103/106	9.04E-02	6	Am-241/243	4.59E-04
I-129	7.78E-02	7	Sr-89/90	1.26E-04
Sr-89/90	6.46E-02	8	Cs-137	1.14E-04
U-235/238	3.52E-02	9	Cm-242/244	6.66E-05
Cs-137	2.76E-02	10	Ar-41	3.96E-05
C-14	2.24E-02	11	C-14	3.88E-05
Kr-88	8.90E-03	12	I-131	3.01E-05
Cm-242/244	7.39E-03	13	Kr-85	1.28E-05
Kr-85	4.35E-03	14	Ru-103/106	2.35E-06
Xe-135	2.69E-03	15	I-133/135	2.11E-06
Xe-133	1.51E-03	16	Co-60	3.83E-07
Ru-103	1.08E-03	17	Ce-141/144	3.69E-07
Ce-141/144	9.85E-04	18	Cs-134	2.33E-07
Am-241/243	9.47E-04	19	Xe-135	8.78E-09
Kr-85m	9.40E-04	20	Ru-103	6.94E-09
Zr-95/Nb-95	4.82E-04	21	Zr-95/Nb-95	6.28E-09
Kr-87	1.89E-04	22	Eu-154/155	7.85E-10
Cs-134	1.03E-04	23	Sb-125	3.10E-10
Nb-95	5.83E-05	24	Ba-La-140	
Co-60	5.36E-05	25	Cr-51	
Xe-131m	8.19E-06	26	Kr-85m	
I-133/135	3.75E-07	27	Kr-87	
Eu-154/155	3.24E-07	28	Kr-88	
Sb-125	4.01E-10	29	Mn-54	
Ba-La-140		30	Mo-99	
Cr-51		31	Nb-95	
Mn-54		32	Np-239	
Mo-99		33	P-32	
Np-239		34	Pm-147	
P-32		35	S-35	
Pm-147		36	Sb-124/125	
S-35		37	Sr-89	
Sb-124/125		38	Tc-99	
Sr-89		39	Xe-131m	
Tc-99		40	Xe-133	
Y-91		41	Y-91	
Zn-65		42	Zn-65	
Total	2.61E+00		Totals	1.33E-01

emitters), and plutonium-238 releases were determined to be greater than $1\text{E-}06$ (see Table 4). However, on a projected 30-year risk basis, only tritium is estimated to potentially cause an airborne pathway MEI risk of greater than $1\text{E-}06$.

In Figure 2 (page 13), the projected critical airborne radionuclides are presented by percent contribution. As shown, tritium (86% of dose/risk) is projected to be the most critical radionuclide. However, iodine-129 (5%) and plutonium-239 (3%), which includes unidentified alpha emissions, may become more important, on a percentage basis, if site airborne tritium releases continue to decline. It should be noted that over 60% of the plutonium-239 total is attributed to unidentified airborne alpha emissions.

Population Airborne Pathway Risk Comparison

As shown in Table 5, airborne pathway population risks follow a similar trend to the MEI risks. However, because of radioactive decay during transport, the shorter-lived radionuclides, such as iodine-131 (half life = 8 days), have less of an impact on the 80-km population risks than they do on the site boundary MEI risks. This is why tritium is the most critical radionuclide, on a cumulative population risk basis, and not iodine-131.

Using the current, 5-year average meteorology and 1990 population (620,100) data and assuming that the entire population is made up of adults, none of the released radionuclides were determined to cause greater than 0.12 excess severe detriment case in the 80-km population, either on a cumulative or projected 30-year basis (see Table 5).

Critical Airborne Exposure Pathways

In Appendix C, charts are provided that show the relative percentage importance of the individual atmospheric exposure pathways for 5-year time periods dating back to 1954. As discussed in the previous section, iodine-131 was the most critical contaminant during 1954-1960 and the vegetation consumption pathway was the most critical, accounting for about 75% of the dose from iodine-131. In subsequent years, tritium (inhalation (48%) and vegetation (33%) pathways), plutonium-239 (vegetation (55%) and inhalation (45%) pathways), and argon-41 (plume (100%) pathway), became more important. This caused the vegetation, inhalation and plume pathways to remain approximately equal (varying between 20% and 40%) in importance until 1990. From 1991 to 1995, because of the shut down of all SRS reactors and the limited operations performed in the separations areas, tritium dominated the airborne pathway MEI risk. Inhalation and vegetation were the critical pathways and the plume pathway was negligible.

In Figure 3 (page 13), the projected critical airborne pathways are presented by percent contribution. Because tritium is projected to remain the critical airborne pathway radionuclide at SRS, the inhalation (48%) and vegetation (35%) pathways will remain critical, with milk (12%) and meat (5%) consumption pathways of lesser importance and the ground and plume shine pathways negligible.

Figure 2. Projected Critical Airborne Radionuclides

Figure 3. Projected Critical Airborne Pathways

Critical Aqueous Radionuclides

In Table 6, cumulative (1954-1995) and projected (30-year) MEI risk comparisons are provided and show the relative importance of each radionuclide measured and/or calculated to have been released to the Savannah River from SRS. In Table 7, similar comparisons are made for cumulative and projected population liquid pathway risks. To maintain consistency with other tables, three significant figures are provided for the risk values. However, because of the large uncertainties associated with risk calculations, it should not be implied that the risk values are that precise.

MEI Liquid Pathway Risk Comparison

Because they were released in relatively large quantities and/or have large bioaccumulation factors in freshwater fish, cesium-137, phosphorus-32, niobium-95, zinc-65, tritium, strontium-89/90, iodine-131, and sulfur-35 were the most critical radionuclides at SRS, on a cumulative MEI risk basis (Table 6). As shown in Appendix A, most of the releases to SRS streams and seepage basins occurred during the early years of operations (prior to 1970) and were usually the result of abnormal operating events, such as fuel failures, cooling coil leaks, or faulty storage containers (Carlton, 1994, 1995, and 1996; Kantelo, 1993; Murphy, 1994).

As shown on the charts in Appendix B, cesium-137 was the most critical radionuclide from 1954-1975. In the 1970's, physical and administrative controls (e.g. filters, redesigned fuel rods and disassembly basin heat exchangers) were implemented and served to lessen the offsite impact of most fission and activation products (Carlton, 1992). During subsequent years tritium, which cannot be filtered from effluent streams, became of more relative importance. In the most current 5-year period (1991-1995), tritium is the major liquid pathway MEI risk, accounting for about 60% of the risk. Cesium-137 accounts for about 28% of the risk. As shown in Table 6, tritium and cesium-137 are projected to remain the critical liquid pathway radionuclides at SRS, unless there are unforeseen changes in operations or new missions added.

It should be noted that in recent years direct process liquid discharges of tritium account for less than 15% of the total amount of tritium released to the Savannah River from SRS. The remainder is legacy tritium that is migrating out of site seepage basins and the Solid Waste Disposal Facility (Arnett, 1996).

Using an average Savannah River flow rate of 10,500 cfs, the cumulative liquid pathway MEI risks attributable to cesium-137, phosphorus-32, niobium-95, zinc-65, tritium, strontium-89/90, iodine-131, and sulfur-35 releases were determined to be greater than $1\text{E-}06$ (see Table 6). However, on a projected 30-year risk basis, only tritium is estimated to potentially cause a liquid pathway MEI risk of greater than $1\text{E-}06$.

In Figure 4 (page 18), the projected critical aqueous radionuclides are presented by percent contribution. As shown, tritium (60% of dose/risk) and cesium-137 (28% of dose/risk) are projected to be the most critical radionuclides. However, iodine-129 (1%), strontium-89/90 (7%), and plutonium-239 (4%) may become more important, on a percentage basis, if site aqueous tritium releases continue to decline. It should be noted that over 50% of the strontium-89/90 total is attributed to unidentified aqueous beta emissions and more than 99% of the plutonium-239 total is attributed to unidentified aqueous alpha emissions.

Table 6. Liquid Pathway MEI Risk Comparisons

(Blank spaces indicate that the radionuclide was not, or is not projected to be, released)

Radionuclide (Historical)	Cumulative Risk (1954 - 1995)		Radionuclide (Recent 5-Yr)	Projected 30-Yr Risk (5-yr Avg Basis)
Cs-137	1.38E-04	1	H-3	1.67E-06
P-32	3.72E-05	2	Cs-137	7.88E-07
Nb-95	1.21E-05	3	Sr-89/90	2.06E-07
Zn-65	5.94E-06	4	Pu-239	1.18E-07
H-3	5.92E-06	5	I-129	2.00E-08
Sr-89/90	1.99E-06	6	U-235/238	5.04E-10
I-131	1.10E-06	7	Pu-238	5.80E-11
S-35	1.09E-06	8	Pm-147	9.66E-12
Ce-141/144	4.22E-07	9	Tc-99	5.40E-12
U-235/238	3.78E-07	10	Am-241/243	5.08E-12
Co-60	3.40E-07	11	Ar-41	
Cr-51	1.97E-07	12	Ba-La-140	
Np-239	1.91E-07	13	C-14	
Sr-89	1.85E-07	14	Ce-141/144	
Pu-239	1.62E-07	15	Cm-242/244	
Ba-La-140	1.11E-07	16	Co-60	
Y-91	9.56E-08	17	Cr-51	
Ru-103/106	8.83E-08	18	Cs-134	
Cm-242/244	8.44E-08	19	Eu-154/155	
Pu-238	2.45E-08	20	I-131	
Cs-134	1.85E-08	21	I-133/135	
Pm-147	9.78E-09	22	Kr-85	
I-129	8.70E-09	23	Kr-85m	
Mo-99	4.76E-09	24	Kr-87	
Sb-124/125	4.37E-09	25	Kr-88	
Mn-54	1.20E-09	26	Mn-54	
Tc-99	8.99E-13	27	Mo-99	
Am-241/243	8.47E-13	28	Nb-95	
Ar-41		29	Np-239	
C-14		30	P-32	
Eu-154/155		31	Ru-103	
I-133/135		32	Ru-103/106	
Kr-85		33	S-35	
Kr-85m		34	Sb-124/125	
Kr-87		35	Sb-125	
Kr-88		36	Sr-89	
Ru-103		37	Xe-131m	
Sb-125		38	Xe-133	
Xe-131m		39	Xe-135	
Xe-133		40	Y-91	
Xe-135		41	Zn-65	
Zr-95/Nb-95		42	Zr-95/Nb-95	
Total	2.06E-04		Totals	2.80E-06

Table 7. Liquid Pathway Population Risk Comparisons

(Blank spaces indicate that the radionuclide was not, or is not projected to be, released)

Radionuclide (Historical)	Cumulative Risk (1954 - 1995)		Radionuclide (Recent 5-Yr)	Projected 30-Yr Risk (5-yr Avg Basis)
Zn-65	8.98E-01	1	H-3	4.71E-02
Cs-137	3.63E-01	2	Pu-239	6.72E-03
H-3	1.67E-01	3	Sr-89/90	3.90E-03
P-32	9.16E-02	4	Cs-137	2.08E-03
Ce-141/144	4.89E-02	5	I-129	5.35E-04
Sr-89/90	3.76E-02	6	U-235/238	1.52E-05
Co-60	2.37E-02	7	Pu-238	3.22E-06
I-131	2.12E-02	8	Pm-147	1.12E-06
Nb-95	2.08E-02	9	Am-241/243	5.89E-07
Ru-103/106	1.31E-02	10	Tc-99	1.46E-07
U-235/238	1.14E-02	11	Ar-41	
Y-91	9.90E-03	12	Ba-La-140	
Cm-242/244	9.65E-03	13	C-14	
Pu-239	9.21E-03	14	Ce-141/144	
Cr-51	8.96E-03	15	Cm-242/244	
S-35	3.44E-03	16	Co-60	
Ba-La-140	3.43E-03	17	Cr-51	
Sr-89	3.28E-03	18	Cs-134	
Np-239	2.12E-03	19	Eu-154/155	
Pu-238	1.36E-03	20	I-131	
Pm-147	1.13E-03	21	I-133/135	
Cs-134	4.37E-04	22	Kr-85	
I-129	2.33E-04	23	Kr-85m	
Sb-124/125	1.28E-04	24	Kr-87	
Mo-99	6.13E-05	25	Kr-88	
Mn-54	1.39E-05	26	Mn-54	
Am-241/243	9.81E-08	27	Mo-99	
Tc-99	2.44E-08	28	Nb-95	
Ar-41		29	Np-239	
C-14		30	P-32	
Eu-154/155		31	Ru-103	
I-133/135		32	Ru-103/106	
Kr-85		33	S-35	
Kr-85m		34	Sb-124/125	
Kr-87		35	Sb-125	
Kr-88		36	Sr-89	
Ru-103		37	Xe-131m	
Sb-125		38	Xe-133	
Xe-131m		39	Xe-135	
Xe-133		40	Y-91	
Xe-135		41	Zn-65	
Zr-95/Nb-95		42	Zr-95/Nb-95	
Total	1.75E+00		Totals	6.04E-02

Population Liquid Pathway Risk Comparison

As shown in Table 7, liquid pathway population risks follow a similar trend to the MEI risks. However, zinc-65, which has an extremely large bioaccumulation factor (50,000 L/kg) in saltwater invertebrates, was the most critical population risk radionuclide. In addition, the shorter-lived radionuclides, such as phosphorus-32 (half life = 14.29 days), have slightly less of an impact on the 80-km population risks than they do on the site boundary, MEI risks.

Using average Savannah River flow rate and 1990 population (620,100) data and assuming that the entire population is made up of adults, none of the released radionuclides were determined to cause greater than 1 excess severe detriment case in the 80-km population, either on a cumulative or projected 30-year basis (see Table 7).

Critical Liquid Exposure Pathways

In Appendix C, charts are provided that show the relative percentage importance of the individual liquid exposure pathways for 5-year time periods dating back to 1954. As discussed in the previous section, cesium-137 was the most critical contaminant during the years 1954-1975 and since the fish consumption pathway accounts for about 97% of the dose from cesium-137, the fish consumption pathway was the most critical during this time period. In subsequent years, the tritium drinking water pathway became more important. During the most recent 5-year period (1991 to 1995), the drinking water pathway accounted for about 67% of the liquid pathway MEI risk and the fish consumption pathway accounted for most of the remainder. The collective recreation pathways (swimming, boating, and shoreline) never accounted for more than 1% of the MEI liquid pathway risk.

In Figure 5 (page 18), the projected critical liquid pathways are presented by percent contribution. Because tritium and cesium-137 are projected to remain the critical aqueous radionuclides at SRS, water ingestion (67%) and fish ingestion (33%) will remain the critical liquid pathways in the future.

Other Long-lived Radionuclides

In addition to technetium-99, several other long-lived radionuclides with low energy radiation emissions that exist in SRS seepage basins and liquid and solid waste inventories were considered in this assessment. Radionuclides such as nickel-59 (half-life = $7.6\text{E}+04$ y), zirconium-93 (half-life = $1.5\text{E}+06$ y), niobium-94 (half-life = $2.0\text{E}+04$ y), and neptunium-237 (half-life = $2.1\text{E}+06$ y) probably exist in minute amounts in some site effluent streams but, because of associated radioanalytical difficulties, have not been measured. However, like technetium-99 (Carlton, 1993b), these low energy and extremely low specific activity radionuclides are of little dose consequence when compared to the more common radionuclides.

In the distant future (>100 years), these long-lived radionuclides may become more important, on a percentage of dose/risk basis, but the total dose consequence will remain small.

Figure 4. Projected Critical Aqueous Radionuclides

Figure 5. Projected Critical Liquid Pathways

Nontypical Exposure Pathways

Nontypical exposure pathways, not included in the standard calculations of the dose to the maximally exposed individual, were considered and quantified separately. These pathways apply to relatively low-probability or unique exposure scenarios.

Critical Sub-populations

Within 80 km of SRS there are no known sensitive sub-populations (e.g. Native Americans) with unique lifestyles or diets that need to be considered separately from the standard consumption/exposure pathways.

Onsite-Hunter Deer and Hog Consumption Pathway

For approximately 6 weeks each year, controlled hunts of deer and feral hogs are conducted at SRS. Hunt participants are volunteers. Before any harvested animal is released to a hunter, SRS personnel perform a field analysis for cesium-137. Like fish, deer and hogs have a high bioaccumulation factor for cesium. Since 1992, the estimated dose from the consumption of the harvested deer and hog meat has been determined for each hunter. The hunter-dose calculation is based on the assumption that the hunter individually consumed the entire edible portion of the animals he harvested from SRS.

In Table 8, the onsite hunter doses from 1992 through 1995 are shown. Because the onsite hunters are volunteers, and because the maximum dose is usually not received by the same hunter every year, the 30-yr projected risk for this pathway is not applicable to this analysis and has not been estimated. However, it should be noted that the maximum annual doses from the onsite-hunter deer and hog consumption pathway have exceeded all standard pathways combined.

Offsite-Hunter Deer and Hog Consumption Pathway

This pathway assumes that deer and hogs that had resided on SRS move offsite prior to being harvested. The estimated doses were based on the maximum annual meat consumption rate of 81 kg per year (Hamby, 1991) and on the average concentration of cesium-137 in all of the deer and hogs harvested from onsite during each year (Arnett, 1993, 1994, 1995, and 1996).

Table 8. Sportsman Doses and Projected Risks

Year	Onsite Hunter	Offsite Hunter	Fisherman
1992	49 mrem	26 mrem	3.1 mrem
1993	57 mrem	4.1 mrem	1.3 mrem
1994	46 mrem	20 mrem	1.3 mrem
1995	30 mrem	15 mrem	1.2 mrem
30-yr Projected Risk	N/A	3.6E-04	3.8E-05

In Table 8, offsite hunter doses from 1992 through 1995 are shown. Also, the 30-yr projected risk, which is conservatively based on the average of the 4 years, is presented. The 30-yr projected risk ($3.6\text{E-}04$) for the offsite hunter exceeds all standard pathways combined.

Fish Consumption Pathway

Since there are no known permanent residences along the Savannah River adjacent to SRS, a subsistence fisherman pathway was not considered. Instead, the recreational fisherman pathway was used in this assessment (EPA, 1991). It is conservatively assumed that the recreational fisherman fishes for a single species of fish from the mouth of the worst case SRS stream. Since 1992, samples of fish have been systematically taken from the mouths of the 5 SRS streams and the subsequent recreational fisherman doses were estimated using a maximum consumption rate of 19 kg/yr (Table 8).

The fish flesh was composited by species for each location and analyzed for tritium, strontium-90, cesium-137, plutonium-238, and plutonium-239. During each year, the maximum potential dose was from bass caught from the mouth of Steel Creek. More than 98% of the recreational fisherman doses shown in Table 8 is attributable to cesium-137.

The 30-yr projected fish-consumption-pathway risk, which is based on the average of the 4 years, also is presented in Table 8. The 30-yr projected risk ($3.8\text{E-}05$) for the recreational fish consumption pathway exceeds all standard pathways combined.

Other Aquatic Organism Consumption Pathways

Other aquatic organisms that exist on SRS, such as waterfowl, amphibians, and reptiles, may leave the site and are potentially consumed by people in the surrounding areas. Currently, there is insufficient data to determine reasonable maximum consumption rates and subsequent doses. However, doses and risks from these other consumption pathways should be similar to, but less than, the fish and deer/hog consumption pathways.

Goat Milk Consumption Pathway

Goats are raised on some farms in the SRS vicinity. It has been shown that the annual MEI dose would increase about 16% if goat milk were substituted for the customary cow milk pathway (Arnet, 1995). Most of this difference is from tritium oxide because the transfer factor (fraction of the daily intake of the nuclide that appears in each liter of milk) for tritium oxide is 17 times more for goat milk than for cow milk (NRC, 1977a). However, because goat milk consumption is far less common and seldom a complete substitute for cow milk, cow milk will remain the primary parameter for the milk consumption pathway.

Agricultural Irrigation Pathway

The 1990 update of the land- and water-use parameters in the vicinity of SRS (Hamby, 1991) revealed that there is no known use of Savannah River water downstream of SRS for agricultural irrigation purposes. The nonexistence of this pathway will be confirmed in future updates of the land- and water-use parameters.

CONCLUSIONS

When comparing radiological risks it should be noted that according to recent U.S. EPA practice, if a potential risk is determined to be less than $1\text{E-}06$ (i.e. one additional case of severe detriment in a group of 1,000,000 people), then the risk is considered minimal. If a calculated risk is greater than $1\text{E-}04$, then some form of corrective action or remediation is usually required. However, if a calculated risk falls between $1\text{E-}06$ and $1\text{E-}04$, the risk is considered acceptable if it is kept as low as reasonably achievable.

During its operational history (1954 - present), many different types of radionuclides were released from SRS facilities (Appendix A). However, only a relatively small number were significant contributors to doses/risks to offsite people.

For the airborne pathway, only iodine-131, tritium, plutonium-239 (including unidentified alpha emitters), argon-41, ruthenium-103/106, iodine-129, strontium-89/90 (including unidentified beta), and plutonium-238 were determined to exceed a risk of $1.0\text{E-}06$, on a cumulative MEI risk basis.

For the liquid pathway, only cesium-137, phosphorus-32, niobium-95, zinc-65, tritium, strontium-89/90 (including unidentified beta), iodine-131, and sulfur-35 were determined to exceed a risk of $1\text{E-}06$, on a cumulative MEI risk basis.

The most critical pathways associated with the airborne pathway MEI cumulative risks were vegetation consumption, inhalation, and plume shine. The most critical pathways associated with the liquid pathway MEI cumulative risks were fish consumption and drinking water ingestion.

For the next 30-years, if site missions and operations remain constant, only tritium is projected to exceed an MEI risk of $1\text{E-}06$ for either the airborne or liquid pathways. However, if combined, projected 30-year liquid pathway MEI risks from cesium-137, strontium-89/90, and plutonium-239 would exceed a risk of $1\text{E-}06$ (Table 6). All other liquid pathway radionuclides have negligible ($<1\text{E-}07$) projected 30-year risks. With the exception of tritium, all other airborne pathway radionuclides have negligible ($<1\text{E-}07$) projected 30-year risks (Table 4).

The most critical pathways associated with the airborne pathway MEI projected risks are inhalation and vegetation consumption. The most critical pathways associated with the liquid pathway MEI projected risks are drinking water ingestion and fish consumption.

For the non-typical pathways (i.e. recreational fisherman and deer and hog hunters), cesium-137 was, and will continue to be, the critical radionuclide.

For population risks, none of the released airborne or liquid pathway radionuclides were determined to cause greater than 1 excess severe detriment case in the 80-km population of 620,100 people, either on a cumulative or projected 30-year basis (see Tables 5 and 7). Even when all radionuclides are added together, the projected 30-year airborne and liquid pathway population risks do not exceed 1 excess severe detriment case.

In the near future the SRS environmental monitoring program should concentrate on the identified projected critical radionuclides and pathways. If site missions or operations change in the future, these critical radionuclides and pathways should be reevaluated.

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Appendix A

Radiological Source Terms and Doses by Pathway

Notes:

- 1) Blank spaces in the charts indicate one of the following conditions:
 - a) the released radionuclide was not measured
(included in gross analyses, as appropriate)
 - b) the radionuclide was monitored, but no release was quantified
 - c) the release was calculated to be zero
- 2) To maintain consistency with other reports, the releases, doses, and risks are reported to 3 significant figures. However, because of the large uncertainties associated with radiological monitoring and dose/risk calculations, it should not be implied that the reported values are that accurate.

Am-241/243

Half-Life

Am-241 - 432.7 years

Am-243 - 7,370 years

Total Curies Released (1954-1995)

Air - 6.11E-03

Streams - 2.00E-06

Basins (Decay Corrected) - 2.83E-01

Total Cumulative Risks (1954-1995)

MEI Air Pathway - 1.43E-08

MEI Liquid Pathway - 8.47E-13

Population Air - 9.47E-04

Population Liquid - 9.81E-08

Projected 30-year Risks Using Recent Annual Doses (average of years 1991-1995)

MEI Air Pathway - 6.94E-09

MEI Liquid Pathway - 5.08E-12

Population Air - 4.59E-04

Population Liquid - 5.89E-07

Critical Pathways

MEI Air Pathway - Vegetation Consumption = 56%, Inhalation = 43%

MEI Liquid Pathway - Water Consumption = 60%, Fish Consumption = 40%

Population Air Pathway - Inhalation = 80%, Vegetation Consumption = 19%

Population Liquid Pathway - Aquatic Food = 85%, Water Consumption = 15%

Discussion

Am-241/243 are relatively long-lived alpha-emitting radionuclides with large ingestion and inhalation dose factors (DOE, 1988b). Based on measured releases, Am-241/243 account for less than 1% of the site's cumulative and projected 30-year MEI and population risks. It should be noted that 1995 was the only year in which trace amounts of Am-241 and Am-243 were measured in liquid effluents. This is because of EMS's implementation of a new actinide analysis method, which has much greater sensitivity than previously employed methods (Arnett, 1996).

Estimated long-term residual inventories of Am-241 ($>3.3\text{E}+03$ Ci) and Pu-241 ($>3.2\text{E}+04$ Ci), which is the parent of Am-241, may cause Am-241 to assume greater importance, on a percentage-of-risk basis, in the distant (>100 years) future.

Table Am-241/243. Effluent Releases

	Am-241,243	Am-241,243	Am-241,243	Am-241,243-Basin
	Air (Curies)	Streams (Curies)	Basins (Curies)	Decay Corrected (Ci)
1954				
1955				
1956				
1957				
1958				
1959				
1960				
1961				
1962				
1963				
1964				
1965				
1966				
1967				
1968				
1969				
1970				
1971				
1972				
1973				
1974				
1975				
1976				
1977	3.39E-04		1.20E-02	1.17E-02
1978	1.23E-03		2.70E-02	2.63E-02
1979	3.55E-04		4.81E-02	4.69E-02
1980	1.07E-03		2.30E-02	2.25E-02
1981	4.94E-04		7.42E-02	7.26E-02
1982	4.98E-04		1.97E-02	1.93E-02
1983	2.57E-04		1.66E-02	1.63E-02
1984	1.42E-04		2.40E-02	2.36E-02
1985	4.26E-04		2.30E-02	2.26E-02
1986	1.54E-04		1.19E-02	1.17E-02
1987	2.04E-04		6.90E-03	6.81E-03
1988	1.18E-04		3.33E-03	3.29E-03
1989	2.01E-04			
1990	1.28E-04		4.12E-08	4.09E-08
1991	1.51E-04		6.44E-07	6.40E-07
1992	1.13E-04			
1993	1.43E-04			
1994	5.62E-05			
1995	3.04E-05	2.00E-06		

Table Am-241/243. MEI Air-Pathway Doses

	Plume (mrem)	Ground (mrem)	Inhalation (mrem)	Vegetation (mrem)	Milk (mrem)	Meat (mrem)	Total Air Pathway (mrem)
1954							
1955							
1956							
1957							
1958							
1959							
1960							
1961							
1962							
1963							
1964							
1965							
1966							
1967							
1968							
1969							
1970							
1971							
1972							
1973							
1974							
1975							
1976							
1977		2.78E-06	4.75E-04	6.10E-04	7.46E-08	8.14E-07	1.09E-03
1978		1.01E-05	1.72E-03	2.21E-03	2.71E-07	2.95E-06	3.95E-03
1979		2.91E-06	4.97E-04	6.39E-04	7.81E-08	8.52E-07	1.14E-03
1980		8.77E-06	1.50E-03	1.93E-03	2.35E-07	2.57E-06	3.44E-03
1981		4.05E-06	6.92E-04	8.89E-04	1.09E-07	1.19E-06	1.59E-03
1982		4.08E-06	6.97E-04	8.96E-04	1.10E-07	1.20E-06	1.60E-03
1983		2.11E-06	3.60E-04	4.63E-04	5.65E-08	6.17E-07	8.25E-04
1984		1.16E-06	1.99E-04	2.56E-04	3.12E-08	3.41E-07	4.56E-04
1985		3.49E-06	5.96E-04	7.67E-04	9.37E-08	1.02E-06	1.37E-03
1986		1.26E-06	2.16E-04	2.77E-04	3.39E-08	3.70E-07	4.94E-04
1987		1.67E-06	2.86E-04	3.67E-04	4.49E-08	4.90E-07	6.55E-04
1988		9.68E-07	1.65E-04	2.12E-04	2.60E-08	2.83E-07	3.79E-04
1989		1.65E-06	2.81E-04	3.62E-04	4.42E-08	4.82E-07	6.45E-04
1990		1.05E-06	1.79E-04	2.30E-04	2.82E-08	3.07E-07	4.11E-04
1991		1.24E-06	2.11E-04	2.72E-04	3.32E-08	3.62E-07	4.85E-04
1992		9.27E-07	1.58E-04	2.03E-04	2.49E-08	2.71E-07	3.63E-04
1993		1.17E-06	2.00E-04	2.57E-04	3.15E-08	3.43E-07	4.59E-04
1994		4.61E-07	7.87E-05	1.01E-04	1.24E-08	1.35E-07	1.80E-04
1995		2.49E-07	4.26E-05	5.47E-05	6.69E-09	7.30E-08	9.76E-05
Totals		5.01E-05	8.55E-03	1.10E-02	1.34E-06	1.47E-05	1.96E-02
Percent		0.26%	43.60%	56.06%	0.01%	0.07%	

Table Am-241/243. Population Air-Pathway Doses

	Plume	Ground	Inhalation	Vegetation	Milk	Meat	Total Air Pathway
	(per.-rem)	(per.-rem)	(per.-rem)	(per.-rem)	(per.-rem)	(per.-rem)	(per.-rem)
1954							
1955							
1956							
1957							
1958							
1959							
1960							
1961							
1962							
1963							
1964							
1965							
1966							
1967							
1968							
1969							
1970							
1971							
1972							
1973							
1974							
1975							
1976							
1977		4.07E-04	5.76E-02	1.39E-02	2.58E-06	1.70E-05	7.20E-02
1978		1.48E-03	2.09E-01	5.04E-02	9.35E-06	6.15E-05	2.61E-01
1979		4.26E-04	6.04E-02	1.46E-02	2.70E-06	1.78E-05	7.54E-02
1980		1.28E-03	1.82E-01	4.39E-02	8.13E-06	5.35E-05	2.27E-01
1981		5.93E-04	8.40E-02	2.03E-02	3.75E-06	2.47E-05	1.05E-01
1982		5.98E-04	8.47E-02	2.04E-02	3.78E-06	2.49E-05	1.06E-01
1983		3.08E-04	4.37E-02	1.05E-02	1.95E-06	1.29E-05	5.46E-02
1984		1.70E-04	2.41E-02	5.82E-03	1.08E-06	7.10E-06	3.01E-02
1985		5.11E-04	7.24E-02	1.75E-02	3.24E-06	2.13E-05	9.04E-02
1986		1.85E-04	2.62E-02	6.31E-03	1.17E-06	7.70E-06	3.27E-02
1987		2.45E-04	3.47E-02	8.36E-03	1.55E-06	1.02E-05	4.33E-02
1988		1.42E-04	2.01E-02	4.84E-03	8.97E-07	5.90E-06	2.50E-02
1989		2.41E-04	3.42E-02	8.24E-03	1.53E-06	1.01E-05	4.27E-02
1990		1.54E-04	2.18E-02	5.25E-03	9.73E-07	6.40E-06	2.72E-02
1991		1.81E-04	2.57E-02	6.19E-03	1.15E-06	7.55E-06	3.21E-02
1992		1.36E-04	1.92E-02	4.63E-03	8.59E-07	5.65E-06	2.40E-02
1993		1.72E-04	2.43E-02	5.86E-03	1.09E-06	7.15E-06	3.04E-02
1994		6.74E-05	9.55E-03	2.30E-03	4.27E-07	2.81E-06	1.19E-02
1995			5.17E-03	1.25E-03	2.31E-07	1.52E-06	6.42E-03
Totals		7.30E-03	1.04E+00	2.50E-01	4.64E-05	3.05E-04	1.30E+00
Percent		0.56%	80.09%	19.32%	0.00%	0.02%	

Table Am-241/243. MEI Liquid-Pathway Doses

	Fish	Water	Shore	Swimming	Boating	Total Liquid Pathway
	(mrem)	(mrem)	(mrem)	(mrem)	(mrem)	(mrem)
1954						
1955						
1956						
1957						
1958						
1959						
1960						
1961						
1962						
1963						
1964						
1965						
1966						
1967						
1968						
1969						
1970						
1971						
1972						
1973						
1974						
1975						
1976						
1977						
1978						
1979						
1980						
1981						
1982						
1983						
1984						
1985						
1986						
1987						
1988						
1989						
1990						
1991						
1992						
1993						
1994						
1995	4.60E-07	7.00E-07	3.20E-10	5.00E-14	6.00E-14	1.16E-06
Totals	4.60E-07	7.00E-07	3.20E-10	5.00E-14	6.00E-14	1.16E-06
Percent	39.64%	60.33%	0.03%	0.00%	0.00%	

Table Am-241/243. Population Liquid-Pathway Doses

	Aquatic Food	Water	Shore	Swimming	Boating	Total Liquid Pathway
	(per.-rem)	(per.-rem)	(per.-rem)	(per.-rem)	(per.-rem)	(per.-rem)
1954						
1955						
1956						
1957						
1958						
1959						
1960						
1961						
1962						
1963						
1964						
1965						
1966						
1967						
1968						
1969						
1970						
1971						
1972						
1973						
1974						
1975						
1976						
1977						
1978						
1979						
1980						
1981						
1982						
1983						
1984						
1985						
1986						
1987						
1988						
1989						
1990						
1991						
1992						
1993						
1994						
1995	1.14E-04	2.00E-05	1.36E-08	9.00E-13	3.20E-12	1.34E-04
Totals	1.14E-04	2.00E-05	1.36E-08	9.00E-13	3.20E-12	1.34E-04
Percent	85.11%	14.88%	0.01%	0.00%	0.00%	

Table Am-241/243 Air. Am-241/243 Atmospheric Releases and Maximally Exposed Individual Doses 1954 - 1995

Table Am-241/243 Liquid. Am-241/243 Liquid Releases and Maximally Exposed Individual Doses 1954 - 1995

Ar-41

Half-Life

Ar-41 - 1.83 hours

Total Curies Released (1954-1995)

Air - $6.36\text{E}+06$

Streams - 0.0

Basins (Decay Corrected) - 0.0

Total Cumulative Risks (1954-1995)

MEI Air Pathway - $5.11\text{E}-06$

MEI Liquid Pathway - 0.0

Population Air - $1.67\text{E}-01$

Population Liquid - 0.0

Projected 30-year Risks Using Recent Annual Doses (average of years 1991-1995)

MEI Air Pathway - $1.21\text{E}-09$

MEI Liquid Pathway - 0.0

Population Air - $3.96\text{E}-05$

Population Liquid - 0.0

Critical Pathways

MEI Air Pathway - Plume = 100%

MEI Liquid Pathway - N/A

Population Air Pathway - Plume = 100%

Population Liquid Pathway - N/A

Discussion

Ar-41 is a short-lived, gaseous activation product that is produced only during reactor operations. On a cumulative risk basis, Ar-41 was the 4th most important airborne radionuclide accounting for about 10% of the total cumulative MEI and population air pathway risks. Because all SRS reactors are now shut down, projected releases of, and risks from, Ar-41 are expected to remain nil. Refer to Carlton, 1995 for a more complete assessment of noble gases, including Ar-41, at SRS.

Table Ar-41. Effluent Releases, MEI Air-Pathway Doses, and Population Dose

	Ar-41	Max. Exp. Ind. Dose	Population Dose
	Air (Curies)	(mrem)	(person-rem)
1954	5.00E+04	5.50E-02	1.80E+00
1955	1.40E+05	1.54E-01	5.04E+00
1956	2.50E+05	2.75E-01	9.00E+00
1957	2.90E+05	3.19E-01	1.04E+01
1958	3.40E+05	3.74E-01	1.22E+01
1959	4.40E+05	4.84E-01	1.58E+01
1960	4.00E+05	4.40E-01	1.44E+01
1961	4.20E+05	4.62E-01	1.51E+01
1962	4.30E+05	4.73E-01	1.55E+01
1963	4.50E+05	4.95E-01	1.62E+01
1964	3.70E+05	4.07E-01	1.33E+01
1965	2.70E+05	2.97E-01	9.72E+00
1966	2.80E+05	3.08E-01	1.01E+01
1967	3.20E+05	3.52E-01	1.15E+01
1968	2.20E+05	2.42E-01	7.92E+00
1969	1.40E+05	1.54E-01	5.04E+00
1970	1.10E+05	1.21E-01	3.96E+00
1971	1.41E+05	1.55E-01	5.08E+00
1972	1.67E+05	1.84E-01	6.01E+00
1973	1.84E+05	2.02E-01	6.62E+00
1974	1.08E+05	1.19E-01	3.89E+00
1975	6.49E+04	7.14E-02	2.34E+00
1976	8.28E+04	9.11E-02	2.98E+00
1977	6.51E+04	7.16E-02	2.34E+00
1978	5.30E+04	5.83E-02	1.91E+00
1979	5.30E+04	5.83E-02	1.91E+00
1980	6.97E+04	7.67E-02	2.51E+00
1981	6.19E+04	6.81E-02	2.23E+00
1982	6.02E+04	6.62E-02	2.17E+00
1983	4.07E+04	4.48E-02	1.47E+00
1984	3.59E+04	3.95E-02	1.29E+00
1985	5.18E+04	5.70E-02	1.86E+00
1986	8.32E+04	9.15E-02	3.00E+00
1987	8.77E+04	9.65E-02	3.16E+00
1988	2.95E+04	3.25E-02	1.06E+00
1989			
1990			
1991			
1992	2.51E+02	2.76E-04	9.04E-03
1993			
1994			
1995			
Totals	6.36E+06	7.00E+00	2.29E+02

Table Ar-41 Air. Argon-41 Atmospheric Releases and Maximally Exposed Individual Doses 1954 - 1995

Ba-La-140

Half-Life

Ba-140 - 12.8 days

La-140 - 40.3 hours

Total Curies Released (1954-1995)

Air - 0.0

Streams - 2.22E+02

Basins (Decay Corrected) - <1.00E-12

Total Cumulative Risks (1954-1995)

MEI Air Pathway - 0.0

MEI Liquid Pathway - 1.11E-07

Population Air - 0.0

Population Liquid - 3.43E-03

Projected 30-year Risks Using Recent Annual Doses (average of years 1991-1995)

MEI Air Pathway - 0.0

MEI Liquid Pathway - 0.0

Population Air - 0.0

Population Liquid - 0.0

Critical Pathways

MEI Air Pathway - N/A

MEI Liquid Pathway - Water Consumption = 88%, Fish Consumption = 9%

Population Air Pathway - N/A

Population Liquid Pathway - Water Consumption = 70%, Aquatic Food = 25%

Discussion

Ba-La-140 are short-lived fission products that have not been measured in site stream or basin effluents since 1971. On a cumulative MEI and population risk basis, Ba-La-140 were the 17th and 16th most important liquid pathway radionuclides, respectively. Future releases of Ba-La-140 are expected to remain nil.

Table Ba-La-140. Effluent Releases

	Ba/La-140	Ba/La-140	Ba/La-140	Ba/La-140-Basin
	Air (Curies)	Streams (Curies)	Basins (Curies)	Decay Corrected (Ci)
1954				
1955				
1956				
1957				
1958				
1959				
1960		2.08E+01		
1961		1.81E+01		
1962		6.79E+01		
1963		5.21E+01		
1964		3.63E+01	4.00E-01	1.82E-267
1965		1.01E+01		
1966		1.56E+00	1.40E-01	9.74E-251
1967		4.25E+00	6.71E-01	1.82E-241
1968		8.95E+00	3.23E+01	3.43E-231
1969		1.30E+00	1.78E+01	7.37E-223
1970		3.32E-01	1.13E+01	1.83E-214
1971		1.30E-01	1.03E-02	6.51E-209
1972				
1973				
1974				
1975				
1976				
1977				
1978				
1979				
1980				
1981				
1982				
1983				
1984				
1985				
1986				
1987				
1988				
1989				
1990				
1991				
1992				
1993				
1994				
1995				
Totals		2.22E+02	6.26E+01	6.51E-209

Table Ba-La-140. MEI Liquid-Pathway Doses

	Fish	Water	Shore	Swimming	Boating	Total Liquid Pathway
	(mrem)	(mrem)	(mrem)	(mrem)	(mrem)	(mrem)
1954						
1955						
1956						
1957						
1958						
1959						
1960	1.27E-03	1.25E-02	3.33E-04	6.03E-05	7.28E-05	1.42E-02
1961	1.10E-03	1.09E-02	2.90E-04	5.25E-05	6.34E-05	1.24E-02
1962	4.14E-03	4.07E-02	1.09E-03	1.97E-04	2.38E-04	4.64E-02
1963	3.18E-03	3.13E-02	8.34E-04	1.51E-04	1.82E-04	3.56E-02
1964	2.21E-03	2.18E-02	5.81E-04	1.05E-04	1.27E-04	2.48E-02
1965	6.16E-04	6.06E-03	1.62E-04	2.93E-05	3.54E-05	6.90E-03
1966	9.52E-05	9.36E-04	2.50E-05	4.52E-06	5.46E-06	1.07E-03
1967	2.59E-04	2.55E-03	6.80E-05	1.23E-05	1.49E-05	2.90E-03
1968	5.46E-04	5.37E-03	1.43E-04	2.60E-05	3.13E-05	6.12E-03
1969	7.93E-05	7.80E-04	2.08E-05	3.77E-06	4.55E-06	8.88E-04
1970	2.03E-05	1.99E-04	5.31E-06	9.63E-07	1.16E-06	2.27E-04
1971	7.93E-06	7.80E-05	2.08E-06	3.77E-07	4.55E-07	8.88E-05
1972						
1973						
1974						
1975						
1976						
1977						
1978						
1979						
1980						
1981						
1982						
1983						
1984						
1985						
1986						
1987						
1988						
1989						
1990						
1991						
1992						
1993						
1994						
1995						
Totals	1.35E-02	1.33E-01	3.55E-03	6.43E-04	7.76E-04	1.52E-01
Percent	8.93%	87.80%	2.34%	0.42%	0.51%	

Table Ba-La-140. Population Liquid-Pathway Doses

	Aquatic Food	Water	Shore	Swimming	Boating	Total Liquid Pathway
	(per.-rem)	(per.-rem)	(per.-rem)	(per.-rem)	(per.-rem)	(per.-rem)
1954						
1955						
1956						
1957						
1958						
1959						
1960	1.10E-01	3.12E-01	1.37E-02	1.10E-03	3.74E-03	4.41E-01
1961	9.61E-02	2.72E-01	1.19E-02	9.59E-04	3.26E-03	3.84E-01
1962	3.61E-01	1.02E+00	4.48E-02	3.60E-03	1.22E-02	1.44E+00
1963	2.77E-01	7.82E-01	3.44E-02	2.76E-03	9.38E-03	1.10E+00
1964	1.93E-01	5.45E-01	2.40E-02	1.92E-03	6.53E-03	7.70E-01
1965	5.36E-02	1.52E-01	6.67E-03	5.35E-04	1.82E-03	2.14E-01
1966	8.28E-03	2.34E-02	1.03E-03	8.27E-05	2.81E-04	3.31E-02
1967	2.26E-02	6.38E-02	2.81E-03	2.25E-04	7.65E-04	9.01E-02
1968	4.75E-02	1.34E-01	5.91E-03	4.74E-04	1.61E-03	1.90E-01
1969	6.90E-03	1.95E-02	8.58E-04	6.89E-05	2.34E-04	2.76E-02
1970	1.76E-03	4.98E-03	2.19E-04	1.76E-05	5.98E-05	7.04E-03
1971	6.90E-04	1.95E-03	8.58E-05	6.89E-06	2.34E-05	2.76E-03
1972						
1973						
1974						
1975						
1976						
1977						
1978						
1979						
1980						
1981						
1982						
1983						
1984						
1985						
1986						
1987						
1988						
1989						
1990						
1991						
1992						
1993						
1994						
1995						
Totals	1.18E+00	3.33E+00	1.46E-01	1.18E-02	3.99E-02	4.70E+00
Percent	25.04%	70.74%	3.11%	0.25%	0.85%	

Table Ba-La-140 Liquid. Ba-La-140 Liquid Releases and Maximally Exposed Individual Doses 1954 - 1995

Br-82

Half-Life

Br-82 - 35.3 hours

Total Curies Released (1954-1995)

Air - 4.00E-02

Streams - 0.0

Basins (Decay Corrected) - 0.0

Total Cumulative Risks (1954-1995)

MEI Air Pathway - Not Calculated

MEI Liquid Pathway - 0.0

Population Air - Not Calculated

Population Liquid - 0.0

Projected 30-year Risks Using Recent Annual Doses (average of years 1991-1995)

MEI Air Pathway - Not Calculated

MEI Liquid Pathway - 0.0

Population Air - Not Calculated

Population Liquid - 0.0

Critical Pathways

MEI Air Pathway - N/A

MEI Liquid Pathway - N/A

Population Air Pathway - N/A

Population Liquid Pathway - N/A

Discussion

Br-82 is a short-lived fission product that was measured to have been released to the atmosphere only in one year (in 1984 from K-Area). The MAXIGASP dosimetry code does not have Br-82 in its radionuclide library, therefore, doses and risks were not calculated. However, because of the small amount released and its short half-life, Br-82 is not of concern on a cumulative or projected risk basis.

Table Br-82. Effluent Releases

	Br-82 to Air	Br-82 to Air	Br-82 to Air	Br-82 to Basins
	Curies	Curies	Curies	Decay Corrected (Ci)
1954				
1955				
1956				
1957				
1958				
1959				
1960				
1961				
1962				
1963				
1964				
1965				
1966				
1967				
1968				
1969				
1970				
1971				
1972				
1973				
1974				
1975				
1976				
1977				
1978				
1979				
1980				
1981				
1982				
1983				
1984	4.00E-02			
1985				
1986				
1987				
1988				
1989				
1990				
1991				
1992				
1993				
1994				
1995				
Totals	4.00E-02			

C-14

Half-Life

C-14 - 5,730 years

Total Curies Released (1954-1995)

Air - $2.97\text{E}+03$

Streams - 0.0

Basins (Decay Corrected) - 0.0

Total Cumulative Risks (1954-1995)

MEI Air Pathway - $5.86\text{E}-07$

MEI Liquid Pathway - 0.0

Population Air - $2.24\text{E}-02$

Population Liquid - 0.0

Projected 30-year Risks Using Recent Annual Doses (average of years 1991-1995)

MEI Air Pathway - $1.02\text{E}-09$

MEI Liquid Pathway - 0.0

Population Air - $3.88\text{E}-05$

Population Liquid - 0.0

Critical Pathways

MEI Air Pathway - Vegetation Consumption = 52%, Milk Consumption = 25%

MEI Liquid Pathway - N/A

Population Air Pathway - Vegetation Consumption = 48%, Milk Consumption = 34%

Population Liquid Pathway - N/A

Discussion

C-14 is a long-lived activation product that has been measured and/or calculated to have been released only in airborne effluents. On a cumulative MEI and population risk basis, C-14 was the 9th and 11th most important air pathway radionuclide, respectively. The cumulative MEI risk was estimated to be less than $1.0\text{E}-06$ and was about 1% of the site total. As long as dissolution of fuel rods continues in the Separations Areas, small amounts of C-14 will continue to be released from SRS. The projected 30-year MEI risk from C-14 is estimated at $1.0\text{E}-09$, which is much less than 1% of the projected site total.

The long-term residual inventory of C-14 is estimated at about $7.0\text{E}+03$ Ci, with most of it located in spent ion-exchange resins that were buried in the Solid Waste Disposal Area (Cook, 1989). In the distant (>100 years) future, this inventory may have an impact on the local groundwater. Refer to Carlton, 1993a for a more complete assessment of radiocarbon at SRS.

Table C-14. Effluent Releases

	C-14 to Air	C-14 to Streams	C-14 to Basins	C-14 to Basins
	Curies	Curies	Curies	Decay Corrected (Ci)
1954				
1955	8.30E+01			
1956	8.40E+01			
1957	8.40E+01			
1958	8.40E+01			
1959	1.38E+02			
1960	1.38E+02			
1961	1.38E+02			
1962	1.38E+02			
1963	1.38E+02			
1964	1.10E+02			
1965	1.10E+02			
1966	1.10E+02			
1967	1.10E+02			
1968	8.70E+01			
1969	8.70E+01			
1970	8.80E+01			
1971	8.70E+01			
1972	8.70E+01			
1973	8.70E+01			
1974	8.00E+01			
1975	6.60E+01			
1976	6.90E+01			
1977	6.30E+01			
1978	5.70E+01			
1979	5.60E+01			
1980	6.60E+01			
1981	6.90E+01			
1982	8.00E+01			
1983	9.00E+01			
1984	8.30E+01			
1985	7.60E+01			
1986	4.60E+01			
1987	4.10E+01			
1988	2.40E+01			
1989	1.80E+01			
1990	6.70E-01			
1991	6.20E-01			
1992	1.86E-01			
1993	1.69E-02			
1994	3.71E-02			
1995				
Totals	2.97E+03			

Table C-14. MEI Air-Pathway Doses

	Plume	Ground	Inhalation	Vegetation	Milk	Meat	Total Air Pathway
	(mrem)	(mrem)	(mrem)	(mrem)	(mrem)	(mrem)	(mrem)
1954							
1955				1.16E-02	5.64E-03	5.15E-03	2.24E-02
1956				1.18E-02	5.71E-03	5.21E-03	2.27E-02
1957				1.18E-02	5.71E-03	5.21E-03	2.27E-02
1958				1.18E-02	5.71E-03	5.21E-03	2.27E-02
1959				1.93E-02	9.38E-03	8.56E-03	3.73E-02
1960				1.93E-02	9.38E-03	8.56E-03	3.73E-02
1961				1.93E-02	9.38E-03	8.56E-03	3.73E-02
1962				1.93E-02	9.38E-03	8.56E-03	3.73E-02
1963				1.93E-02	9.38E-03	8.56E-03	3.73E-02
1964				1.54E-02	7.48E-03	6.82E-03	2.97E-02
1965				1.54E-02	7.48E-03	6.82E-03	2.97E-02
1966				1.54E-02	7.48E-03	6.82E-03	2.97E-02
1967				1.54E-02	7.48E-03	6.82E-03	2.97E-02
1968				1.22E-02	5.92E-03	5.39E-03	2.35E-02
1969				1.22E-02	5.92E-03	5.39E-03	2.35E-02
1970				1.23E-02	5.98E-03	5.46E-03	2.38E-02
1971				1.22E-02	5.92E-03	5.39E-03	2.35E-02
1972				1.22E-02	5.92E-03	5.39E-03	2.35E-02
1973				1.22E-02	5.92E-03	5.39E-03	2.35E-02
1974				1.12E-02	5.44E-03	4.96E-03	2.16E-02
1975				9.24E-03	4.49E-03	4.09E-03	1.78E-02
1976				9.66E-03	4.69E-03	4.28E-03	1.86E-02
1977				8.82E-03	4.28E-03	3.91E-03	1.70E-02
1978				7.98E-03	3.88E-03	3.53E-03	1.54E-02
1979				7.84E-03	3.81E-03	3.47E-03	1.51E-02
1980				9.24E-03	4.49E-03	4.09E-03	1.78E-02
1981				9.66E-03	4.69E-03	4.28E-03	1.86E-02
1982				1.12E-02	5.44E-03	4.96E-03	2.16E-02
1983				1.26E-02	6.12E-03	5.58E-03	2.43E-02
1984				1.16E-02	5.64E-03	5.15E-03	2.24E-02
1985				1.06E-02	5.17E-03	4.71E-03	2.05E-02
1986				6.44E-03	3.13E-03	2.85E-03	1.24E-02
1987				5.74E-03	2.79E-03	2.54E-03	1.11E-02
1988				3.36E-03	1.63E-03	1.49E-03	6.48E-03
1989				2.52E-03	1.22E-03	1.12E-03	4.86E-03
1990				9.38E-05	4.56E-05	4.15E-05	1.81E-04
1991				8.68E-05	4.22E-05	3.84E-05	1.67E-04
1992				2.60E-05	1.26E-05	1.15E-05	5.02E-05
1993				2.37E-06	1.15E-06	1.05E-06	4.56E-06
1994				5.19E-06	2.52E-06	2.30E-06	1.00E-05
1995							
Totals				4.16E-01	2.02E-01	1.84E-01	8.03E-01
Percent				51.85%	25.19%	22.96%	

Table C-14. Population Air-Pathway Doses

	Plume	Ground	Inhalation	Vegetation	Milk	Meat	Total Air Pathway
	(per.-rem)	(per.-rem)	(per.-rem)	(per.-rem)	(per.-rem)	(per.-rem)	(per.-rem)
1954							
1955				4.07E-01	2.91E-01	1.58E-01	8.55E-01
1956				4.12E-01	2.94E-01	1.60E-01	8.65E-01
1957				4.12E-01	2.94E-01	1.60E-01	8.65E-01
1958				4.12E-01	2.94E-01	1.60E-01	8.65E-01
1959				6.76E-01	4.83E-01	2.62E-01	1.42E+00
1960				6.76E-01	4.83E-01	2.62E-01	1.42E+00
1961				6.76E-01	4.83E-01	2.62E-01	1.42E+00
1962				6.76E-01	4.83E-01	2.62E-01	1.42E+00
1963				6.76E-01	4.83E-01	2.62E-01	1.42E+00
1964				5.39E-01	3.85E-01	2.09E-01	1.13E+00
1965				5.39E-01	3.85E-01	2.09E-01	1.13E+00
1966				5.39E-01	3.85E-01	2.09E-01	1.13E+00
1967				5.39E-01	3.85E-01	2.09E-01	1.13E+00
1968				4.26E-01	3.05E-01	1.65E-01	8.96E-01
1969				4.26E-01	3.05E-01	1.65E-01	8.96E-01
1970				4.31E-01	3.08E-01	1.67E-01	9.06E-01
1971				4.26E-01	3.05E-01	1.65E-01	8.96E-01
1972				4.26E-01	3.05E-01	1.65E-01	8.96E-01
1973				4.26E-01	3.05E-01	1.65E-01	8.96E-01
1974				3.92E-01	2.80E-01	1.52E-01	8.24E-01
1975				3.23E-01	2.31E-01	1.25E-01	6.80E-01
1976				3.38E-01	2.42E-01	1.31E-01	7.11E-01
1977				3.09E-01	2.21E-01	1.20E-01	6.49E-01
1978				2.79E-01	2.00E-01	1.08E-01	5.87E-01
1979				2.74E-01	1.96E-01	1.06E-01	5.77E-01
1980				3.23E-01	2.31E-01	1.25E-01	6.80E-01
1981				3.38E-01	2.42E-01	1.31E-01	7.11E-01
1982				3.92E-01	2.80E-01	1.52E-01	8.24E-01
1983				4.41E-01	3.15E-01	1.71E-01	9.27E-01
1984				4.07E-01	2.91E-01	1.58E-01	8.55E-01
1985				3.72E-01	2.66E-01	1.44E-01	7.83E-01
1986				2.25E-01	1.61E-01	8.74E-02	4.74E-01
1987				2.01E-01	1.44E-01	7.79E-02	4.22E-01
1988				1.18E-01	8.40E-02	4.56E-02	2.47E-01
1989				8.82E-02	6.30E-02	3.42E-02	1.85E-01
1990				3.28E-03	2.35E-03	1.27E-03	6.90E-03
1991				3.04E-03	2.17E-03	1.18E-03	6.39E-03
1992				9.11E-04	6.51E-04	3.53E-04	1.92E-03
1993				8.28E-05	5.92E-05	3.21E-05	1.74E-04
1994				1.82E-04	1.30E-04	7.05E-05	3.82E-04
1995							
Totals				1.46E+01	1.04E+01	5.65E+00	3.06E+01
Percent				47.57%	33.98%	18.45%	

Table C-14 Air. C-14 Atmospheric Releases and Maximally Exposed Individual Doses 1954 - 1995

Ce-141/144

Half-Life

Ce-141 - 32.5 days

Ce-144 - 284.6 days

Total Curies Released (1954-1995)

Air - 4.21E+00

Streams - 3.50E+02

Basins (Decay Corrected) - 3.54E+02

Total Cumulative Risks (1954-1995)

MEI Air Pathway - 2.52E-08

MEI Liquid Pathway - 4.22E-07

Population Air - 9.85E-04

Population Liquid - 4.89E-02

Projected 30-year Risks Using Recent Annual Doses (average of years 1991-1995)

MEI Air Pathway - 1.03E-11

MEI Liquid Pathway - 0.0

Population Air - 3.69E-07

Population Liquid - 0.0

Critical Pathways

MEI Air Pathway - Vegetation Consumption = 82%, Inhalation = 12%

MEI Liquid Pathway - Water Consumption = 97%, Fish Consumption = 2%

Population Air Pathway - Vegetation Consumption = 53%, Inhalation = 37%

Population Liquid Pathway - Aquatic Food = 77%, Water Consumption = 23%

Discussion

Ce-141/144 are relatively short-lived, but abundant, fission products. On a cumulative MEI and population risk basis, Ce-141/144 were the 17th and 18th most important air pathway radionuclides, respectively and the 9th and 5th most important liquid pathway radionuclides, respectively. However, Ce-141/144 accounted for less than 1% of the site's cumulative air and liquid pathway risks. The projected 30-year MEI air and liquid pathway risks from Ce-141/144 emissions are 1.0E-11 and 0.0, respectively.

Ce-141/144. Effluent Releases

	Ce-141/144	Ce-141/144	Ce-141/144	Ce-141/144-Basin
	Air (Curies)	Streams (Curies)	Basins (Curies)	Decay Corrected (Ci)
1954				
1955				
1956				
1957				
1958				
1959				
1960	2.43E-01	4.07E+01	8.32E+01	2.41E-12
1961	2.84E-01	3.58E+01	3.97E+01	2.81E-12
1962	2.13E-01	2.26E+01	1.21E+01	2.08E-12
1963	2.39E-01	5.03E+01	3.06E+01	1.28E-11
1964	3.20E-01	8.74E+01	3.04E+01	3.11E-11
1965	2.41E-01	3.13E+01	4.31E+01	1.07E-10
1966	1.75E-01	1.96E+01	2.88E+00	1.75E-11
1967	9.31E-02	1.69E+01	3.29E+00	4.87E-11
1968	5.50E-01	3.46E+01	3.68E+01	1.33E-09
1969	8.11E-01	5.45E+00	1.27E+01	1.12E-09
1970	2.29E-01	2.72E+00	1.09E+01	2.33E-09
1971	1.54E-01	2.46E+00	3.58E+00	1.87E-09
1972	3.40E-01	4.20E-02	2.96E+00	3.76E-09
1973	4.30E-02	1.47E-01	5.00E+00	1.55E-08
1974	2.20E-02	1.53E-01	2.50E+00	1.89E-08
1975	1.64E-02	3.90E-02	1.50E+00	2.76E-08
1976	1.16E-02	9.00E-03	5.69E-01	2.55E-08
1977	1.50E-02	1.44E-01	3.80E-01	4.15E-08
1978	1.40E-02	9.60E-04	2.23E+00	5.94E-07
1979	1.80E-02		2.47E+01	1.60E-05
1980	1.60E-02		4.20E-01	6.63E-07
1981	2.70E-02		2.87E+00	1.10E-05
1982	8.20E-03		6.71E-01	6.29E-06
1983	9.30E-03		3.82E-01	8.72E-06
1984	1.40E-02		9.42E-02	5.24E-06
1985	5.46E-02		2.82E-01	3.82E-05
1986	1.10E-02		4.16E-01	1.37E-04
1987	3.15E-02		1.65E-01	1.33E-04
1988	4.57E-03		8.10E-02	1.59E-04
1989	7.63E-04	4.50E-05	1.88E-05	8.98E-08
1990	3.06E-04			
1991	6.48E-07			
1992	1.16E-07			
1993				
1994				
1995	2.85E-04			
Totals	4.21E+00	3.50E+02	3.54E+02	5.16E-04

Ce-141/144. MEI Air-Pathway Doses

	Plume	Ground	Inhalation	Vegetation	Milk	Meat	Total Air Pathway
	(mrem)	(mrem)	(mrem)	(mrem)	(mrem)	(mrem)	(mrem)
1954							
1955							
1956							
1957							
1958							
1959							
1960		9.72E-05	2.33E-04	1.63E-03	2.31E-05	1.34E-05	2.00E-03
1961		1.14E-04	2.73E-04	1.90E-03	2.70E-05	1.56E-05	2.33E-03
1962		8.52E-05	2.04E-04	1.43E-03	2.02E-05	1.17E-05	1.75E-03
1963		9.56E-05	2.29E-04	1.60E-03	2.27E-05	1.31E-05	1.96E-03
1964		1.28E-04	3.07E-04	2.14E-03	3.04E-05	1.76E-05	2.63E-03
1965		9.64E-05	2.31E-04	1.61E-03	2.29E-05	1.33E-05	1.98E-03
1966		7.00E-05	1.68E-04	1.17E-03	1.66E-05	9.63E-06	1.44E-03
1967		3.72E-05	8.94E-05	6.24E-04	8.84E-06	5.12E-06	7.64E-04
1968		2.20E-04	5.28E-04	3.69E-03	5.23E-05	3.03E-05	4.52E-03
1969		3.24E-04	7.79E-04	5.43E-03	7.70E-05	4.46E-05	6.66E-03
1970		9.16E-05	2.20E-04	1.53E-03	2.18E-05	1.26E-05	1.88E-03
1971		6.16E-05	1.48E-04	1.03E-03	1.46E-05	8.47E-06	1.26E-03
1972		1.36E-04	3.26E-04	2.28E-03	3.23E-05	1.87E-05	2.79E-03
1973		1.72E-05	4.13E-05	2.88E-04	4.09E-06	2.37E-06	3.53E-04
1974		8.80E-06	2.11E-05	1.47E-04	2.09E-06	1.21E-06	1.81E-04
1975		6.56E-06	1.57E-05	1.10E-04	1.56E-06	9.02E-07	1.35E-04
1976		4.64E-06	1.11E-05	7.77E-05	1.10E-06	6.38E-07	9.52E-05
1977		6.00E-06	1.44E-05	1.01E-04	1.43E-06	8.25E-07	1.23E-04
1978		5.60E-06	1.34E-05	9.38E-05	1.33E-06	7.70E-07	1.15E-04
1979		7.20E-06	1.73E-05	1.21E-04	1.71E-06	9.90E-07	1.48E-04
1980		6.40E-06	1.54E-05	1.07E-04	1.52E-06	8.80E-07	1.31E-04
1981		1.08E-05	2.59E-05	1.81E-04	2.57E-06	1.49E-06	2.22E-04
1982		3.28E-06	7.87E-06	5.49E-05	7.79E-07	4.51E-07	6.73E-05
1983		3.72E-06	8.93E-06	6.23E-05	8.84E-07	5.12E-07	7.64E-05
1984		5.60E-06	1.34E-05	9.38E-05	1.33E-06	7.70E-07	1.15E-04
1985		2.18E-05	5.24E-05	3.66E-04	5.19E-06	3.00E-06	4.48E-04
1986		4.40E-06	1.06E-05	7.37E-05	1.05E-06	6.05E-07	9.03E-05
1987		1.26E-05	3.02E-05	2.11E-04	2.99E-06	1.73E-06	2.59E-04
1988		1.83E-06	4.39E-06	3.06E-05	4.34E-07	2.51E-07	3.75E-05
1989		3.05E-07	7.32E-07	5.11E-06	7.25E-08	4.20E-08	6.26E-06
1990		1.22E-07	2.94E-07	2.05E-06	2.91E-08	1.68E-08	2.51E-06
1991		2.59E-10	6.22E-10	4.34E-09	6.16E-11	3.56E-11	5.32E-09
1992		4.64E-11	1.11E-10	7.77E-10	1.10E-11	6.38E-12	9.52E-10
1993							
1994							
1995		1.14E-07	2.74E-07	1.91E-06	2.71E-08	1.57E-08	2.34E-06
Totals		1.68E-03	4.04E-03	2.82E-02	4.00E-04	2.32E-04	3.46E-02
Percent		4.87%	11.69%	81.61%	1.16%	0.67%	

Ce-141/144. Population Air-Pathway Doses

	Plume	Ground	Inhalation	Vegetation	Milk	Meat	Total Air Pathway
	(per.-rem)	(per.-rem)	(per.-rem)	(per.-rem)	(per.-rem)	(per.-rem)	(per.-rem)
1954							
1955							
1956							
1957							
1958							
1959							
1960		6.32E-03	2.92E-02	4.13E-02	8.02E-04	2.67E-04	7.79E-02
1961		7.38E-03	3.41E-02	4.83E-02	9.37E-04	3.12E-04	9.10E-02
1962		5.54E-03	2.56E-02	3.62E-02	7.03E-04	2.34E-04	6.82E-02
1963		6.21E-03	2.87E-02	4.06E-02	7.89E-04	2.63E-04	7.66E-02
1964		8.32E-03	3.84E-02	5.44E-02	1.06E-03	3.52E-04	1.03E-01
1965		6.27E-03	2.89E-02	4.10E-02	7.95E-04	2.65E-04	7.72E-02
1966		4.55E-03	2.10E-02	2.98E-02	5.78E-04	1.93E-04	5.61E-02
1967		2.42E-03	1.12E-02	1.58E-02	3.07E-04	1.02E-04	2.98E-02
1968		1.43E-02	6.60E-02	9.35E-02	1.82E-03	6.05E-04	1.76E-01
1969		2.11E-02	9.73E-02	1.38E-01	2.68E-03	8.92E-04	2.60E-01
1970		5.95E-03	2.75E-02	3.89E-02	7.56E-04	2.52E-04	7.34E-02
1971		4.00E-03	1.85E-02	2.62E-02	5.08E-04	1.69E-04	4.93E-02
1972		8.84E-03	4.08E-02	5.78E-02	1.12E-03	3.74E-04	1.09E-01
1973		1.12E-03	5.16E-03	7.31E-03	1.42E-04	4.73E-05	1.38E-02
1974		5.72E-04	2.64E-03	3.74E-03	7.26E-05	2.42E-05	7.05E-03
1975		4.26E-04	1.97E-03	2.79E-03	5.41E-05	1.80E-05	5.25E-03
1976		3.02E-04	1.39E-03	1.97E-03	3.83E-05	1.28E-05	3.72E-03
1977		3.90E-04	1.80E-03	2.55E-03	4.95E-05	1.65E-05	4.81E-03
1978		3.64E-04	1.68E-03	2.38E-03	4.62E-05	1.54E-05	4.49E-03
1979		4.68E-04	2.16E-03	3.06E-03	5.94E-05	1.98E-05	5.77E-03
1980		4.16E-04	1.92E-03	2.72E-03	5.28E-05	1.76E-05	5.13E-03
1981		7.02E-04	3.24E-03	4.59E-03	8.91E-05	2.97E-05	8.65E-03
1982		2.13E-04	9.84E-04	1.39E-03	2.71E-05	9.02E-06	2.63E-03
1983		2.42E-04	1.12E-03	1.58E-03	3.07E-05	1.02E-05	2.98E-03
1984		3.64E-04	1.68E-03	2.38E-03	4.62E-05	1.54E-05	4.49E-03
1985		1.42E-03	6.55E-03	9.28E-03	1.80E-04	6.01E-05	1.75E-02
1986		2.86E-04	1.32E-03	1.87E-03	3.63E-05	1.21E-05	3.52E-03
1987		8.19E-04	3.78E-03	5.36E-03	1.04E-04	3.47E-05	1.01E-02
1988		1.19E-04	5.48E-04	7.77E-04	1.51E-05	5.03E-06	1.46E-03
1989		1.98E-05	9.16E-05	1.30E-04	2.52E-06	8.39E-07	2.44E-04
1990		7.96E-06	3.67E-05	5.20E-05	1.01E-06	3.37E-07	9.80E-05
1991		1.68E-08	7.78E-08	1.10E-07	2.14E-09	7.13E-10	2.08E-07
1992		3.02E-09	1.39E-08	1.97E-08	3.83E-10	1.28E-10	3.72E-08
1993							
1994							
1995			3.42E-05	4.85E-05	9.41E-07	3.14E-07	8.39E-05
Totals		1.09E-01	5.05E-01	7.16E-01	1.39E-02	4.63E-03	1.35E+00
Percent		8.11%	37.45%	53.06%	1.03%	0.34%	

Ce-141/144. MEI Liquid-Pathway Doses

	Fish	Water	Shore	Swimming	Boating	Total Liquid Pathway
	(mrem)	(mrem)	(mrem)	(mrem)	(mrem)	(mrem)
1954						
1955						
1956						
1957						
1958						
1959						
1960	1.63E-03	6.51E-02	3.30E-04	2.60E-06	3.05E-06	6.71E-02
1961	1.43E-03	5.73E-02	2.90E-04	2.29E-06	2.69E-06	5.90E-02
1962	9.04E-04	3.62E-02	1.83E-04	1.45E-06	1.70E-06	3.73E-02
1963	2.01E-03	8.05E-02	4.07E-04	3.22E-06	3.77E-06	8.29E-02
1964	3.50E-03	1.40E-01	7.08E-04	5.59E-06	6.56E-06	1.44E-01
1965	1.25E-03	5.01E-02	2.54E-04	2.00E-06	2.35E-06	5.16E-02
1966	7.84E-04	3.14E-02	1.59E-04	1.25E-06	1.47E-06	3.23E-02
1967	6.76E-04	2.70E-02	1.37E-04	1.08E-06	1.27E-06	2.79E-02
1968	1.38E-03	5.54E-02	2.80E-04	2.21E-06	2.60E-06	5.70E-02
1969	2.18E-04	8.72E-03	4.41E-05	3.49E-07	4.09E-07	8.98E-03
1970	1.09E-04	4.35E-03	2.20E-05	1.74E-07	2.04E-07	4.48E-03
1971	9.84E-05	3.94E-03	1.99E-05	1.57E-07	1.85E-07	4.05E-03
1972	1.68E-06	6.72E-05	3.40E-07	2.69E-09	3.15E-09	6.92E-05
1973	5.88E-06	2.35E-04	1.19E-06	9.41E-09	1.10E-08	2.42E-04
1974	6.12E-06	2.45E-04	1.24E-06	9.79E-09	1.15E-08	2.52E-04
1975	1.56E-06	6.24E-05	3.16E-07	2.50E-09	2.93E-09	6.43E-05
1976	3.60E-07	1.44E-05	7.29E-08	5.76E-10	6.75E-10	1.48E-05
1977	5.76E-06	2.30E-04	1.17E-06	9.22E-09	1.08E-08	2.37E-04
1978	3.84E-08	1.54E-06	7.78E-09	6.14E-11	7.20E-11	1.58E-06
1979						
1980						
1981						
1982						
1983						
1984						
1985						
1986						
1987						
1988						
1989	1.80E-09	7.20E-08	3.65E-10	2.88E-12	3.38E-12	7.42E-08
1990						
1991						
1992						
1993						
1994						
1995						
Totals	1.40E-02	5.61E-01	2.84E-03	2.24E-05	2.63E-05	5.77E-01
Percent	2.43%	97.07%	0.49%	0.00%	0.00%	

Ce-141/144. Population Liquid-Pathway Doses

	Aquatic Food (per.-rem)	Water (per.-rem)	Shore (per.-rem)	Swimming (per.-rem)	Boating (per.-rem)	Total Liquid Pathway (per.-rem)
1954						
1955						
1956						
1957						
1958						
1959						
1960	5.98E+00	1.79E+00	1.38E-02	4.48E-05	1.59E-04	7.79E+00
1961	5.26E+00	1.58E+00	1.22E-02	3.94E-05	1.40E-04	6.85E+00
1962	3.32E+00	9.94E-01	7.68E-03	2.49E-05	8.81E-05	4.32E+00
1963	7.39E+00	2.21E+00	1.71E-02	5.53E-05	1.96E-04	9.62E+00
1964	1.28E+01	3.85E+00	2.97E-02	9.61E-05	3.41E-04	1.67E+01
1965	4.60E+00	1.38E+00	1.06E-02	3.44E-05	1.22E-04	5.99E+00
1966	2.88E+00	8.62E-01	6.66E-03	2.16E-05	7.64E-05	3.75E+00
1967	2.48E+00	7.44E-01	5.75E-03	1.86E-05	6.59E-05	3.23E+00
1968	5.09E+00	1.52E+00	1.18E-02	3.81E-05	1.35E-04	6.62E+00
1969	8.01E-01	2.40E-01	1.85E-03	6.00E-06	2.13E-05	1.04E+00
1970	4.00E-01	1.20E-01	9.25E-04	2.99E-06	1.06E-05	5.20E-01
1971	3.62E-01	1.08E-01	8.36E-04	2.71E-06	9.59E-06	4.71E-01
1972	6.17E-03	1.85E-03	1.43E-05	4.62E-08	1.64E-07	8.04E-03
1973	2.16E-02	6.47E-03	5.00E-05	1.62E-07	5.73E-07	2.81E-02
1974	2.25E-02	6.73E-03	5.20E-05	1.68E-07	5.97E-07	2.93E-02
1975	5.73E-03	1.72E-03	1.33E-05	4.29E-08	1.52E-07	7.46E-03
1976	1.32E-03	3.96E-04	3.06E-06	9.90E-09	3.51E-08	1.72E-03
1977	2.12E-02	6.34E-03	4.90E-05	1.58E-07	5.62E-07	2.76E-02
1978	1.41E-04	4.22E-05	3.26E-07	1.06E-09	3.74E-09	1.84E-04
1979						
1980						
1981						
1982						
1983						
1984						
1985						
1986						
1987						
1988						
1989	6.62E-06	1.98E-06	1.53E-08	4.95E-11	1.76E-10	8.61E-06
1990						
1991						
1992						
1993						
1994						
1995						

Table Ce-141/144 Air. Ce-141/144 Atmospheric Releases and Maximally Exposed Individual Dose 1954 -1995

Table Ce-141/144 Liquid. Ce-141/144 Liquid Releases and Maximally Exposed Individual Doses 1954 - 1995

Cm-242/244

Half-Life

Cm-242 - 162.8 days

Cm-244 - 18.1 years

Total Curies Released (1954-1995)

Air - 9.19E-02

Streams - 3.86E-01

Basins (Decay Corrected) - <1.00E-12

Total Cumulative Risks (1954-1995)

MEI Air Pathway - 1.11E-07

MEI Liquid Pathway - 8.44E-08

Population Air - 7.39E-03

Population Liquid - 9.65E-03

Projected 30-year Risks Using Recent Annual Doses (average of years 1991-1995)

MEI Air Pathway - 9.99E-10

MEI Liquid Pathway - 0.0

Population Air - 6.66E-05

Population Liquid - 0.0

Critical Pathways

MEI Air Pathway - Vegetation Consumption = 55%, Inhalation = 44%

MEI Liquid Pathway - Water Consumption = 60%, Fish Consumption = 40%

Population Air Pathway - Inhalation = 81%, Vegetation Consumption = 19%

Population Liquid Pathway - Aquatic Food = 85%, Water Consumption = 15%

Discussion

Cm-242/244 are medium-lived alpha-emitting radionuclides with relatively large ingestion and inhalation dose factors (DOE, 1988). Based on measured releases, Cm-242/244 account for less than 1% of the site's cumulative and projected 30-year MEI and population air and liquid pathway risks. However, estimated residual inventories of Cm-244 (>5.0E+04 Ci) may cause Cm-244 to assume greater importance, on a percentage-of-risk basis, in the near to distant (30-100 years) future.

Table Cm-242/244. Effluent Releases

	Cm-242,244	Cm-242,244	Cm-242,244=Basins
Air (Curies)	Streams (Curies)	Basins (Curies)	Decay Corrected (Ci)
1954			
1955			
1956			
1957			
1958			
1959			
1960			
1961			
1962			
1963			
1964	3.17E-02		
1965			
1966			
1967	3.00E-02		
1968			
1969	2.11E-02	3.00E-02	
1970	9.10E-04		
1971	3.04E-03	3.24E-01	
1972	3.90E-04	2.79E-02	
1973	3.79E-04	3.64E-03	
1974	3.90E-04		3.94E-02
1975			
1976	3.30E-04		2.60E-02
1977	3.39E-04		4.70E-02
1978	1.37E-04		1.00E-02
1979	3.89E-04		4.81E-02
1980	8.96E-04		1.00E-02
1981	1.63E-04		3.04E-02
1982	1.65E-04		8.25E-03
1983	5.06E-04		1.44E-02
1984	2.59E-04		2.90E-02
1985	2.46E-04		2.80E-02
1986	2.80E-05		2.70E-02
1987	3.22E-04		6.00E-03
1988	6.70E-05		3.37E-03
1989	2.80E-05		
1990	2.04E-05		
1991	4.25E-05		
1992	2.31E-05		
1993	5.64E-05		
1994	1.61E-05		
1995			
Totals	9.19E-02	3.86E-01	4.20E-01
			1.04E-119

Table Cm-242/244. MEI Air-Pathway Doses

	Plume	Ground	Inhalation	Vegetation	Milk	Meat	Total Air Pathway
	(mrem)	(mrem)	(mrem)	(mrem)	(mrem)	(mrem)	(mrem)
1954							
1955							
1956							
1957							
1958							
1959							
1960							
1961							
1962							
1963							
1964		3.80E-06	2.35E-02	2.88E-02	3.49E-06	4.12E-05	5.24E-02
1965							
1966							
1967		3.60E-06	2.22E-02	2.73E-02	3.30E-06	3.90E-05	4.95E-02
1968							
1969		2.53E-06	1.56E-02	1.92E-02	2.32E-06	2.74E-05	3.48E-02
1970		1.09E-07	6.73E-04	8.28E-04	1.00E-07	1.18E-06	1.50E-03
1971		3.65E-07	2.25E-03	2.77E-03	3.34E-07	3.95E-06	5.02E-03
1972		4.68E-08	2.89E-04	3.55E-04	4.29E-08	5.07E-07	6.44E-04
1973		4.55E-08	2.80E-04	3.45E-04	4.17E-08	4.93E-07	6.26E-04
1974		4.68E-08	2.89E-04	3.55E-04	4.29E-08	5.07E-07	6.44E-04
1975							
1976		3.96E-08	2.44E-04	3.00E-04	3.63E-08	4.29E-07	5.45E-04
1977		4.07E-08	2.51E-04	3.08E-04	3.73E-08	4.41E-07	5.60E-04
1978		1.64E-08	1.01E-04	1.25E-04	1.51E-08	1.78E-07	2.26E-04
1979		4.67E-08	2.88E-04	3.54E-04	4.28E-08	5.06E-07	6.42E-04
1980		1.08E-07	6.63E-04	8.15E-04	9.86E-08	1.16E-06	1.48E-03
1981		1.96E-08	1.21E-04	1.48E-04	1.79E-08	2.12E-07	2.69E-04
1982		1.98E-08	1.22E-04	1.50E-04	1.82E-08	2.15E-07	2.73E-04
1983		6.07E-08	3.74E-04	4.60E-04	5.57E-08	6.58E-07	8.36E-04
1984		3.11E-08	1.92E-04	2.36E-04	2.85E-08	3.37E-07	4.28E-04
1985		2.95E-08	1.82E-04	2.24E-04	2.71E-08	3.20E-07	4.06E-04
1986		3.36E-09	2.07E-05	2.55E-05	3.08E-09	3.64E-08	4.62E-05
1987		3.86E-08	2.38E-04	2.93E-04	3.54E-08	4.19E-07	5.32E-04
1988		8.04E-09	4.96E-05	6.10E-05	7.37E-09	8.71E-08	1.11E-04
1989		3.36E-09	2.07E-05	2.55E-05	3.08E-09	3.64E-08	4.62E-05
1990		2.45E-09	1.51E-05	1.86E-05	2.24E-09	2.65E-08	3.37E-05
1991		5.10E-09	3.15E-05	3.87E-05	4.68E-09	5.53E-08	7.02E-05
1992		2.77E-09	1.71E-05	2.10E-05	2.54E-09	3.00E-08	3.82E-05
1993		6.77E-09	4.17E-05	5.13E-05	6.20E-09	7.33E-08	9.31E-05
1994		1.93E-09	1.19E-05	1.47E-05	1.77E-09	2.09E-08	2.66E-05
1995							
Totals		1.10E-05	6.80E-02	8.37E-02	1.01E-05	1.20E-04	1.52E-01
Percent		0.01%	44.81%	55.10%	0.01%	0.08%	

Table Cm-242/244. Population Air-Pathway Doses

	Plume	Ground	Inhalation	Vegetation	Milk	Meat	Total Air Pathway
	(per.-rem)	(per.-rem)	(per.-rem)	(per.-rem)	(per.-rem)	(per.-rem)	(per.-rem)
1954							
1955							
1956							
1957							
1958							
1959							
1960							
1961							
1962							
1963							
1964	2.98E-04	2.82E+00	6.66E-01	1.24E-04	8.24E-04	3.49E+00	
1965							
1966							
1967	2.82E-04	2.67E+00	6.30E-01	1.17E-04	7.80E-04	3.30E+00	
1968							
1969	1.98E-04	1.88E+00	4.43E-01	8.23E-05	5.49E-04	2.32E+00	
1970	8.55E-06	8.10E-02	1.91E-02	3.55E-06	2.37E-05	1.00E-01	
1971	2.86E-05	2.71E-01	6.38E-02	1.19E-05	7.90E-05	3.35E-01	
1972	3.67E-06	3.47E-02	8.19E-03	1.52E-06	1.01E-05	4.29E-02	
1973	3.56E-06	3.37E-02	7.96E-03	1.48E-06	9.85E-06	4.17E-02	
1974	3.67E-06	3.47E-02	8.19E-03	1.52E-06	1.01E-05	4.29E-02	
1975							
1976	3.10E-06	2.94E-02	6.93E-03	1.29E-06	8.58E-06	3.63E-02	
1977	3.19E-06	3.02E-02	7.12E-03	1.32E-06	8.81E-06	3.73E-02	
1978	1.29E-06	1.22E-02	2.88E-03	5.34E-07	3.56E-06	1.51E-02	
1979	3.66E-06	3.46E-02	8.17E-03	1.52E-06	1.01E-05	4.28E-02	
1980	8.42E-06	7.97E-02	1.88E-02	3.49E-06	2.33E-05	9.86E-02	
1981	1.53E-06	1.45E-02	3.42E-03	6.36E-07	4.24E-06	1.79E-02	
1982	1.55E-06	1.47E-02	3.47E-03	6.44E-07	4.29E-06	1.82E-02	
1983	4.76E-06	4.50E-02	1.06E-02	1.97E-06	1.32E-05	5.57E-02	
1984	2.43E-06	2.31E-02	5.44E-03	1.01E-06	6.73E-06	2.85E-02	
1985	2.31E-06	2.19E-02	5.17E-03	9.59E-07	6.40E-06	2.71E-02	
1986	2.63E-07	2.49E-03	5.88E-04	1.09E-07	7.28E-07	3.08E-03	
1987	3.03E-06	2.87E-02	6.76E-03	1.26E-06	8.37E-06	3.54E-02	
1988	6.30E-07	5.96E-03	1.41E-03	2.61E-07	1.74E-06	7.37E-03	
1989	2.63E-07	2.49E-03	5.88E-04	1.09E-07	7.28E-07	3.08E-03	
1990	1.92E-07	1.82E-03	4.28E-04	7.96E-08	5.30E-07	2.24E-03	
1991	4.00E-07	3.78E-03	8.93E-04	1.66E-07	1.11E-06	4.68E-03	
1992	2.17E-07	2.06E-03	4.85E-04	9.01E-08	6.01E-07	2.54E-03	
1993	5.30E-07	5.02E-03	1.18E-03	2.20E-07	1.47E-06	6.21E-03	
1994	1.51E-07	1.43E-03	3.38E-04	6.28E-08	4.19E-07	1.77E-03	
1995							
Totals	8.64E-04	8.18E+00	1.93E+00	3.59E-04	2.39E-03	1.01E+01	
Percent							
	0.01%	80.88%	19.08%	0.00%	0.02%		

Table Cm-242/244. MEI Liquid-Pathway Doses

	Fish	Water	Shore	Swimming	Boating	Total Liquid Pathway
	(mrem)	(mrem)	(mrem)	(mrem)	(mrem)	(mrem)
1954						
1955						
1956						
1957						
1958						
1959						
1960						
1961						
1962						
1963						
1964						
1965						
1966						
1967						
1968						
1969	3.60E-03	5.40E-03	7.20E-08	3.60E-12	4.20E-12	9.00E-03
1970						
1971	3.89E-02	5.83E-02	7.78E-07	3.89E-11	4.54E-11	9.72E-02
1972	3.35E-03	5.02E-03	6.70E-08	3.35E-12	3.91E-12	8.37E-03
1973	4.37E-04	6.55E-04	8.74E-09	4.37E-13	5.10E-13	1.09E-03
1974						
1975						
1976						
1977						
1978						
1979						
1980						
1981						
1982						
1983						
1984						
1985						
1986						
1987						
1988						
1989						
1990						
1991						
1992						
1993						
1994						
1995						
Totals	4.63E-02	6.94E-02	9.25E-07	4.63E-11	5.40E-11	1.16E-01
Percent	40.00%	60.00%	0.00%	0.00%	0.00%	

Table Cm-242/244. Population Liquid-Pathway Doses

	Aquatic Food	Water	Shore	Swimming	Boating	Total Liquid Pathway
	(per.-rem)	(per.-rem)	(per.-rem)	(per.-rem)	(per.-rem)	(per.-rem)
1954						
1955						
1956						
1957						
1958						
1959						
1960						
1961						
1962						
1963						
1964						
1965						
1966						
1967						
1968						
1969	8.76E-01	1.53E-01	3.00E-06	6.30E-11	2.16E-10	1.03E+00
1970						
1971	9.46E+00	1.65E+00	3.24E-05	6.80E-10	2.33E-09	1.11E+01
1972	8.15E-01	1.42E-01	2.79E-06	5.86E-11	2.01E-10	9.57E-01
1973	1.06E-01	1.86E-02	3.64E-07	7.64E-12	2.62E-11	1.25E-01
1974						
1975						
1976						
1977						
1978						
1979						
1980						
1981						
1982						
1983						
1984						
1985						
1986						
1987						
1988						
1989						
1990						
1991						
1992						
1993						
1994						
1995						
Totals	1.13E+01	1.97E+00	3.86E-05	8.10E-10	2.78E-09	1.32E+01
Percent	85.13%	14.87%	0.00%	0.00%	0.00%	

Table Cm-242/244 Air. Cm-242/244 Atmospheric Releases and Maximally Exposed Individual Doses 1954 - 1995

Table Cm-242/244 Liquid. Cm-242/244 Liquid Releases and Maximally Exposed Individual Doses 1954 - 1995

Co-58

Half-Life

Co-58 - 77.88 days

Total Curies Released (1954-1995)

Air - 0.0

Streams - 0.0

Basins (Decay Corrected) - $<1.00\text{E-}12$

Total Cumulative Risks (1954-1995)

MEI Air Pathway - 0.0

MEI Liquid Pathway - 0.0

Population Air - 0.0

Population Liquid - 0.0

Projected 30-year Risks Using Recent Annual Doses (average of years 1991-1995)

MEI Air Pathway - 0.0

MEI Liquid Pathway - 0.0

Population Air - 0.0

Population Liquid - 0.0

Critical Pathways

MEI Air Pathway - N/A

MEI Liquid Pathway - N/A

Population Air Pathway - N/A

Population Liquid Pathway - N/A

Discussion

Co-58 is a short-lived activation product that was not released to the atmosphere or site streams. Therefore, offsite doses and risks have not been calculated. Past releases to site seepage basins have all essentially decayed away.

Table Co-58. Effluent Releases

	Co-58 to Air	Co-58 to Streams	Co-58 to Basins	Co-58 to Basins
	Curies	Curies	Curies	Decay Corrected (Ci)
1954				
1955				
1956				
1957				
1958				
1959				
1960				
1961				
1962				
1963				
1964				
1965				
1966				
1967				
1968				
1969				
1970				
1971			9.70E-01	5.05E-38
1972			1.00E-01	1.86E-37
1973			3.90E-01	2.60E-35
1974			6.20E-01	1.48E-33
1975			4.81E-01	4.10E-32
1976			1.13E-01	3.44E-31
1977			6.00E-03	6.54E-31
1978			5.39E-04	2.10E-30
1979				
1980				
1981			7.02E-04	1.25E-25
1982			2.24E-04	1.43E-24
1983			2.12E-02	4.84E-21
1984			1.40E-02	1.14E-19
1985			7.00E-03	2.04E-18
1986			2.25E-03	2.35E-17
1987			9.37E-04	3.50E-16
1988			2.78E-04	3.71E-15
1989				
1990				
1991				
1992				
1993				
1994				
1995				
Totals			2.73E+00	4.09E-15

Co-60

Half-Life

Co-60 - 5.27 years

Total Curies Released (1954-1995)

Air - $9.16\text{E-}02$

Streams - $6.64\text{E+}01$

Basins (Decay Corrected) - $7.83\text{E-}01$

Total Cumulative Risks (1954-1995)

MEI Air Pathway - $8.79\text{E-}09$

MEI Liquid Pathway - $3.40\text{E-}07$

Population Air - $5.36\text{E-}04$

Population Liquid - $2.37\text{E-}02$

Projected 30-year Risks Using Recent Annual Doses (average of years 1991-1995)

MEI Air Pathway - $3.82\text{E-}11$

MEI Liquid Pathway - 0.0

Population Air - $3.83\text{E-}07$

Population Liquid - 0.0

Critical Pathways

MEI Air Pathway - Ground Shine = 91%, Vegetation Consumption = 8%

MEI Liquid Pathway - Fish Consumption = 60%, Shore = 34%

Population Air Pathway - Ground Shine = 96%, Vegetation Consumption = 3%

Population Liquid Pathway - Aquatic Food = 68%, Shore = 20%

Discussion

Co-60 is a medium-lived, very abundant, activation product. Based on measured releases, Co-60 accounts for less than 2% of the site's cumulative and projected 30-year MEI and population air and liquid pathway risks. However, estimated residual inventories of Co-60 ($>3.9\text{E+}06$ Ci) may cause Co-60 to assume greater importance, on a percentage-of-risk basis, in the near (0-30 years) future. Because most of this large residual inventory is buried in the SWDF, it may have an impact on the local groundwater. Refer to Carlton, 1996 for a more complete assessment of Co-60 at SRS.

Table Co-60. Effluent Releases

	Co-60 to Air	Co-60 to Streams	Co-60 to Basins	Co-60 to Basins
	Curies	Curies	Curies	Decay Corrected (Ci)
1954		6.00E-02		
1955		2.24E-01		
1956		6.06E-01		
1957		1.64E+00	2.36E+00	1.60E-02
1958		1.07E+00	9.08E-01	7.02E-03
1959		2.65E+00	4.74E-01	4.18E-03
1960		7.79E+00	2.66E-01	2.68E-03
1961		6.33E+00	1.59E-01	1.82E-03
1962		1.27E+01	8.15E-02	1.07E-03
1963		5.07E+00	7.54E-01	1.13E-02
1964		3.11E+00	2.70E+00	4.60E-02
1965		1.08E+01	1.64E+00	3.18E-02
1966		5.06E+00	2.73E-01	6.04E-03
1967		1.69E+00	2.45E-01	6.18E-03
1968	3.93E-02	1.84E+00	1.88E+00	5.41E-02
1969	1.10E-02	2.10E-01	1.40E+00	4.60E-02
1970	2.75E-03	1.72E-01	4.93E-01	1.85E-02
1971	2.22E-02	4.63E+00	4.70E-01	2.01E-02
1972	7.21E-03	1.81E-01	4.00E-02	1.95E-03
1973	1.78E-03	2.74E-02	4.30E-02	2.39E-03
1974	3.87E-03	3.00E-03	4.91E-01	3.11E-02
1975	1.11E-03	9.00E-03	4.22E-01	3.05E-02
1976	1.29E-04	2.00E-03	4.68E-01	3.85E-02
1977	3.80E-04	1.03E-01	3.98E-01	3.74E-02
1978	3.80E-04	3.94E-04	1.66E-01	1.78E-02
1979	4.00E-04	4.06E-01	1.03E-01	1.26E-02
1980	6.17E-04	1.55E-03	2.21E-01	3.08E-02
1981	8.90E-05	2.46E-04	1.61E-01	2.56E-02
1982	4.40E-05	1.11E-04	2.64E-01	4.78E-02
1983	1.68E-04	1.85E-03	2.25E-01	4.65E-02
1984	5.40E-05	3.12E-04	2.66E-01	6.27E-02
1985			2.92E-01	7.85E-02
1986	8.00E-06		1.31E-01	4.01E-02
1987			1.46E-02	5.10E-03
1988	3.00E-06		8.12E-04	3.24E-04
1989			5.21E-04	2.37E-04
1990	5.04E-07		2.86E-05	1.48E-05
1991	2.09E-06			
1992	3.60E-07			
1993	5.89E-09			
1994	6.16E-06			
1995	5.76E-05			
Totals	9.16E-02	6.64E+01	1.78E+01	7.83E-01

Table Co-60: MEI Air-Pathway Doses

	Plume	Ground	Inhalation	Vegetation	Milk	Meat	Total Air Pathway
	(mrem)	(mrem)	(mrem)	(mrem)	(mrem)	(mrem)	(mrem)
1954							
1955							
1956							
1957							
1958							
1959							
1960							
1961							
1962							
1963							
1964							
1965							
1966							
1967							
1968		4.72E-03	1.61E-05	3.93E-04	9.83E-06	3.62E-05	5.17E-03
1969		1.32E-03	4.51E-06	1.10E-04	2.75E-06	1.01E-05	1.45E-03
1970		3.30E-04	1.13E-06	2.75E-05	6.88E-07	2.53E-06	3.62E-04
1971		2.66E-03	9.10E-06	2.22E-04	5.55E-06	2.04E-05	2.92E-03
1972		8.65E-04	2.96E-06	7.21E-05	1.80E-06	6.63E-06	9.49E-04
1973		2.14E-04	7.30E-07	1.78E-05	4.45E-07	1.64E-06	2.34E-04
1974		4.64E-04	1.59E-06	3.87E-05	9.68E-07	3.56E-06	5.09E-04
1975		1.33E-04	4.55E-07	1.11E-05	2.78E-07	1.02E-06	1.46E-04
1976		1.55E-05	5.29E-08	1.29E-06	3.23E-08	1.19E-07	1.70E-05
1977		4.56E-05	1.56E-07	3.80E-06	9.50E-08	3.50E-07	5.00E-05
1978		4.56E-05	1.56E-07	3.80E-06	9.50E-08	3.50E-07	5.00E-05
1979		4.80E-05	1.64E-07	4.00E-06	1.00E-07	3.68E-07	5.26E-05
1980		7.40E-05	2.53E-07	6.17E-06	1.54E-07	5.68E-07	8.12E-05
1981		1.07E-05	3.65E-08	8.90E-07	2.23E-08	8.19E-08	1.17E-05
1982		5.28E-06	1.80E-08	4.40E-07	1.10E-08	4.05E-08	5.79E-06
1983		2.02E-05	6.89E-08	1.68E-06	4.20E-08	1.55E-07	2.21E-05
1984		6.48E-06	2.21E-08	5.40E-07	1.35E-08	4.97E-08	7.11E-06
1985							
1986		9.60E-07	3.28E-09	8.00E-08	2.00E-09	7.36E-09	1.05E-06
1987							
1988		3.60E-07	1.23E-09	3.00E-08	7.50E-10	2.76E-09	3.95E-07
1989							
1990		6.05E-08	2.07E-10	5.04E-09	1.26E-10	4.64E-10	6.63E-08
1991		2.51E-07	8.57E-10	2.09E-08	5.23E-10	1.92E-09	2.75E-07
1992		4.32E-08	1.48E-10	3.60E-09	9.00E-11	3.31E-10	4.74E-08
1993		7.07E-10	2.41E-12	5.89E-11	1.47E-12	5.42E-12	7.75E-10
1994		7.39E-07	2.53E-09	6.16E-08	1.54E-09	5.67E-09	8.11E-07
1995		6.91E-06	2.36E-08	5.76E-07	1.44E-08	5.30E-08	7.58E-06
Totals		1.10E-02	3.75E-05	9.16E-04	2.29E-05	8.42E-05	1.20E-02
Percent		91.20%	0.31%	7.60%	0.19%	0.70%	

Table Co-60. Population Air-Pathway Doses

	Plume	Ground	Inhalation	Vegetation	Milk	Meat	Total Air Pathway
	(per.-rem)	(per.-rem)	(per.-rem)	(per.-rem)	(per.-rem)	(per.-rem)	(per.-rem)
1954							
1955							
1956							
1957							
1958							
1959							
1960							
1961							
1962							
1963							
1964							
1965							
1966							
1967							
1968		3.03E-01	1.97E-03	9.43E-03	3.42E-04	7.47E-04	3.15E-01
1969		8.47E-02	5.50E-04	2.64E-03	9.57E-05	2.09E-04	8.82E-02
1970		2.12E-02	1.38E-04	6.60E-04	2.39E-05	5.23E-05	2.20E-02
1971		1.71E-01	1.11E-03	5.33E-03	1.93E-04	4.22E-04	1.78E-01
1972		5.55E-02	3.61E-04	1.73E-03	6.27E-05	1.37E-04	5.78E-02
1973		1.37E-02	8.90E-05	4.27E-04	1.55E-05	3.38E-05	1.43E-02
1974		2.98E-02	1.94E-04	9.29E-04	3.37E-05	7.35E-05	3.10E-02
1975		8.55E-03	5.55E-05	2.66E-04	9.66E-06	2.11E-05	8.90E-03
1976		9.93E-04	6.45E-06	3.10E-05	1.12E-06	2.45E-06	1.03E-03
1977		2.93E-03	1.90E-05	9.12E-05	3.31E-06	7.22E-06	3.05E-03
1978		2.93E-03	1.90E-05	9.12E-05	3.31E-06	7.22E-06	3.05E-03
1979		3.08E-03	2.00E-05	9.60E-05	3.48E-06	7.60E-06	3.21E-03
1980		4.75E-03	3.09E-05	1.48E-04	5.37E-06	1.17E-05	4.95E-03
1981		6.85E-04	4.45E-06	2.14E-05	7.74E-07	1.69E-06	7.14E-04
1982		3.39E-04	2.20E-06	1.06E-05	3.83E-07	8.36E-07	3.53E-04
1983		1.29E-03	8.40E-06	4.03E-05	1.46E-06	3.19E-06	1.35E-03
1984		4.16E-04	2.70E-06	1.30E-05	4.70E-07	1.03E-06	4.33E-04
1985							
1986		6.16E-05	4.00E-07	1.92E-06	6.96E-08	1.52E-07	6.41E-05
1987							
1988		2.31E-05	1.50E-07	7.20E-07	2.61E-08	5.70E-08	2.41E-05
1989							
1990		3.88E-06	2.52E-08	1.21E-07	4.38E-09	9.58E-09	4.04E-06
1991		1.61E-05	1.05E-07	5.02E-07	1.82E-08	3.97E-08	1.68E-05
1992		2.77E-06	1.80E-08	8.64E-08	3.13E-09	6.84E-09	2.89E-06
1993		4.54E-08	2.95E-10	1.41E-09	5.12E-11	1.12E-10	4.72E-08
1994		4.74E-05	3.08E-07	1.48E-06	5.36E-08	1.17E-07	4.94E-05
1995			2.88E-06	1.38E-05	5.01E-07	1.09E-06	1.83E-05
Totals		7.05E-01	4.58E-03	2.20E-02	7.97E-04	1.74E-03	7.34E-01
Percent		96.04%	0.62%	3.00%	0.11%	0.24%	

Table Co-60. MEI Liquid-Pathway Doses

	Fish	Water	Shore	Swimming	Boating	Total Liquid Pathway
	(mrem)	(mrem)	(mrem)	(mrem)	(mrem)	(mrem)
1954	1.56E-04	1.20E-04	1.44E-04	2.46E-07	2.88E-07	4.21E-04
1955	5.82E-04	4.48E-04	5.38E-04	9.18E-07	1.08E-06	1.57E-03
1956	1.58E-03	1.21E-03	1.45E-03	2.48E-06	2.91E-06	4.25E-03
1957	4.26E-03	3.28E-03	3.94E-03	6.72E-06	7.87E-06	1.15E-02
1958	2.78E-03	2.14E-03	2.57E-03	4.39E-06	5.14E-06	7.50E-03
1959	6.89E-03	5.30E-03	6.36E-03	1.09E-05	1.27E-05	1.86E-02
1960	2.03E-02	1.56E-02	1.87E-02	3.19E-05	3.74E-05	5.46E-02
1961	1.65E-02	1.27E-02	1.52E-02	2.60E-05	3.04E-05	4.44E-02
1962	3.30E-02	2.54E-02	3.05E-02	5.21E-05	6.10E-05	8.90E-02
1963	1.32E-02	1.01E-02	1.22E-02	2.08E-05	2.43E-05	3.55E-02
1964	8.09E-03	6.22E-03	7.46E-03	1.28E-05	1.49E-05	2.18E-02
1965	2.81E-02	2.16E-02	2.59E-02	4.43E-05	5.18E-05	7.57E-02
1966	1.32E-02	1.01E-02	1.21E-02	2.07E-05	2.43E-05	3.55E-02
1967	4.39E-03	3.38E-03	4.06E-03	6.93E-06	8.11E-06	1.18E-02
1968	4.78E-03	3.68E-03	4.42E-03	7.54E-06	8.83E-06	1.29E-02
1969	5.46E-04	4.20E-04	5.04E-04	8.61E-07	1.01E-06	1.47E-03
1970	4.47E-04	3.44E-04	4.13E-04	7.05E-07	8.26E-07	1.21E-03
1971	1.20E-02	9.26E-03	1.11E-02	1.90E-05	2.22E-05	3.25E-02
1972	4.71E-04	3.62E-04	4.34E-04	7.42E-07	8.69E-07	1.27E-03
1973	7.12E-05	5.48E-05	6.58E-05	1.12E-07	1.32E-07	1.92E-04
1974	7.80E-06	6.00E-06	7.20E-06	1.23E-08	1.44E-08	2.10E-05
1975	2.34E-05	1.80E-05	2.16E-05	3.69E-08	4.32E-08	6.31E-05
1976	5.20E-06	4.00E-06	4.80E-06	8.20E-09	9.60E-09	1.40E-05
1977	2.68E-04	2.06E-04	2.47E-04	4.22E-07	4.94E-07	7.22E-04
1978	1.02E-06	7.88E-07	9.46E-07	1.62E-09	1.89E-09	2.76E-06
1979	1.06E-03	8.12E-04	9.74E-04	1.66E-06	1.95E-06	2.85E-03
1980	4.03E-06	3.10E-06	3.72E-06	6.36E-09	7.44E-09	1.09E-05
1981	6.40E-07	4.92E-07	5.90E-07	1.01E-09	1.18E-09	1.72E-06
1982	2.89E-07	2.22E-07	2.66E-07	4.55E-10	5.33E-10	7.78E-07
1983	4.81E-06	3.70E-06	4.44E-06	7.59E-09	8.88E-09	1.30E-05
1984	8.11E-07	6.24E-07	7.49E-07	1.28E-09	1.50E-09	2.19E-06
1985						
1986						
1987						
1988						
1989						
1990						
1991						
1992						
1993						
1994						
1995						
Totals	1.73E-01	1.33E-01	1.59E-01	2.72E-04	3.19E-04	4.65E-01
Percent	37.10%	28.54%	34.24%	0.06%	0.07%	

Table Co-60. Population Liquid-Pathway Doses

	Aquatic Food	Water	Shore	Swimming	Boating	Total Liquid Pathway
	(per.-rem)	(per.-rem)	(per.-rem)	(per.-rem)	(per.-rem)	(per.-rem)
1954	1.99E-02	3.48E-03	6.00E-03	4.44E-06	1.50E-05	2.94E-02
1955	7.41E-02	1.30E-02	2.24E-02	1.66E-05	5.60E-05	1.10E-01
1956	2.01E-01	3.51E-02	6.06E-02	4.48E-05	1.52E-04	2.97E-01
1957	5.43E-01	9.51E-02	1.64E-01	1.21E-04	4.10E-04	8.02E-01
1958	3.54E-01	6.21E-02	1.07E-01	7.92E-05	2.68E-04	5.24E-01
1959	8.77E-01	1.54E-01	2.65E-01	1.96E-04	6.63E-04	1.30E+00
1960	2.58E+00	4.52E-01	7.79E-01	5.76E-04	1.95E-03	3.81E+00
1961	2.10E+00	3.67E-01	6.33E-01	4.68E-04	1.58E-03	3.10E+00
1962	4.20E+00	7.37E-01	1.27E+00	9.40E-04	3.18E-03	6.21E+00
1963	1.68E+00	2.94E-01	5.07E-01	3.75E-04	1.27E-03	2.48E+00
1964	1.03E+00	1.80E-01	3.11E-01	2.30E-04	7.78E-04	1.52E+00
1965	3.57E+00	6.26E-01	1.08E+00	7.99E-04	2.70E-03	5.28E+00
1966	1.67E+00	2.93E-01	5.06E-01	3.74E-04	1.27E-03	2.48E+00
1967	5.59E-01	9.80E-02	1.69E-01	1.25E-04	4.23E-04	8.27E-01
1968	6.09E-01	1.07E-01	1.84E-01	1.36E-04	4.60E-04	9.00E-01
1969	6.95E-02	1.22E-02	2.10E-02	1.55E-05	5.25E-05	1.03E-01
1970	5.69E-02	9.98E-03	1.72E-02	1.27E-05	4.30E-05	8.42E-02
1971	1.53E+00	2.69E-01	4.63E-01	3.43E-04	1.16E-03	2.27E+00
1972	5.99E-02	1.05E-02	1.81E-02	1.34E-05	4.53E-05	8.86E-02
1973	9.07E-03	1.59E-03	2.74E-03	2.03E-06	6.85E-06	1.34E-02
1974	9.93E-04	1.74E-04	3.00E-04	2.22E-07	7.50E-07	1.47E-03
1975	2.98E-03	5.22E-04	9.00E-04	6.66E-07	2.25E-06	4.40E-03
1976	6.62E-04	1.16E-04	2.00E-04	1.48E-07	5.00E-07	9.79E-04
1977	3.41E-02	5.97E-03	1.03E-02	7.62E-06	2.58E-05	5.04E-02
1978	1.30E-04	2.29E-05	3.94E-05	2.92E-08	9.85E-08	1.93E-04
1979	1.34E-01	2.35E-02	4.06E-02	3.00E-05	1.02E-04	1.99E-01
1980	5.13E-04	8.99E-05	1.55E-04	1.15E-07	3.88E-07	7.58E-04
1981	8.14E-05	1.43E-05	2.46E-05	1.82E-08	6.15E-08	1.20E-04
1982	3.67E-05	6.44E-06	1.11E-05	8.21E-09	2.78E-08	5.43E-05
1983	6.12E-04	1.07E-04	1.85E-04	1.37E-07	4.63E-07	9.05E-04
1984	1.03E-04	1.81E-05	3.12E-05	2.31E-08	7.80E-08	1.53E-04
1985						
1986						
1987						
1988						
1989						
1990						
1991						
1992						
1993						
1994						
1995						
Totals	2.20E+01	3.85E+00	6.64E+00	4.91E-03	1.66E-02	3.25E+01
Percent	67.64%	11.85%	20.44%	0.02%	0.05%	

Table Co-60 Air. Co-60 Atmospheric Releases and Maximally Exposed Individual Doses 1954 - 1995

Table Co-60 Liquid. Co-60 Liquid Releases and Maximally Exposed Individual Doses 1954 - 1995

Cr-51

Half-Life

Cr-51 - 27.7 days

Total Curies Released (1954-1995)

Air - 0.0

Streams - 4.49E+03

Basins (Decay Corrected) - <1.00E-12

Total Cumulative Risks (1954-1995)

MEI Air Pathway - 0.0

MEI Liquid Pathway - 1.97E-07

Population Air - 0.0

Population Liquid - 8.96E-03

Projected 30-year Risks Using Recent Annual Doses (average of years 1991-1995)

MEI Air Pathway - 0.0

MEI Liquid Pathway - 0.0

Population Air - 0.0

Population Liquid - 0.0

Critical Pathways

MEI Air Pathway - N/A

MEI Liquid Pathway - Fish Consumption = 83%, Water Consumption = 16%

Population Air Pathway - N/A

Population Liquid Pathway - Aquatic Food = 90%, Water Consumption = 10%

Discussion

Cr-51 is a short-lived activation product that has not been measured in site airborne effluents and has not been measured in liquid effluents to site streams since 1979. On a cumulative MEI and population risk basis, Cr-51 was the 12th and 15th most important liquid pathway radionuclide, respectively. The cumulative MEI risk was estimated to be less than 1.0E-06 and was less 1% of the site total. Refer to Carlton, 1996 for a more complete assessment of Cr-51 at SRS.

Table Cr-51. Effluent Releases

	Cr-51 to Air	Cr-51 to Streams	Cr-51 to Basins	Cr-51 to Basins
	Curies	Curies	Curies	Decay Corrected (Ci)
1954				
1955				
1956				
1957				
1958				
1959				
1960		1.14E+01		
1961		6.15E+01		
1962		2.11E+02		
1963		1.28E+03		
1964		1.09E+03	6.09E+01	8.58E-122
1965		7.83E+02	9.97E+01	1.29E-117
1966		6.25E+02	7.64E+00	9.08E-115
1967		2.42E+02	2.52E+00	2.75E-111
1968		8.58E+01	1.18E+02	1.18E-105
1969		6.85E+01	2.96E+02	2.72E-101
1970		1.59E+01	8.55E+00	7.22E-99
1971		7.33E+00	2.51E+01	1.95E-94
1972		1.38E+00	3.13E+01	2.23E-90
1973		4.45E-01	1.41E+01	9.22E-87
1974		5.95E-01	7.88E+00	4.73E-83
1975		1.16E-01	4.57E+00	2.52E-79
1976		3.62E-01	6.38E+00	3.23E-75
1977		6.62E-01	6.13E+00	2.85E-71
1978		4.04E-02	1.54E+00	6.57E-68
1979		5.38E-01	1.27E+00	4.98E-64
1980			1.55E+00	5.58E-60
1981			2.45E+00	8.09E-56
1982			2.88E+00	8.73E-52
1983			1.18E+00	3.29E-48
1984			5.93E+00	1.52E-43
1985			3.82E+00	8.97E-40
1986			5.54E-01	1.19E-36
1987			9.80E-02	1.94E-33
1988			2.67E-03	4.85E-31
1989			5.21E-04	8.69E-28
1990				
1991				
1992				
1993				
1994				
1995				
Totals		4.49E+03	7.10E+02	8.70E-28

Table Cr-51. MEI Liquid-Pathway Doses

	Fish	Water	Shore	Swimming	Boating	Total Liquid Pathway
	(mrem)	(mrem)	(mrem)	(mrem)	(mrem)	(mrem)
1954						
1955						
1956						
1957						
1958						
1959						
1960	5.70E-04	1.11E-04	5.93E-06	4.22E-07	4.90E-07	6.87E-04
1961	3.08E-03	5.97E-04	3.20E-05	2.28E-06	2.64E-06	3.71E-03
1962	1.06E-02	2.05E-03	1.10E-04	7.81E-06	9.07E-06	1.27E-02
1963	6.40E-02	1.24E-02	6.66E-04	4.74E-05	5.50E-05	7.72E-02
1964	5.45E-02	1.06E-02	5.67E-04	4.03E-05	4.69E-05	6.57E-02
1965	3.92E-02	7.60E-03	4.07E-04	2.90E-05	3.37E-05	4.72E-02
1966	3.13E-02	6.06E-03	3.25E-04	2.31E-05	2.69E-05	3.77E-02
1967	1.21E-02	2.35E-03	1.26E-04	8.95E-06	1.04E-05	1.46E-02
1968	4.29E-03	8.32E-04	4.46E-05	3.17E-06	3.69E-06	5.17E-03
1969	3.43E-03	6.64E-04	3.56E-05	2.53E-06	2.95E-06	4.13E-03
1970	7.95E-04	1.54E-04	8.27E-06	5.88E-07	6.84E-07	9.59E-04
1971	3.67E-04	7.11E-05	3.81E-06	2.71E-07	3.15E-07	4.42E-04
1972	6.90E-05	1.34E-05	7.18E-07	5.11E-08	5.93E-08	8.32E-05
1973	2.23E-05	4.32E-06	2.31E-07	1.65E-08	1.91E-08	2.68E-05
1974	2.98E-05	5.77E-06	3.09E-07	2.20E-08	2.56E-08	3.59E-05
1975	5.80E-06	1.13E-06	6.03E-08	4.29E-09	4.99E-09	6.99E-06
1976	1.81E-05	3.51E-06	1.88E-07	1.34E-08	1.56E-08	2.18E-05
1977	3.31E-05	6.42E-06	3.44E-07	2.45E-08	2.85E-08	3.99E-05
1978	2.02E-06	3.92E-07	2.10E-08	1.49E-09	1.74E-09	2.44E-06
1979	2.69E-05	5.22E-06	2.80E-07	1.99E-08	2.31E-08	3.24E-05
1980						
1981						
1982						
1983						
1984						
1985						
1986						
1987						
1988						
1989						
1990						
1991						
1992						
1993						
1994						
1995						
Totals	2.24E-01	4.35E-02	2.33E-03	1.66E-04	1.93E-04	2.70E-01
Percent	82.92%	16.09%	0.86%	0.06%	0.07%	

Table Cr-51. Population Liquid-Pathway Doses

	Aquatic Food	Water	Shore	Swimming	Boating	Total Liquid Pathway
	(per.-rem)	(per.-rem)	(per.-rem)	(per.-rem)	(per.-rem)	(per.-rem)
1954						
1955						
1956						
1957						
1958						
1959						
1960	2.79E-02	2.96E-03	2.51E-04	7.52E-06	2.62E-05	3.12E-02
1961	1.51E-01	1.60E-02	1.35E-03	4.06E-05	1.41E-04	1.68E-01
1962	5.17E-01	5.49E-02	4.64E-03	1.39E-04	4.85E-04	5.77E-01
1963	3.14E+00	3.33E-01	2.82E-02	8.45E-04	2.94E-03	3.50E+00
1964	2.67E+00	2.83E-01	2.40E-02	7.19E-04	2.51E-03	2.98E+00
1965	1.92E+00	2.04E-01	1.72E-02	5.17E-04	1.80E-03	2.14E+00
1966	1.53E+00	1.63E-01	1.38E-02	4.13E-04	1.44E-03	1.71E+00
1967	5.93E-01	6.29E-02	5.32E-03	1.60E-04	5.57E-04	6.62E-01
1968	2.10E-01	2.23E-02	1.89E-03	5.66E-05	1.97E-04	2.35E-01
1969	1.68E-01	1.78E-02	1.51E-03	4.52E-05	1.58E-04	1.87E-01
1970	3.90E-02	4.13E-03	3.50E-04	1.05E-05	3.66E-05	4.35E-02
1971	1.80E-02	1.91E-03	1.61E-04	4.84E-06	1.69E-05	2.00E-02
1972	3.38E-03	3.59E-04	3.04E-05	9.11E-07	3.17E-06	3.77E-03
1973	1.09E-03	1.16E-04	9.79E-06	2.94E-07	1.02E-06	1.22E-03
1974	1.46E-03	1.55E-04	1.31E-05	3.93E-07	1.37E-06	1.63E-03
1975	2.84E-04	3.02E-05	2.55E-06	7.66E-08	2.67E-07	3.17E-04
1976	8.87E-04	9.41E-05	7.96E-06	2.39E-07	8.33E-07	9.90E-04
1977	1.62E-03	1.72E-04	1.46E-05	4.37E-07	1.52E-06	1.81E-03
1978	9.90E-05	1.05E-05	8.89E-07	2.67E-08	9.29E-08	1.10E-04
1979	1.32E-03	1.40E-04	1.18E-05	3.55E-07	1.24E-06	1.47E-03
1980						
1981						
1982						
1983						
1984						
1985						
1986						
1987						
1988						
1989						
1990						
1991						
1992						
1993						
1994						
1995						
Totals	1.10E+01	1.17E+00	9.87E-02	2.96E-03	1.03E-02	1.23E+01
Percent	89.58%	9.51%	0.80%	0.02%	0.08%	

Table Cr-51 Liquid. Cr-51 Liquid Releases and Maximally Exposed Individual Doses 1954 - 1995

Cs-134

Half-Life

Cs-134 - 2.07 years

Total Curies Released (1954-1995)

Air - 4.60E-02

Streams - 5.47E-01

Basins (Decay Corrected) - 4.39E-02

Total Cumulative Risks (1954-1995)

MEI Air Pathway - 2.35E-09

MEI Liquid Pathway - 1.85E-08

Population Air - 1.03E-04

Population Liquid - 4.37E-04

Projected 30-year Risks Using Recent Annual Doses (average of years 1991-1995)

MEI Air Pathway - 1.16E-11

MEI Liquid Pathway - 0.0

Population Air - 2.33E-07

Population Liquid - 0.0

Critical Pathways

MEI Air Pathway - Ground Shine = 47%, Vegetation Consumption = 40%

MEI Liquid Pathway - Fish Consumption = 97%, Shore = 2%,

Population Air Pathway - Ground Shine = 69%, Vegetation Consumption = 21%

Population Liquid Pathway - Aquatic Food = 83%, Water Consumption = 15%

Discussion

Cs-134 is a medium-lived activation product (from Cs-133 (n,gamma)). On a cumulative MEI and population risk basis, Cs-134 was the 21st and 22nd most important liquid pathway radionuclide, respectively and the 24th and 23rd most important air pathway radionuclide, respectively. The cumulative and projected 30-year MEI air and liquid pathway risks are estimated to be much less than 1.0E-06 and are much less than 1% of the site total. However, estimated residual inventories ($>1.9\text{E}+04$ Ci) may cause Cs-134 to assume greater importance, on a percentage-of-risk basis, in the near (0-30 years) future.

Refer to Carlton, 1992 for a more complete assessment of Cs-134 at SRS.

Table Cs-134. Effluent Releases

	Cs-134	Cs-134	Cs-134	Cs-134-Basin
	Air (Curies)	Streams (Curies)	Basins (Curies)	Decay Corrected (Ci)
1954				
1955				
1956				
1957				
1958				
1959				
1960				
1961				
1962				
1963				
1964				
1965			2.64E+00	1.10E-04
1966			8.50E-01	4.96E-05
1967			1.41E+00	1.15E-04
1968				
1969				
1970				
1971	5.08E-03		1.59E+00	4.98E-04
1972	1.55E-03	4.00E-02	1.22E+00	5.35E-04
1973		2.06E-01	6.23E-01	3.82E-04
1974	3.00E-05	5.80E-02	6.41E-01	5.51E-04
1975	2.00E-04	1.75E-01	4.93E-01	5.93E-04
1976	1.70E-04	1.70E-02	4.83E-01	8.13E-04
1977	4.33E-04	4.73E-02	2.35E-01	5.54E-04
1978	1.25E-04	3.54E-03	7.22E-01	2.38E-03
1979	2.68E-04		1.15E+00	5.31E-03
1980	3.80E-04		7.19E-02	4.64E-04
1981	6.41E-04		7.71E-02	6.97E-04
1982	3.80E-05		5.08E-02	6.43E-04
1983	5.60E-05		8.86E-02	1.57E-03
1984	3.80E-05		1.70E-01	4.21E-03
1985	3.00E-05		6.77E-02	2.35E-03
1986	6.94E-04		1.27E-01	6.16E-03
1987	3.55E-02		1.22E-01	8.29E-03
1988	6.58E-04		8.00E-02	7.61E-03
1989	9.20E-05		2.02E-04	2.69E-05
1990	1.84E-05			
1991	6.40E-06			
1992	3.75E-08			
1993	1.49E-06			
1994	8.41E-09			
1995	3.01E-05			
Totals	4.60E-02	5.47E-01	1.29E+01	4.39E-02

Table Cs-134. MEI Air-Pathway Doses

	Plume	Ground	Inhalation	Vegetation	Milk	Meat	Total Air Pathway
	(mrem)	(mrem)	(mrem)	(mrem)	(mrem)	(mrem)	(mrem)
1954							
1955							
1956							
1957							
1958							
1959							
1960							
1961							
1962							
1963							
1964							
1965							
1966							
1967							
1968							
1969							
1970							
1971		1.68E-04	6.60E-07	1.42E-04	4.06E-05	3.86E-06	3.55E-04
1972		5.12E-05	2.02E-07	4.34E-05	1.24E-05	1.18E-06	1.08E-04
1973							
1974		9.90E-07	3.90E-09	8.40E-07	2.40E-07	2.28E-08	2.10E-06
1975		6.60E-06	2.60E-08	5.60E-06	1.60E-06	1.52E-07	1.40E-05
1976		5.61E-06	2.21E-08	4.76E-06	1.36E-06	1.29E-07	1.19E-05
1977		1.43E-05	5.63E-08	1.21E-05	3.46E-06	3.29E-07	3.03E-05
1978		4.13E-06	1.63E-08	3.50E-06	1.00E-06	9.50E-08	8.74E-06
1979		8.84E-06	3.48E-08	7.50E-06	2.14E-06	2.04E-07	1.87E-05
1980		1.25E-05	4.94E-08	1.06E-05	3.04E-06	2.89E-07	2.66E-05
1981		2.12E-05	8.33E-08	1.79E-05	5.13E-06	4.87E-07	4.48E-05
1982		1.25E-06	4.94E-09	1.06E-06	3.04E-07	2.89E-08	2.66E-06
1983		1.85E-06	7.28E-09	1.57E-06	4.48E-07	4.26E-08	3.91E-06
1984		1.25E-06	4.94E-09	1.06E-06	3.04E-07	2.89E-08	2.66E-06
1985		9.90E-07	3.90E-09	8.40E-07	2.40E-07	2.28E-08	2.10E-06
1986		2.29E-05	9.02E-08	1.94E-05	5.55E-06	5.27E-07	4.85E-05
1987		1.17E-03	4.62E-06	9.94E-04	2.84E-04	2.70E-05	2.48E-03
1988		2.17E-05	8.55E-08	1.84E-05	5.26E-06	5.00E-07	4.60E-05
1989		3.04E-06	1.20E-08	2.58E-06	7.36E-07	6.99E-08	6.43E-06
1990		6.07E-07	2.39E-09	5.15E-07	1.47E-07	1.40E-08	1.29E-06
1991		2.11E-07	8.32E-10	1.79E-07	5.12E-08	4.86E-09	4.47E-07
1992		1.24E-09	4.88E-12	1.05E-09	3.00E-10	2.85E-11	2.62E-09
1993		4.92E-08	1.94E-10	4.17E-08	1.19E-08	1.13E-09	1.04E-07
1994		2.78E-10	1.09E-12	2.35E-10	6.73E-11	6.39E-12	5.88E-10
1995		9.93E-07	3.91E-09	8.43E-07	2.41E-07	2.29E-08	2.10E-06
Totals		1.52E-03	5.99E-06	1.29E-03	3.68E-04	3.50E-05	3.22E-03
Percent		47.22%	0.19%	40.06%	11.45%	1.09%	

Table Cs-134. Population Air-Pathway Doses

	Plume	Ground	Inhalation	Vegetation	Milk	Meat	Total Air Pathway
	(per.-rem)	(per.-rem)	(per.-rem)	(per.-rem)	(per.-rem)	(per.-rem)	(per.-rem)
1954							
1955							
1956							
1957							
1958							
1959							
1960							
1961							
1962							
1963							
1964							
1965							
1966							
1967							
1968							
1969							
1970							
1971		1.07E-02	8.13E-05	3.30E-03	1.42E-03	7.62E-05	1.55E-02
1972		3.26E-03	2.48E-05	1.01E-03	4.34E-04	2.33E-05	4.74E-03
1973							
1974		6.30E-05	4.80E-07	1.95E-05	8.40E-06	4.50E-07	9.18E-05
1975		4.20E-04	3.20E-06	1.30E-04	5.60E-05	3.00E-06	6.12E-04
1976		3.57E-04	2.72E-06	1.11E-04	4.76E-05	2.55E-06	5.20E-04
1977		9.09E-04	6.93E-06	2.81E-04	1.21E-04	6.50E-06	1.33E-03
1978		2.63E-04	2.00E-06	8.13E-05	3.50E-05	1.88E-06	3.83E-04
1979		5.63E-04	4.29E-06	1.74E-04	7.50E-05	4.02E-06	8.20E-04
1980		7.98E-04	6.08E-06	2.47E-04	1.06E-04	5.70E-06	1.16E-03
1981		1.35E-03	1.03E-05	4.17E-04	1.79E-04	9.62E-06	1.96E-03
1982		7.98E-05	6.08E-07	2.47E-05	1.06E-05	5.70E-07	1.16E-04
1983		1.18E-04	8.96E-07	3.64E-05	1.57E-05	8.40E-07	1.71E-04
1984		7.98E-05	6.08E-07	2.47E-05	1.06E-05	5.70E-07	1.16E-04
1985		6.30E-05	4.80E-07	1.95E-05	8.40E-06	4.50E-07	9.18E-05
1986		1.46E-03	1.11E-05	4.51E-04	1.94E-04	1.04E-05	2.12E-03
1987		7.46E-02	5.68E-04	2.31E-02	9.94E-03	5.33E-04	1.09E-01
1988		1.38E-03	1.05E-05	4.28E-04	1.84E-04	9.87E-06	2.01E-03
1989		1.93E-04	1.47E-06	5.98E-05	2.58E-05	1.38E-06	2.82E-04
1990		3.86E-05	2.94E-07	1.20E-05	5.15E-06	2.76E-07	5.63E-05
1991		1.34E-05	1.02E-07	4.16E-06	1.79E-06	9.60E-08	1.96E-05
1992		7.88E-08	6.00E-10	2.44E-08	1.05E-08	5.63E-10	1.15E-07
1993		3.13E-06	2.38E-08	9.69E-07	4.17E-07	2.24E-08	4.56E-06
1994		1.77E-08	1.35E-10	5.47E-09	2.35E-09	1.26E-10	2.57E-08
1995			4.82E-07	1.96E-05	8.43E-06	4.52E-07	2.89E-05
Totals		9.66E-02	7.37E-04	2.99E-02	1.29E-02	6.91E-04	1.41E-01
Percent		68.59%	0.52%	21.24%	9.15%	0.49%	

Table Cs-134. MEI Liquid-Pathway Doses

	Fish	Water	Shore	Swimming	Boating	Total Liquid Pathway
	(mrem)	(mrem)	(mrem)	(mrem)	(mrem)	(mrem)
1954						
1955						
1956						
1957						
1958						
1959						
1960						
1961						
1962						
1963						
1964						
1965						
1966						
1967						
1968						
1969						
1970						
1971						
1972	1.80E-02	2.32E-04	2.68E-04	7.60E-08	8.80E-08	1.85E-02
1973	9.27E-02	1.19E-03	1.38E-03	3.91E-07	4.53E-07	9.53E-02
1974	2.61E-02	3.36E-04	3.89E-04	1.10E-07	1.28E-07	2.68E-02
1975	7.88E-02	1.02E-03	1.17E-03	3.33E-07	3.85E-07	8.09E-02
1976	7.65E-03	9.86E-05	1.14E-04	3.23E-08	3.74E-08	7.86E-03
1977	2.13E-02	2.74E-04	3.17E-04	8.99E-08	1.04E-07	2.19E-02
1978	1.59E-03	2.05E-05	2.37E-05	6.73E-09	7.79E-09	1.64E-03
1979						
1980						
1981						
1982						
1983						
1984						
1985						
1986						
1987						
1988						
1989						
1990						
1991						
1992						
1993						
1994						
1995						
Totals	2.46E-01	3.17E-03	3.66E-03	1.04E-06	1.20E-06	2.53E-01
Percent	97.30%	1.25%	1.45%	0.00%	0.00%	

Table Cs-134. Population Liquid-Pathway Doses

	Aquatic Food	Water	Shore	Swimming	Boating	Total Liquid Pathway
	(per.-rem)	(per.-rem)	(per.-rem)	(per.-rem)	(per.-rem)	(per.-rem)
1954						
1955						
1956						
1957						
1958						
1959						
1960						
1961						
1962						
1963						
1964						
1965						
1966						
1967						
1968						
1969						
1970						
1971						
1972	3.63E-02	6.40E-03	1.12E-03	1.36E-06	4.80E-06	4.38E-02
1973	1.87E-01	3.30E-02	5.77E-03	7.00E-06	2.47E-05	2.26E-01
1974	5.26E-02	9.28E-03	1.62E-03	1.97E-06	6.96E-06	6.35E-02
1975	1.59E-01	2.80E-02	4.90E-03	5.95E-06	2.10E-05	1.92E-01
1976	1.54E-02	2.72E-03	4.76E-04	5.78E-07	2.04E-06	1.86E-02
1977	4.29E-02	7.57E-03	1.32E-03	1.61E-06	5.68E-06	5.18E-02
1978	3.21E-03	5.66E-04	9.91E-05	1.20E-07	4.25E-07	3.88E-03
1979						
1980						
1981						
1982						
1983						
1984						
1985						
1986						
1987						
1988						
1989						
1990						
1991						
1992						
1993						
1994						
1995						
Totals	4.96E-01	8.75E-02	1.53E-02	1.86E-05	6.56E-05	5.99E-01
Percent	82.82%	14.61%	2.56%	0.00%	0.01%	

Table Cs-134 Air. Cs-134 Atmospheric Releases and Maximally Exposed Individual Doses 1954 - 1995

Table Cs-134 Liquid. Cs-134 Liquid Releases and Maximally Exposed Individual Doses 1954 -1995

Cs-137

Half-Life

Cs-137 - 30.2 years

Total Curies Released (1954-1995)

Air - 3.53E+00

Streams - 6.09E+02

Basins (Decay Corrected) - 6.22E+02

Total Cumulative Risks (1954-1995)

MEI Air Pathway - 3.55E-07

MEI Liquid Pathway - 1.38E-04

Population Air - 2.76E-02

Population Liquid - 3.63E-01

Projected 30-year Risks Using Recent Annual Doses (average of years 1991-1995)

MEI Air Pathway - 9.90E-09

MEI Liquid Pathway - 7.88E-07

Population Air - 1.14E-04

Population Liquid - 2.08E-03

Critical Pathways

MEI Air Pathway - Ground = 80%, Vegetation Consumption = 15%

MEI Liquid Pathway - Fish Consumption = 97%, Water Consumption = 1%

Population Air Pathway - Ground = 93%, Vegetation Consumption = 5%

Population Liquid Pathway - Aquatic Food = 76%, Water Consumption = 13%

Discussion

Cs-137 is a medium-lived, very abundant fission product. On a cumulative MEI and population risk basis, Cs-137 was the 1st and 2nd most important liquid pathway radionuclide, respectively. Because of its large bioaccumulation factor in fish (3000 L/kg) Cs-137 accounted for about 67% of the site's cumulative liquid pathway MEI risk and about 20% of the population risk. On a cumulative MEI and population risk basis, Cs-137 was the 10th most important air pathway radionuclide. The projected 30-year MEI liquid pathway risk is estimated to be 7.9E-07, which is the 2nd most important. The projected 30-year MEI air pathway risk is estimated to be 9.9E-09, which is the 6th most important. Estimated residual inventories of Cs-137 ($>3.1\text{E}+05$ Ci) will cause Cs-137 to remain of importance, on a percentage-of-risk basis, in the near-to-distant (0-100 years) future. Refer to Carlton, 1992 for a more complete assessment of Cs-137 at SRS.

Table Cs-137. Effluent Releases

	Cs-137 to Air	Cs-137 to Streams	Cs-137 to Basins	Cs-137-Basin
	Curies	Curies	Curies	Decay Corrected (Ci)
1954		1.80E-01		
1955	1.35E+00	6.72E-01	7.02E-01	2.80E-01
1956	2.39E-01	1.82E+00	1.61E+00	6.58E-01
1957	6.27E-02	4.93E+01	7.90E+02	3.30E+02
1958	2.59E-02	3.22E+00	1.00E+02	4.28E+01
1959	1.38E-01	7.94E+00	3.35E+01	1.47E+01
1960	1.24E-01	3.48E+01	8.80E+00	3.94E+00
1961	4.80E-02	1.90E+01	2.17E+01	9.94E+00
1962	3.70E-02	3.76E+01	6.50E+01	3.05E+01
1963	2.52E-02	9.74E+01	2.57E+01	1.23E+01
1964	6.67E-02	1.09E+02	2.13E+01	1.05E+01
1965	1.77E-02	3.39E+01	2.18E+01	1.09E+01
1966	4.82E-02	3.67E+01	1.69E+01	8.68E+00
1967	1.81E-02	7.89E+01	2.18E+01	1.15E+01
1968	4.03E-02	4.35E+01	2.93E+01	1.58E+01
1969	8.53E-02	2.20E+01	3.14E+01	1.73E+01
1970	4.15E-02	2.13E+01	2.35E+01	1.32E+01
1971	9.33E-03	3.06E+00	8.63E+00	4.97E+00
1972	2.44E-02	1.30E+00	8.84E+00	5.21E+00
1973	2.58E-03	9.17E-01	7.06E+00	4.26E+00
1974	1.32E-03	1.50E+00	7.59E+00	4.69E+00
1975	1.06E-03	7.60E-01	7.29E+00	4.61E+00
1976	1.32E-03	3.03E-01	8.79E+00	5.68E+00
1977	1.86E-03	5.10E-01	6.24E+00	4.13E+00
1978	2.04E-03	2.14E-01	1.03E+01	6.97E+00
1979	5.37E-03	2.12E-01	6.22E+00	4.31E+00
1980	2.63E-03	1.61E-01	1.79E+00	1.27E+00
1981	3.07E-03	2.23E-01	2.65E+00	1.92E+00
1982	9.61E-04	1.61E-01	2.82E+00	2.09E+00
1983	9.94E-04	1.48E-01	3.30E+00	2.51E+00
1984	1.94E-03	2.39E-01	5.90E+00	4.58E+00
1985	5.18E-03	9.90E-02	6.20E+00	4.93E+00
1986	2.95E-03	1.05E-01	1.13E+01	9.19E+00
1987	1.07E+00	3.81E-01	1.53E+01	1.27E+01
1988	1.78E-03	5.64E-01	6.28E+00	5.35E+00
1989	9.56E-04	2.05E-01	7.18E-03	6.26E-03
1990	2.10E-03	4.85E-02	4.89E-05	4.36E-05
1991	3.27E-04	2.64E-02	1.24E-04	1.13E-04
1992	2.50E-04	1.01E-01		
1993	6.34E-04	2.46E-01		
1994	1.58E-04	1.41E-01		
1995	1.50E-02	6.57E-02		
Totals	3.53E+00	6.09E+02	1.34E+03	6.22E+02

Table Cs-137: MEI Air-Pathway Doses

	Plume (mrem)	Ground (mrem)	Inhalation (mrem)	Vegetation (mrem)	Milk (mrem)	Meat (mrem)	Total Air Pathway (mrem)
1954							
1955		1.49E-01	1.19E-04	2.84E-02	8.64E-03	8.24E-04	1.86E-01
1956		2.63E-02	2.10E-05	5.02E-03	1.53E-03	1.46E-04	3.30E-02
1957		6.90E-03	5.52E-06	1.32E-03	4.01E-04	3.82E-05	8.66E-03
1958		2.85E-03	2.28E-06	5.44E-04	1.66E-04	1.58E-05	3.58E-03
1959		1.52E-02	1.21E-05	2.90E-03	8.83E-04	8.42E-05	1.91E-02
1960		1.36E-02	1.09E-05	2.60E-03	7.94E-04	7.56E-05	1.71E-02
1961		5.28E-03	4.22E-06	1.01E-03	3.07E-04	2.93E-05	6.63E-03
1962		4.07E-03	3.26E-06	7.77E-04	2.37E-04	2.26E-05	5.11E-03
1963		2.77E-03	2.22E-06	5.29E-04	1.61E-04	1.54E-05	3.48E-03
1964		7.34E-03	5.87E-06	1.40E-03	4.27E-04	4.07E-05	9.21E-03
1965		1.95E-03	1.56E-06	3.72E-04	1.13E-04	1.08E-05	2.44E-03
1966		5.30E-03	4.24E-06	1.01E-03	3.08E-04	2.94E-05	6.66E-03
1967		1.99E-03	1.59E-06	3.80E-04	1.16E-04	1.10E-05	2.50E-03
1968		4.43E-03	3.55E-06	8.46E-04	2.58E-04	2.46E-05	5.57E-03
1969		9.38E-03	7.51E-06	1.79E-03	5.46E-04	5.20E-05	1.18E-02
1970		4.57E-03	3.65E-06	8.72E-04	2.66E-04	2.53E-05	5.73E-03
1971		1.03E-03	8.21E-07	1.96E-04	5.97E-05	5.69E-06	1.29E-03
1972		2.68E-03	2.15E-06	5.12E-04	1.56E-04	1.49E-05	3.37E-03
1973		2.84E-04	2.27E-07	5.42E-05	1.65E-05	1.57E-06	3.56E-04
1974		1.45E-04	1.16E-07	2.77E-05	8.45E-06	8.05E-07	1.82E-04
1975		1.17E-04	9.33E-08	2.23E-05	6.78E-06	6.47E-07	1.46E-04
1976		1.45E-04	1.16E-07	2.77E-05	8.45E-06	8.05E-07	1.82E-04
1977		2.05E-04	1.64E-07	3.91E-05	1.19E-05	1.13E-06	2.57E-04
1978		2.24E-04	1.80E-07	4.28E-05	1.31E-05	1.24E-06	2.82E-04
1979		5.91E-04	4.73E-07	1.13E-04	3.44E-05	3.28E-06	7.42E-04
1980		2.89E-04	2.31E-07	5.52E-05	1.68E-05	1.60E-06	3.63E-04
1981		3.38E-04	2.70E-07	6.45E-05	1.96E-05	1.87E-06	4.24E-04
1982		1.06E-04	8.46E-08	2.02E-05	6.15E-06	5.86E-07	1.33E-04
1983		1.09E-04	8.75E-08	2.09E-05	6.36E-06	6.06E-07	1.37E-04
1984		2.13E-04	1.71E-07	4.07E-05	1.24E-05	1.18E-06	2.68E-04
1985		5.70E-04	4.56E-07	1.09E-04	3.32E-05	3.16E-06	7.15E-04
1986		3.25E-04	2.60E-07	6.20E-05	1.89E-05	1.80E-06	4.07E-04
1987		1.18E-01	9.42E-05	2.25E-02	6.85E-03	6.53E-04	1.48E-01
1988		1.96E-04	1.57E-07	3.74E-05	1.14E-05	1.09E-06	2.46E-04
1989		1.05E-04	8.41E-08	2.01E-05	6.12E-06	5.83E-07	1.32E-04
1990		2.31E-04	1.85E-07	4.41E-05	1.34E-05	1.28E-06	2.90E-04
1991		3.60E-05	2.88E-08	6.87E-06	2.09E-06	1.99E-07	4.52E-05
1992		2.75E-05	2.20E-08	5.25E-06	1.60E-06	1.53E-07	3.45E-05
1993		6.97E-05	5.58E-08	1.33E-05	4.06E-06	3.87E-07	8.76E-05
1994		1.74E-05	1.39E-08	3.32E-06	1.01E-06	9.64E-08	2.18E-05
1995		1.65E-03	1.32E-06	3.15E-04	9.60E-05	9.15E-06	2.07E-03
Totals		3.88E-01	3.10E-04	7.40E-02	2.26E-02	2.15E-03	4.87E-01
Percent		79.65%	0.06%	15.21%	4.63%	0.44%	

Table Cs-137. Population Air-Pathway Doses

	Plume	Ground	Inhalation	Vegetation	Milk	Meat	Total Air Pathway
	(per.-rem)	(per.-rem)	(per.-rem)	(per.-rem)	(per.-rem)	(per.-rem)	(per.-rem)
1954							
1955		1.35E+01	1.49E-02	6.75E-01	3.11E-01	1.76E-02	1.45E+01
1956		2.39E+00	2.63E-03	1.20E-01	5.50E-02	3.11E-03	2.57E+00
1957		6.27E-01	6.90E-04	3.14E-02	1.44E-02	8.15E-04	6.74E-01
1958		2.59E-01	2.85E-04	1.30E-02	5.96E-03	3.37E-04	2.79E-01
1959		1.38E+00	1.52E-03	6.90E-02	3.17E-02	1.79E-03	1.48E+00
1960		1.24E+00	1.36E-03	6.20E-02	2.85E-02	1.61E-03	1.33E+00
1961		4.80E-01	5.28E-04	2.40E-02	1.10E-02	6.24E-04	5.16E-01
1962		3.70E-01	4.07E-04	1.85E-02	8.51E-03	4.81E-04	3.98E-01
1963		2.52E-01	2.77E-04	1.26E-02	5.80E-03	3.28E-04	2.71E-01
1964		6.67E-01	7.34E-04	3.34E-02	1.53E-02	8.67E-04	7.17E-01
1965		1.77E-01	1.95E-04	8.85E-03	4.07E-03	2.30E-04	1.90E-01
1966		4.82E-01	5.30E-04	2.41E-02	1.11E-02	6.27E-04	5.18E-01
1967		1.81E-01	1.99E-04	9.05E-03	4.16E-03	2.35E-04	1.95E-01
1968		4.03E-01	4.43E-04	2.02E-02	9.27E-03	5.24E-04	4.33E-01
1969		8.53E-01	9.38E-04	4.27E-02	1.96E-02	1.11E-03	9.17E-01
1970		4.15E-01	4.57E-04	2.08E-02	9.55E-03	5.40E-04	4.46E-01
1971		9.33E-02	1.03E-04	4.67E-03	2.15E-03	1.21E-04	1.00E-01
1972		2.44E-01	2.68E-04	1.22E-02	5.61E-03	3.17E-04	2.62E-01
1973		2.58E-02	2.84E-05	1.29E-03	5.93E-04	3.35E-05	2.77E-02
1974		1.32E-02	1.45E-05	6.60E-04	3.04E-04	1.72E-05	1.42E-02
1975		1.06E-02	1.17E-05	5.30E-04	2.44E-04	1.38E-05	1.14E-02
1976		1.32E-02	1.45E-05	6.60E-04	3.04E-04	1.72E-05	1.42E-02
1977		1.86E-02	2.05E-05	9.30E-04	4.28E-04	2.42E-05	2.00E-02
1978		2.04E-02	2.24E-05	1.02E-03	4.69E-04	2.65E-05	2.19E-02
1979		5.37E-02	5.91E-05	2.69E-03	1.24E-03	6.98E-05	5.77E-02
1980		2.63E-02	2.89E-05	1.32E-03	6.05E-04	3.42E-05	2.83E-02
1981		3.07E-02	3.38E-05	1.54E-03	7.06E-04	3.99E-05	3.30E-02
1982		9.61E-03	1.06E-05	4.81E-04	2.21E-04	1.25E-05	1.03E-02
1983		9.94E-03	1.09E-05	4.97E-04	2.29E-04	1.29E-05	1.07E-02
1984		1.94E-02	2.13E-05	9.70E-04	4.46E-04	2.52E-05	2.09E-02
1985		5.18E-02	5.70E-05	2.59E-03	1.19E-03	6.73E-05	5.57E-02
1986		2.95E-02	3.25E-05	1.48E-03	6.79E-04	3.84E-05	3.17E-02
1987		1.07E+01	1.18E-02	5.35E-01	2.46E-01	1.39E-02	1.15E+01
1988		1.78E-02	1.96E-05	8.90E-04	4.09E-04	2.31E-05	1.91E-02
1989		9.56E-03	1.05E-05	4.78E-04	2.20E-04	1.24E-05	1.03E-02
1990		2.10E-02	2.31E-05	1.05E-03	4.83E-04	2.73E-05	2.26E-02
1991		3.27E-03	3.60E-06	1.64E-04	7.52E-05	4.25E-06	3.52E-03
1992		2.50E-03	2.75E-06	1.25E-04	5.75E-05	3.25E-06	2.69E-03
1993		6.34E-03	6.97E-06	3.17E-04	1.46E-04	8.24E-06	6.82E-03
1994		1.58E-03	1.74E-06	7.90E-05	3.63E-05	2.05E-06	1.70E-03
1995		1.50E-01	1.65E-04	7.50E-03	3.45E-03	1.95E-04	1.13E-02
Totals		3.51E+01	3.88E-02	1.76E+00	8.11E-01	4.58E-02	3.78E+01
Percent		92.96%	0.10%	4.67%	2.15%	0.12%	

Table Cs-137. MEI Liquid-Pathway Doses

	Fish	Water	Shore	Swimming	Boating	Total Liquid Pathway
	(mrem)	(mrem)	(mrem)	(mrem)	(mrem)	(mrem)
1954	5.40E-02	7.02E-04	3.78E-04	1.21E-07	1.42E-07	5.58E-02
1955	2.02E-01	2.62E-03	1.41E-03	4.50E-07	5.31E-07	2.08E-01
1956	5.46E-01	7.10E-03	3.82E-03	1.22E-06	1.44E-06	5.64E-01
1957	1.48E+01	1.92E-01	1.04E-01	3.30E-05	3.89E-05	1.53E+01
1958	9.66E-01	1.26E-02	6.76E-03	2.16E-06	2.54E-06	9.98E-01
1959	2.38E+00	3.10E-02	1.67E-02	5.32E-06	6.27E-06	2.46E+00
1960	1.04E+01	1.36E-01	7.31E-02	2.33E-05	2.75E-05	1.08E+01
1961	5.70E+00	7.41E-02	3.99E-02	1.27E-05	1.50E-05	5.89E+00
1962	1.13E+01	1.47E-01	7.90E-02	2.52E-05	2.97E-05	1.17E+01
1963	2.92E+01	3.80E-01	2.05E-01	6.53E-05	7.69E-05	3.02E+01
1964	3.27E+01	4.25E-01	2.29E-01	7.30E-05	8.61E-05	3.38E+01
1965	1.02E+01	1.32E-01	7.12E-02	2.27E-05	2.68E-05	1.05E+01
1966	1.10E+01	1.43E-01	7.71E-02	2.46E-05	2.90E-05	1.14E+01
1967	2.37E+01	3.08E-01	1.66E-01	5.29E-05	6.23E-05	2.45E+01
1968	1.31E+01	1.70E-01	9.14E-02	2.91E-05	3.44E-05	1.35E+01
1969	6.60E+00	8.58E-02	4.62E-02	1.47E-05	1.74E-05	6.82E+00
1970	6.39E+00	8.31E-02	4.47E-02	1.43E-05	1.68E-05	6.60E+00
1971	9.18E-01	1.19E-02	6.43E-03	2.05E-06	2.42E-06	9.49E-01
1972	3.90E-01	5.07E-03	2.73E-03	8.71E-07	1.03E-06	4.03E-01
1973	2.75E-01	3.58E-03	1.93E-03	6.14E-07	7.24E-07	2.84E-01
1974	4.50E-01	5.85E-03	3.15E-03	1.01E-06	1.19E-06	4.65E-01
1975	2.28E-01	2.96E-03	1.60E-03	5.09E-07	6.00E-07	2.36E-01
1976	9.09E-02	1.18E-03	6.36E-04	2.03E-07	2.39E-07	9.39E-02
1977	1.53E-01	1.99E-03	1.07E-03	3.42E-07	4.03E-07	1.58E-01
1978	6.42E-02	8.35E-04	4.49E-04	1.43E-07	1.69E-07	6.63E-02
1979	6.36E-02	8.27E-04	4.45E-04	1.42E-07	1.67E-07	6.57E-02
1980	4.83E-02	6.28E-04	3.38E-04	1.08E-07	1.27E-07	4.99E-02
1981	6.69E-02	8.70E-04	4.68E-04	1.49E-07	1.76E-07	6.91E-02
1982	4.83E-02	6.28E-04	3.38E-04	1.08E-07	1.27E-07	4.99E-02
1983	4.44E-02	5.77E-04	3.11E-04	9.92E-08	1.17E-07	4.59E-02
1984	7.17E-02	9.32E-04	5.02E-04	1.60E-07	1.89E-07	7.41E-02
1985	2.97E-02	3.86E-04	2.08E-04	6.63E-08	7.82E-08	3.07E-02
1986	3.15E-02	4.10E-04	2.21E-04	7.04E-08	8.30E-08	3.26E-02
1987	1.14E-01	1.49E-03	8.00E-04	2.55E-07	3.01E-07	1.18E-01
1988	1.69E-01	2.20E-03	1.18E-03	3.78E-07	4.46E-07	1.75E-01
1989	6.15E-02	8.00E-04	4.31E-04	1.37E-07	1.62E-07	6.36E-02
1990	1.46E-02	1.89E-04	1.02E-04	3.25E-08	3.83E-08	1.50E-02
1991	7.92E-03	1.03E-04	5.54E-05	1.77E-08	2.09E-08	8.18E-03
1992	3.03E-02	3.94E-04	2.12E-04	6.77E-08	7.98E-08	3.13E-02
1993	7.38E-02	9.59E-04	5.17E-04	1.65E-07	1.94E-07	7.63E-02
1994	4.23E-02	5.50E-04	2.96E-04	9.45E-08	1.11E-07	4.37E-02
1995	1.97E-02	2.56E-04	1.38E-04	4.40E-08	5.19E-08	2.04E-02
Totals	1.83E+02	2.37E+00	1.28E+00	4.08E-04	4.81E-04	1.89E+02
Percent	96.77%	1.26%	0.68%	0.00%	0.00%	

Table Cs-137. Population Liquid-Pathway Doses

	Aquatic Food	Water	Shore	Swimming	Boating	Total Liquid Pathway
	(per.-rem)	(per.-rem)	(per.-rem)	(per.-rem)	(per.-rem)	(per.-rem)
1954	1.11E-01	1.98E-02	1.60E-02	2.16E-06	7.56E-06	1.47E-01
1955	4.15E-01	7.39E-02	5.98E-02	8.06E-06	2.82E-05	5.49E-01
1956	1.12E+00	2.00E-01	1.62E-01	2.18E-05	7.64E-05	1.49E+00
1957	3.05E+01	5.42E+00	4.39E+00	5.92E-04	2.07E-03	4.03E+01
1958	1.99E+00	3.54E-01	2.87E-01	3.86E-05	1.35E-04	2.63E+00
1959	4.91E+00	8.73E-01	7.07E-01	9.53E-05	3.33E-04	6.49E+00
1960	2.15E+01	3.83E+00	3.10E+00	4.18E-04	1.46E-03	2.84E+01
1961	1.17E+01	2.09E+00	1.69E+00	2.28E-04	7.98E-04	1.55E+01
1962	2.32E+01	4.14E+00	3.35E+00	4.51E-04	1.58E-03	3.07E+01
1963	6.02E+01	1.07E+01	8.67E+00	1.17E-03	4.09E-03	7.96E+01
1964	6.74E+01	1.20E+01	9.70E+00	1.31E-03	4.58E-03	8.91E+01
1965	2.10E+01	3.73E+00	3.02E+00	4.07E-04	1.42E-03	2.77E+01
1966	2.27E+01	4.04E+00	3.27E+00	4.40E-04	1.54E-03	3.00E+01
1967	4.88E+01	8.68E+00	7.02E+00	9.47E-04	3.31E-03	6.45E+01
1968	2.69E+01	4.79E+00	3.87E+00	5.22E-04	1.83E-03	3.55E+01
1969	1.36E+01	2.42E+00	1.96E+00	2.64E-04	9.24E-04	1.80E+01
1970	1.32E+01	2.34E+00	1.90E+00	2.56E-04	8.95E-04	1.74E+01
1971	1.89E+00	3.37E-01	2.72E-01	3.67E-05	1.29E-04	2.50E+00
1972	8.03E-01	1.43E-01	1.16E-01	1.56E-05	5.46E-05	1.06E+00
1973	5.67E-01	1.01E-01	8.16E-02	1.10E-05	3.85E-05	7.49E-01
1974	9.27E-01	1.65E-01	1.34E-01	1.80E-05	6.30E-05	1.23E+00
1975	4.70E-01	8.36E-02	6.76E-02	9.12E-06	3.19E-05	6.21E-01
1976	1.87E-01	3.33E-02	2.70E-02	3.64E-06	1.27E-05	2.48E-01
1977	3.15E-01	5.61E-02	4.54E-02	6.12E-06	2.14E-05	4.17E-01
1978	1.32E-01	2.35E-02	1.90E-02	2.57E-06	8.99E-06	1.75E-01
1979	1.31E-01	2.33E-02	1.89E-02	2.54E-06	8.90E-06	1.73E-01
1980	9.95E-02	1.77E-02	1.43E-02	1.93E-06	6.76E-06	1.32E-01
1981	1.38E-01	2.45E-02	1.98E-02	2.68E-06	9.37E-06	1.82E-01
1982	9.95E-02	1.77E-02	1.43E-02	1.93E-06	6.76E-06	1.32E-01
1983	9.15E-02	1.63E-02	1.32E-02	1.78E-06	6.22E-06	1.21E-01
1984	1.48E-01	2.63E-02	2.13E-02	2.87E-06	1.00E-05	1.95E-01
1985	6.12E-02	1.09E-02	8.81E-03	1.19E-06	4.16E-06	8.09E-02
1986	6.49E-02	1.16E-02	9.35E-03	1.26E-06	4.41E-06	8.58E-02
1987	2.35E-01	4.19E-02	3.39E-02	4.57E-06	1.60E-05	3.11E-01
1988	3.49E-01	6.20E-02	5.02E-02	6.77E-06	2.37E-05	4.61E-01
1989	1.27E-01	2.26E-02	1.82E-02	2.46E-06	8.61E-06	1.67E-01
1990	3.00E-02	5.34E-03	4.32E-03	5.82E-07	2.04E-06	3.96E-02
1991	1.63E-02	2.90E-03	2.35E-03	3.17E-07	1.11E-06	2.16E-02
1992	6.24E-02	1.11E-02	8.99E-03	1.21E-06	4.24E-06	8.25E-02
1993	1.52E-01	2.71E-02	2.19E-02	2.95E-06	1.03E-05	2.01E-01
1994	8.71E-02	1.55E-02	1.25E-02	1.69E-06	5.92E-06	1.15E-01
1995	4.06E-02	7.23E-03	5.85E-03	7.88E-07	2.76E-06	5.37E-02
Totals	3.76E+02	6.70E+01	5.42E+01	7.31E-03	2.56E-02	4.98E+02
Percent	75.64%	13.46%	10.89%	0.00%	0.01%	

Table Cs-137 Air. Cs-137 Atmospheric Releases and Maximally Exposed Individual Doses 1954 - 1995

Table Cs-137 Liquid. Cs-137 Liquid Releases and Maximally Exposed Individual Doses 1954 - 1995

Eu-154/155

Half-Life

Eu-154 - 8.59 years

Eu-155 - 4.71 years

Total Curies Released (1954-1995)

Air - 6.57E-05

Streams - 0.0

Basins (Decay Corrected) - 0.0

Total Cumulative Risks (1954-1995)

MEI Air Pathway - 5.00E-12

MEI Liquid Pathway - 0.0

Population Air - 4.80E-13

Population Liquid - 0.0

Projected 30-year Risks Using Recent Annual Doses (average of years 1991-1995)

MEI Air Pathway - 3.24E-07

MEI Liquid Pathway - 0.0

Population Air - 7.85E-10

Population Liquid - 0.0

Critical Pathways

MEI Air Pathway - Ground = 95%, Vegetation Consumption = 3%

MEI Liquid Pathway - N/A

Population Air Pathway - Ground = 97%, Vegetation Consumption = 1%

Population Liquid Pathway - N/A

Discussion

Eu-154/155 are medium-lived fission products that were measured only in air effluents during two years. On a cumulative MEI and population risk basis, Eu-154/155 were the 20th and 22nd most important air pathway radionuclides, respectively. The cumulative and projected 30-year MEI air pathway risk is estimated to be much less than 1.0E-06 and is much less than 1% of the site total. However, estimated residual inventories (>3.7E+04 Ci) may cause Eu-154/155 to assume greater importance, on a percentage-of-risk basis, in the near (0-30 years) future.

Table Eu-154/155. Effluent Releases

	Eu-154,155	Eu-154,155	Eu-154,155	Eu-154,155-Basin
	Air (Curies)	Streams (Curies)	Basins (Curies)	Decay Corrected (Ci)
1954				
1955				
1956				
1957				
1958				
1959				
1960				
1961				
1962				
1963				
1964				
1965				
1966				
1967				
1968				
1969				
1970				
1971				
1972				
1973				
1974				
1975				
1976				
1977				
1978				
1979				
1980				
1981				
1982				
1983				
1984				
1985				
1986				
1987				
1988				
1989				
1990	6.46E-05			
1991				
1992				
1993				
1994				
1995	1.05E-06			
Totals	6.57E-05			

Table Eu-154/155. MEI Air-Pathway Doses

	Plume	Ground	Inhalation	Vegetation	Milk	Meat	Total Air Pathway
	(mrem)	(mrem)	(mrem)	(mrem)	(mrem)	(mrem)	(mrem)
1954							
1955							
1956							
1957							
1958							
1959							
1960							
1961							
1962							
1963							
1964							
1965							
1966							
1967							
1968							
1969							
1970							
1971							
1972							
1973							
1974							
1975							
1976							
1977							
1978							
1979							
1980							
1981							
1982							
1983							
1984							
1985							
1986							
1987							
1988							
1989							
1990		6.46E-06	4.65E-08	2.26E-07	2.84E-11	3.55E-09	6.74E-06
1991							
1992							
1993							
1994							
1995		1.05E-07	7.57E-10	3.68E-09	4.63E-13	5.79E-11	1.10E-07
Totals		6.57E-06	4.73E-08	2.30E-07	2.89E-11	3.61E-09	6.85E-06
Percent		95.90%	0.69%	3.36%	0.00%	0.05%	

Table Eu-154/155. Population Air-Pathway Doses

	Plume	Ground	Inhalation	Vegetation	Milk	Meat	Total Air Pathway
	(per.-rem)	(per.-rem)	(per.-rem)	(per.-rem)	(per.-rem)	(per.-rem)	(per.-rem)
1954							
1955							
1956							
1957							
1958							
1959							
1960							
1961							
1962							
1963							
1964							
1965							
1966							
1967							
1968							
1969							
1970							
1971							
1972							
1973							
1974							
1975							
1976							
1977							
1978							
1979							
1980							
1981							
1982							
1983							
1984							
1985							
1986							
1987							
1988							
1989							
1990		4.33E-04	5.56E-06	5.30E-06	9.69E-10	1.55E-07	4.44E-04
1991							
1992							
1993							
1994							
1995			9.05E-08	8.63E-08	1.58E-11	2.52E-09	1.79E-07
Totals		4.33E-04	5.65E-06	5.38E-06	9.85E-10	1.58E-07	4.44E-04
Percent		97.48%	1.27%	1.21%	0.00%	0.04%	

Table Eu-154/155 Air. Eu-154/155 Atmospheric Releases and Maximally Exposed Individual Doses 1954 - 1995

H-3

Half-Life

H-3 - 12.3 years

Total Curies Released (1954-1995)

Air - $2.56\text{E}+07$

Streams - $1.62\text{E}+06$

Basins (Decay Corrected) - $4.10\text{E}+05$

Total Cumulative Risks (1954-1995)

MEI Air Pathway - $1.07\text{E}-05$

MEI Liquid Pathway - $5.92\text{E}-06$

Population Air - $9.18\text{E}-01$

Population Liquid - $1.67\text{E}-01$

Projected 30-year Risks Using Recent Annual Doses (average of years 1991-1995)

MEI Air Pathway - $1.41\text{E}-06$

MEI Liquid Pathway - $1.67\text{E}-06$

Population Air - $1.21\text{E}-01$

Population Liquid - $4.71\text{E}-02$

Critical Pathways

MEI Air Pathway - Inhalation = 48%, Vegetation Consumption = 33%

MEI Liquid Pathway - Water Consumption = 98%, Fish Consumption = 2%

Population Air Pathway - Inhalation = 75%, Vegetation Consumption = 14%

Population Liquid Pathway - Water Consumption = 99%, Aquatic Food = 1%

Discussion

H-3 is a medium-lived, very abundant activation and ternary fission product. On a cumulative MEI and population risk basis, H-3 was the 5th and 3rd most important liquid pathway radionuclide, respectively. On a cumulative MEI and population risk basis, H-3 was the 2nd and 1st most important air pathway radionuclide, respectively. Based on effluent releases during the past 5-years, the projected 30-year MEI liquid pathway risk is estimated to be $1.7\text{E}-06$, which is the 1st most important. The projected 30-year MEI air pathway risk is estimated to be $1.4\text{E}-06$, which also is the 1st most important. Estimated residual inventories ($>7.0\text{E}+06$ Ci) will cause H-3 to remain of importance, on a percentage-of-risk basis, in the near-to-distant (0-100 years) future. Refer to Murphy, 1994 for a more complete assessment of H-3 at SRS.

Table H-3. Effluent Releases

	Total H-3 to Air	HTO to Air	H-3 to Streams	H-3 to Basins	H-3 to Basins
	(Curies)	(Curies)	(Curies)	(Curies)	Decay Corrected (Ci)
1954		Not Available	3.66E+02		
1955	3.61E+04	Not Available	5.87E+03		
1956	4.69E+05	Not Available	9.39E+03		
1957	1.20E+06	Not Available	1.50E+04	9.18E+03	1.08E+03
1958	2.36E+06	Not Available	2.44E+04	6.44E+03	8.01E+02
1959	1.05E+06	Not Available	4.20E+04	1.40E+04	1.84E+03
1960	9.51E+05	Not Available	4.85E+04	1.77E+04	2.46E+03
1961	8.86E+05	Not Available	5.58E+04	3.39E+04	4.99E+03
1962	1.11E+06	Not Available	4.84E+04	3.48E+04	5.42E+03
1963	1.13E+06	Not Available	7.74E+04	2.92E+04	4.81E+03
1964	1.52E+06	Not Available	8.54E+04	4.46E+04	7.78E+03
1965	7.44E+05	Not Available	1.04E+05	4.53E+04	8.36E+03
1966	6.75E+05	Not Available	8.19E+04	8.37E+04	1.63E+04
1967	6.89E+05	Not Available	6.96E+04	6.01E+04	1.24E+04
1968	7.62E+05	Not Available	6.16E+04	6.91E+04	1.51E+04
1969	4.96E+05	Not Available	6.42E+04	4.72E+04	1.09E+04
1970	5.13E+05	Not Available	3.68E+04	5.78E+04	1.41E+04
1971	6.21E+05	Not Available	3.80E+04	3.62E+04	9.36E+03
1972	8.22E+05	Not Available	4.60E+04	4.70E+04	1.29E+04
1973	6.01E+05	Not Available	7.08E+04	6.57E+04	1.90E+04
1974	9.37E+05	Not Available	6.00E+04	3.65E+04	1.12E+04
1975	5.18E+05	Not Available	5.56E+04	3.56E+04	1.15E+04
1976	3.04E+05	Not Available	5.96E+04	5.85E+04	2.01E+04
1977	3.81E+05	Not Available	4.38E+04	2.76E+04	1.00E+04
1978	3.60E+05	Not Available	3.76E+04	2.99E+04	1.15E+04
1979	3.33E+05	Not Available	2.94E+04	4.31E+04	1.75E+04
1980	3.17E+05	Not Available	2.47E+04	3.55E+04	1.52E+04
1981	3.95E+05	Not Available	2.38E+04	4.16E+04	1.89E+04
1982	4.34E+05	Not Available	3.25E+04	2.90E+04	1.39E+04
1983	6.18E+05	Not Available	3.40E+04	3.73E+04	1.90E+04
1984	7.86E+05	Not Available	3.28E+04	3.63E+04	1.95E+04
1985	6.74E+05	4.90E+05	2.50E+04	4.00E+04	2.28E+04
1986	4.23E+05	2.85E+05	2.78E+04	5.17E+04	3.11E+04
1987	5.97E+05	2.70E+05	2.26E+04	3.40E+04	2.17E+04
1988	4.66E+05	2.88E+05	1.93E+04	1.37E+04	9.24E+03
1989	3.25E+05	2.18E+05	1.75E+04	1.22E+04	8.70E+03
1990	2.52E+05	1.75E+05	1.54E+04	2.97E+02	2.24E+02
1991	2.00E+05	1.37E+05	2.74E+04	3.31E+02	2.64E+02
1992	1.56E+05	1.00E+05	1.38E+04	1.50E+02	1.27E+02
1993	1.91E+05	1.33E+05	1.27E+04	8.05E+01	7.19E+01
1994	1.60E+05	1.07E+05	1.09E+04		
1995	9.67E+04	5.50E+04	1.14E+04		
Totals	2.56E+07	2.26E+06	1.62E+06	1.27E+06	4.10E+05

Table H-3. MEI Air-Pathway Doses

	Plume	Ground	Inhalation	Vegetation	Milk	Meat	Total Air Pathway
	(mrem)	(mrem)	(mrem)	(mrem)	(mrem)	(mrem)	(mrem)
1954							
1955			1.05E-02	7.22E-03	2.92E-03	1.23E-03	2.18E-02
1956			1.36E-01	9.38E-02	3.80E-02	1.59E-02	2.84E-01
1957			3.48E-01	2.40E-01	9.72E-02	4.08E-02	7.26E-01
1958			6.84E-01	4.72E-01	1.91E-01	8.02E-02	1.43E+00
1959			3.05E-01	2.10E-01	8.51E-02	3.57E-02	6.35E-01
1960			2.76E-01	1.90E-01	7.70E-02	3.23E-02	5.75E-01
1961			2.57E-01	1.77E-01	7.18E-02	3.01E-02	5.36E-01
1962			3.22E-01	2.22E-01	8.99E-02	3.77E-02	6.72E-01
1963			3.28E-01	2.26E-01	9.15E-02	3.84E-02	6.84E-01
1964			4.41E-01	3.04E-01	1.23E-01	5.17E-02	9.20E-01
1965			2.16E-01	1.49E-01	6.03E-02	2.53E-02	4.50E-01
1966			1.96E-01	1.35E-01	5.47E-02	2.30E-02	4.08E-01
1967			2.00E-01	1.38E-01	5.58E-02	2.34E-02	4.17E-01
1968			2.21E-01	1.52E-01	6.17E-02	2.59E-02	4.61E-01
1969			1.44E-01	9.92E-02	4.02E-02	1.69E-02	3.00E-01
1970			1.49E-01	1.03E-01	4.16E-02	1.74E-02	3.10E-01
1971			1.80E-01	1.24E-01	5.03E-02	2.11E-02	3.76E-01
1972			2.38E-01	1.64E-01	6.66E-02	2.79E-02	4.97E-01
1973			1.74E-01	1.20E-01	4.87E-02	2.04E-02	3.64E-01
1974			2.72E-01	1.87E-01	7.59E-02	3.19E-02	5.67E-01
1975			1.50E-01	1.04E-01	4.20E-02	1.76E-02	3.13E-01
1976			8.82E-02	6.08E-02	2.46E-02	1.03E-02	1.84E-01
1977			1.10E-01	7.62E-02	3.09E-02	1.30E-02	2.31E-01
1978			1.04E-01	7.20E-02	2.92E-02	1.22E-02	2.18E-01
1979			9.66E-02	6.66E-02	2.70E-02	1.13E-02	2.01E-01
1980			9.19E-02	6.34E-02	2.57E-02	1.08E-02	1.92E-01
1981			1.15E-01	7.90E-02	3.20E-02	1.34E-02	2.39E-01
1982			1.26E-01	8.68E-02	3.52E-02	1.48E-02	2.63E-01
1983			1.79E-01	1.24E-01	5.01E-02	2.10E-02	3.74E-01
1984			2.28E-01	1.57E-01	6.37E-02	2.67E-02	4.76E-01
1985			1.42E-01	9.80E-02	3.97E-02	1.67E-02	2.96E-01
1986			8.27E-02	5.70E-02	2.31E-02	9.69E-03	1.72E-01
1987			7.83E-02	5.40E-02	2.19E-02	9.18E-03	1.63E-01
1988			8.35E-02	5.76E-02	2.33E-02	9.79E-03	1.74E-01
1989			6.32E-02	4.36E-02	1.77E-02	7.41E-03	1.32E-01
1990			5.08E-02	3.50E-02	1.42E-02	5.95E-03	1.06E-01
1991			3.97E-02	2.74E-02	1.11E-02	4.66E-03	8.29E-02
1992			2.90E-02	2.00E-02	8.10E-03	3.40E-03	6.05E-02
1993			3.86E-02	2.66E-02	1.08E-02	4.52E-03	8.05E-02
1994			3.10E-02	2.14E-02	8.67E-03	3.64E-03	6.47E-02
1995			1.60E-02	1.10E-02	4.46E-03	1.87E-03	3.33E-02
Totals			7.04E+00	4.86E+00	1.97E+00	8.25E-01	1.47E+01
Percent			47.93%	33.06%	13.39%	5.62%	

Table H-3. Population Air-Pathway Doses

	Plume	Ground	Inhalation	Vegetation	Milk	Meat	Total Air Pathway
	(per.-rem)	(per.-rem)	(per.-rem)	(per.-rem)	(per.-rem)	(per.-rem)	(per.-rem)
1954							
1955			.141E+00	2.71E-01	1.52E-01	3.97E-02	1.87E+00
1956			1.83E+01	3.52E+00	1.97E+00	5.16E-01	2.43E+01
1957			4.68E+01	9.00E+00	5.04E+00	1.32E+00	6.22E+01
1958			9.20E+01	1.77E+01	9.91E+00	2.60E+00	1.22E+02
1959			4.10E+01	7.88E+00	4.41E+00	1.16E+00	5.44E+01
1960			3.71E+01	7.13E+00	3.99E+00	1.05E+00	4.93E+01
1961			3.46E+01	6.65E+00	3.72E+00	9.75E-01	4.59E+01
1962			4.33E+01	8.33E+00	4.66E+00	1.22E+00	5.75E+01
1963			4.41E+01	8.48E+00	4.75E+00	1.24E+00	5.85E+01
1964			5.93E+01	1.14E+01	6.38E+00	1.67E+00	7.87E+01
1965			2.90E+01	5.58E+00	3.12E+00	8.18E-01	3.85E+01
1966			2.63E+01	5.06E+00	2.84E+00	7.43E-01	3.50E+01
1967			2.69E+01	5.17E+00	2.89E+00	7.58E-01	3.57E+01
1968			2.97E+01	5.72E+00	3.20E+00	8.38E-01	3.95E+01
1969			1.93E+01	3.72E+00	2.08E+00	5.46E-01	2.57E+01
1970			2.00E+01	3.85E+00	2.15E+00	5.64E-01	2.66E+01
1971			2.42E+01	4.66E+00	2.61E+00	6.83E-01	3.22E+01
1972			3.21E+01	6.17E+00	3.45E+00	9.04E-01	4.26E+01
1973			2.34E+01	4.51E+00	2.52E+00	6.61E-01	3.11E+01
1974			3.65E+01	7.03E+00	3.94E+00	1.03E+00	4.85E+01
1975			2.02E+01	3.89E+00	2.18E+00	5.70E-01	2.68E+01
1976			1.19E+01	2.28E+00	1.28E+00	3.34E-01	1.57E+01
1977			1.49E+01	2.86E+00	1.60E+00	4.19E-01	1.97E+01
1978			1.40E+01	2.70E+00	1.51E+00	3.96E-01	1.86E+01
1979			1.30E+01	2.50E+00	1.40E+00	3.66E-01	1.72E+01
1980			1.24E+01	2.38E+00	1.33E+00	3.49E-01	1.64E+01
1981			1.54E+01	2.96E+00	1.66E+00	4.35E-01	2.05E+01
1982			1.69E+01	3.26E+00	1.82E+00	4.77E-01	2.25E+01
1983			2.41E+01	4.64E+00	2.60E+00	6.80E-01	3.20E+01
1984			3.07E+01	5.90E+00	3.30E+00	8.65E-01	4.07E+01
1985			1.91E+01	3.68E+00	2.06E+00	5.39E-01	2.54E+01
1986			1.11E+01	2.14E+00	1.20E+00	3.14E-01	1.48E+01
1987			1.05E+01	2.03E+00	1.13E+00	2.97E-01	1.40E+01
1988			1.12E+01	2.16E+00	1.21E+00	3.17E-01	1.49E+01
1989			8.50E+00	1.64E+00	9.16E-01	2.40E-01	1.13E+01
1990			6.83E+00	1.31E+00	7.35E-01	1.93E-01	9.07E+00
1991			5.34E+00	1.03E+00	5.75E-01	1.51E-01	7.10E+00
1992			3.90E+00	7.50E-01	4.20E-01	1.10E-01	5.18E+00
1993			5.19E+00	9.98E-01	5.59E-01	1.46E-01	6.89E+00
1994			4.17E+00	8.03E-01	4.49E-01	1.18E-01	5.54E+00
1995			2.15E+00	4.13E-01	2.31E-01	6.05E-02	2.85E+00
Totals			9.47E+02	1.82E+02	1.02E+02	2.67E+01	1.26E+03
Percent			75.29%	14.48%	8.11%	2.12%	

Table H-3. MEI Liquid-Pathway Doses

	Fish	Water	Shore	Swimming	Boating	Total Liquid Pathway
	(mrem)	(mrem)	(mrem)	(mrem)	(mrem)	(mrem)
1954	4.03E-05	1.79E-03		7.69E-07		1.83E-03
1955	6.46E-04	2.88E-02		1.23E-05		2.94E-02
1956	1.03E-03	4.60E-02		1.97E-05		4.70E-02
1957	1.65E-03	7.35E-02		3.15E-05		7.50E-02
1958	2.68E-03	1.20E-01		5.12E-05		1.22E-01
1959	4.62E-03	2.06E-01		8.82E-05		2.10E-01
1960	5.34E-03	2.38E-01		1.02E-04		2.43E-01
1961	6.14E-03	2.73E-01		1.17E-04		2.79E-01
1962	5.32E-03	2.37E-01		1.02E-04		2.42E-01
1963	8.51E-03	3.79E-01		1.63E-04		3.87E-01
1964	9.39E-03	4.18E-01		1.79E-04		4.27E-01
1965	1.14E-02	5.10E-01		2.18E-04		5.20E-01
1966	9.01E-03	4.01E-01		1.72E-04		4.10E-01
1967	7.66E-03	3.41E-01		1.46E-04		3.48E-01
1968	6.78E-03	3.02E-01		1.29E-04		3.08E-01
1969	7.06E-03	3.15E-01		1.35E-04		3.21E-01
1970	4.05E-03	1.80E-01		7.73E-05		1.84E-01
1971	4.18E-03	1.86E-01		7.98E-05		1.90E-01
1972	5.06E-03	2.25E-01		9.66E-05		2.30E-01
1973	7.79E-03	3.47E-01		1.49E-04		3.54E-01
1974	6.60E-03	2.94E-01		1.26E-04		3.00E-01
1975	6.12E-03	2.72E-01		1.17E-04		2.78E-01
1976	6.56E-03	2.92E-01		1.25E-04		2.98E-01
1977	4.82E-03	2.15E-01		9.20E-05		2.19E-01
1978	4.14E-03	1.84E-01		7.90E-05		1.88E-01
1979	3.23E-03	1.44E-01		6.17E-05		1.47E-01
1980	2.72E-03	1.21E-01		5.19E-05		1.24E-01
1981	2.62E-03	1.17E-01		5.00E-05		1.19E-01
1982	3.58E-03	1.59E-01		6.83E-05		1.63E-01
1983	3.74E-03	1.67E-01		7.14E-05		1.70E-01
1984	3.61E-03	1.61E-01		6.89E-05		1.64E-01
1985	2.75E-03	1.23E-01		5.25E-05		1.25E-01
1986	3.06E-03	1.36E-01		5.84E-05		1.39E-01
1987	2.49E-03	1.11E-01		4.75E-05		1.13E-01
1988	2.12E-03	9.46E-02		4.05E-05		9.65E-02
1989	1.93E-03	8.58E-02		3.68E-05		8.75E-02
1990	1.69E-03	7.55E-02		3.23E-05		7.70E-02
1991	3.01E-03	1.34E-01		5.75E-05		1.37E-01
1992	1.52E-03	6.76E-02		2.90E-05		6.90E-02
1993	1.40E-03	6.22E-02		2.67E-05		6.35E-02
1994	1.20E-03	5.34E-02		2.29E-05		5.45E-02
1995	1.25E-03	5.59E-02		2.39E-05		5.70E-02
Totals	1.79E-01	7.95E+00		3.41E-03		8.12E+00
Percent	2.20%	98.00%		0.04%		

Table H-3. Population Liquid-Pathway Doses

	Aquatic Food (per.-rem)	Water (per.-rem)	Shore (per.-rem)	Swimming (per.-rem)	Boating (per.-rem)	Total Liquid Pathway (per.-rem)
1954	3.53E-04	5.12E-02		1.39E-05		5.16E-02
1955	5.66E-03	8.22E-01		2.23E-04		8.28E-01
1956	9.06E-03	1.31E+00		3.57E-04		1.32E+00
1957	1.45E-02	2.10E+00		5.70E-04		2.12E+00
1958	2.35E-02	3.42E+00		9.27E-04		3.44E+00
1959	4.05E-02	5.88E+00		1.60E-03		5.92E+00
1960	4.68E-02	6.79E+00		1.84E-03		6.84E+00
1961	5.38E-02	7.81E+00		2.12E-03		7.87E+00
1962	4.67E-02	6.78E+00		1.84E-03		6.82E+00
1963	7.47E-02	1.08E+01		2.94E-03		1.09E+01
1964	8.24E-02	1.20E+01		3.25E-03		1.20E+01
1965	1.00E-01	1.46E+01		3.95E-03		1.47E+01
1966	7.90E-02	1.15E+01		3.11E-03		1.15E+01
1967	6.72E-02	9.74E+00		2.64E-03		9.81E+00
1968	5.94E-02	8.62E+00		2.34E-03		8.69E+00
1969	6.20E-02	8.99E+00		2.44E-03		9.05E+00
1970	3.55E-02	5.15E+00		1.40E-03		5.19E+00
1971	3.67E-02	5.32E+00		1.44E-03		5.36E+00
1972	4.44E-02	6.44E+00		1.75E-03		6.49E+00
1973	6.83E-02	9.91E+00		2.69E-03		9.98E+00
1974	5.79E-02	8.40E+00		2.28E-03		8.46E+00
1975	5.37E-02	7.78E+00		2.11E-03		7.84E+00
1976	5.75E-02	8.34E+00		2.26E-03		8.40E+00
1977	4.23E-02	6.13E+00		1.66E-03		6.18E+00
1978	3.63E-02	5.26E+00		1.43E-03		5.30E+00
1979	2.84E-02	4.12E+00		1.12E-03		4.15E+00
1980	2.38E-02	3.46E+00		9.39E-04		3.48E+00
1981	2.30E-02	3.33E+00		9.04E-04		3.36E+00
1982	3.14E-02	4.55E+00		1.24E-03		4.58E+00
1983	3.28E-02	4.76E+00		1.29E-03		4.79E+00
1984	3.17E-02	4.59E+00		1.25E-03		4.62E+00
1985	2.41E-02	3.50E+00		9.50E-04		3.53E+00
1986	2.68E-02	3.89E+00		1.06E-03		3.92E+00
1987	2.18E-02	3.16E+00		8.59E-04		3.19E+00
1988	1.86E-02	2.70E+00		7.33E-04		2.72E+00
1989	1.69E-02	2.45E+00		6.65E-04		2.47E+00
1990	1.49E-02	2.16E+00		5.85E-04		2.17E+00
1991	2.64E-02	3.84E+00		1.04E-03		3.86E+00
1992	1.33E-02	1.93E+00		5.24E-04		1.95E+00
1993	1.23E-02	1.78E+00		4.83E-04		1.79E+00
1994	1.05E-02	1.53E+00		4.14E-04		1.54E+00
1995	1.10E-02	1.60E+00		4.33E-04		1.61E+00
Totals	1.57E+00	2.27E+02		6.17E-02		2.29E+02
Percent	0.68%	99.29%		0.03%		

Table H-3 Air. Tritium Oxide Atmospheric Releases and Maximally Exposed Individual Doses 1954 - 1995

Table H-3 Liquid. Tritium Oxide Liquid Releases and Maximally Exposed Individual Doses 1954 - 1995

I-129

Half-Life

I-129 - $1.6\text{E}+07$ years

Total Curies Released (1954-1995)

Air - $5.72\text{E}+00$

Streams - $3.89\text{E}-01$

Basins (Decay Corrected) - 0.0 (not measured)

Total Cumulative Risks (1954-1995)

MEI Air Pathway - $2.82\text{E}-06$

MEI Liquid Pathway - $8.70\text{E}-09$

Population Air - $7.78\text{E}-02$

Population Liquid - $2.33\text{E}-04$

Projected 30-year Risks Using Recent Annual Doses (average of years 1991-1995)

MEI Air Pathway - $8.01\text{E}-08$

MEI Liquid Pathway - $2.00\text{E}-08$

Population Air - $2.19\text{E}-03$

Population Liquid - $5.35\text{E}-04$

Critical Pathways

MEI Air Pathway - Vegetation Consumption = 84%, Milk = 13%

MEI Liquid Pathway - Water Consumption = 72%, Fish Consumption = 28%

Population Air Pathway - Vegetation Consumption = 75%, Milk = 17%

Population Liquid Pathway - Water Consumption = 76%, Aquatic Food = 24%

Discussion

I-129 is a long-lived fission product that, because of its low beta/gamma energies and low specific activity, is difficult to measure in effluents. From 1955 to 1982, airborne releases of I-129 were estimated based on fission yields. From 1980 to 1993, liquid releases of I-129 were estimated based on measured concentrations in samples of groundwater outcropping from the F-Area and H-Area seepage basins (Kantelo, 1987). Air and liquid releases of I-129 have been measured routinely by SRTC since 1983 and 1994, respectively. On a cumulative MEI and population risk basis, I-129 was the 23rd most important liquid pathway radionuclide. On a cumulative MEI and population risk basis, I-129 was the 6th and 7th most important air pathway radionuclide, respectively. The projected 30-year MEI liquid pathway risk is estimated to be $2.0\text{E}-08$, which is the 5th most important. The projected 30-year MEI air pathway risk is estimated to be $8.0\text{E}-08$, which is the 2nd most important. Because of its long half life and estimated long-term residual inventory ($>2.2\text{E}+01$ Ci), I-129 will continue to be of importance, on a percentage-of-risk basis, in the near and distant future.

Refer to Kantelo, 1993 for a more complete assessment of I-129 at SRS.

Table I-129. Effluent Releases

	I-129	I-129	I-129	I-129-Basin
	Air (Curies)	Streams (Curies)	Basins (Curies)	Decay Corrected (Ci)
1954				
1955	2.12E-01			
1956	2.12E-01			
1957	2.12E-01			
1958	2.12E-01			
1959	2.12E-01			
1960	2.12E-01			
1961	2.12E-01			
1962	2.12E-01			
1963	2.12E-01			
1964	2.12E-01			
1965	2.12E-01			
1966	2.12E-01			
1967	2.12E-01			
1968	2.12E-01			
1969	2.12E-01			
1970	2.12E-01			
1971	2.12E-01			
1972	2.12E-01			
1973	2.12E-01			
1974	1.70E-01			
1975	1.40E-01			
1976	1.50E-01			
1977	1.40E-01			
1978	1.30E-01			
1979	1.30E-01			
1980	1.60E-01	2.00E-02		
1981	1.60E-01	2.20E-02		
1982	5.90E-02	2.20E-02		
1983	4.10E-02	2.20E-02		
1984	3.54E-02	2.20E-02		
1985	6.50E-02	2.20E-02		
1986	8.70E-02	2.20E-02		
1987	7.20E-02	2.20E-02		
1988	6.30E-02	2.20E-02		
1989	5.19E-02	2.20E-02		
1990	1.30E-02	2.20E-02		
1991	1.01E-02	2.20E-02		
1992	3.50E-03	2.20E-02		
1993	4.96E-03	2.20E-02		
1994	3.80E-03	7.39E-02		
1995	4.70E-03	9.49E-03		
Totals	5.72E+00	3.89E-01		

Table I-129. MEI Air-Pathway Doses

	Plume (mrem)	Ground (mrem)	Inhalation (mrem)	Vegetation (mrem)	Milk (mrem)	Meat (mrem)	Total Air Pathway (mrem)
1954							
1955		1.31E-03	1.06E-04	1.21E-01	1.84E-02	2.54E-03	1.43E-01
1956		1.31E-03	1.06E-04	1.21E-01	1.84E-02	2.54E-03	1.43E-01
1957		1.31E-03	1.06E-04	1.21E-01	1.84E-02	2.54E-03	1.43E-01
1958		1.31E-03	1.06E-04	1.21E-01	1.84E-02	2.54E-03	1.43E-01
1959		1.31E-03	1.06E-04	1.21E-01	1.84E-02	2.54E-03	1.43E-01
1960		1.31E-03	1.06E-04	1.21E-01	1.84E-02	2.54E-03	1.43E-01
1961		1.31E-03	1.06E-04	1.21E-01	1.84E-02	2.54E-03	1.43E-01
1962		1.31E-03	1.06E-04	1.21E-01	1.84E-02	2.54E-03	1.43E-01
1963		1.31E-03	1.06E-04	1.21E-01	1.84E-02	2.54E-03	1.43E-01
1964		1.31E-03	1.06E-04	1.21E-01	1.84E-02	2.54E-03	1.43E-01
1965		1.31E-03	1.06E-04	1.21E-01	1.84E-02	2.54E-03	1.43E-01
1966		1.31E-03	1.06E-04	1.21E-01	1.84E-02	2.54E-03	1.43E-01
1967		1.31E-03	1.06E-04	1.21E-01	1.84E-02	2.54E-03	1.43E-01
1968		1.31E-03	1.06E-04	1.21E-01	1.84E-02	2.54E-03	1.43E-01
1969		1.31E-03	1.06E-04	1.21E-01	1.84E-02	2.54E-03	1.43E-01
1970		1.31E-03	1.06E-04	1.21E-01	1.84E-02	2.54E-03	1.43E-01
1971		1.31E-03	1.06E-04	1.21E-01	1.84E-02	2.54E-03	1.43E-01
1972		1.31E-03	1.06E-04	1.21E-01	1.84E-02	2.54E-03	1.43E-01
1973		1.31E-03	1.06E-04	1.21E-01	1.84E-02	2.54E-03	1.43E-01
1974		1.05E-03	8.50E-05	9.69E-02	1.48E-02	2.04E-03	1.15E-01
1975		8.68E-04	7.00E-05	7.98E-02	1.22E-02	1.68E-03	9.46E-02
1976		9.30E-04	7.50E-05	8.55E-02	1.31E-02	1.80E-03	1.01E-01
1977		8.68E-04	7.00E-05	7.98E-02	1.22E-02	1.68E-03	9.46E-02
1978		8.06E-04	6.50E-05	7.41E-02	1.13E-02	1.56E-03	8.78E-02
1979		8.06E-04	6.50E-05	7.41E-02	1.13E-02	1.56E-03	8.78E-02
1980		9.92E-04	8.00E-05	9.12E-02	1.39E-02	1.92E-03	1.08E-01
1981		9.92E-04	8.00E-05	9.12E-02	1.39E-02	1.92E-03	1.08E-01
1982		3.66E-04	2.95E-05	3.36E-02	5.13E-03	7.08E-04	3.99E-02
1983		2.54E-04	2.05E-05	2.34E-02	3.57E-03	4.92E-04	2.77E-02
1984		2.19E-04	1.77E-05	2.02E-02	3.08E-03	4.25E-04	2.39E-02
1985		4.03E-04	3.25E-05	3.71E-02	5.66E-03	7.80E-04	4.39E-02
1986		5.39E-04	4.35E-05	4.96E-02	7.57E-03	1.04E-03	5.88E-02
1987		4.46E-04	3.60E-05	4.10E-02	6.26E-03	8.64E-04	4.87E-02
1988		3.91E-04	3.15E-05	3.59E-02	5.48E-03	7.56E-04	4.26E-02
1989		3.22E-04	2.60E-05	2.96E-02	4.52E-03	6.23E-04	3.51E-02
1990		8.06E-05	6.50E-06	7.41E-03	1.13E-03	1.56E-04	8.78E-03
1991		6.26E-05	5.05E-06	5.76E-03	8.79E-04	1.21E-04	6.82E-03
1992		2.17E-05	1.75E-06	2.00E-03	3.05E-04	4.20E-05	2.36E-03
1993		3.08E-05	2.48E-06	2.83E-03	4.32E-04	5.95E-05	3.35E-03
1994		2.36E-05	1.90E-06	2.17E-03	3.31E-04	4.56E-05	2.57E-03
1995		2.91E-05	2.35E-06	2.68E-03	4.09E-04	5.64E-05	3.18E-03
Totals		3.55E-02	2.86E-03	3.26E+00	4.98E-01	6.87E-02	3.87E+00
Percent		0.92%	0.07%	84.36%	12.88%	1.78%	

Table I-129. Population Air-Pathway Doses

	Plume	Ground	Inhalation	Vegetation	Milk	Meat	Total Air Pathway
	(per.-rem)	(per.-rem)	(per.-rem)	(per.-rem)	(per.-rem)	(per.-rem)	(per.-rem)
1954							
1955		2.10E-01	1.27E-02	2.97E+00	7.00E-01	5.72E-02	3.95E+00
1956		2.10E-01	1.27E-02	2.97E+00	7.00E-01	5.72E-02	3.95E+00
1957		2.10E-01	1.27E-02	2.97E+00	7.00E-01	5.72E-02	3.95E+00
1958		2.10E-01	1.27E-02	2.97E+00	7.00E-01	5.72E-02	3.95E+00
1959		2.10E-01	1.27E-02	2.97E+00	7.00E-01	5.72E-02	3.95E+00
1960		2.10E-01	1.27E-02	2.97E+00	7.00E-01	5.72E-02	3.95E+00
1961		2.10E-01	1.27E-02	2.97E+00	7.00E-01	5.72E-02	3.95E+00
1962		2.10E-01	1.27E-02	2.97E+00	7.00E-01	5.72E-02	3.95E+00
1963		2.10E-01	1.27E-02	2.97E+00	7.00E-01	5.72E-02	3.95E+00
1964		2.10E-01	1.27E-02	2.97E+00	7.00E-01	5.72E-02	3.95E+00
1965		2.10E-01	1.27E-02	2.97E+00	7.00E-01	5.72E-02	3.95E+00
1966		2.10E-01	1.27E-02	2.97E+00	7.00E-01	5.72E-02	3.95E+00
1967		2.10E-01	1.27E-02	2.97E+00	7.00E-01	5.72E-02	3.95E+00
1968		2.10E-01	1.27E-02	2.97E+00	7.00E-01	5.72E-02	3.95E+00
1969		2.10E-01	1.27E-02	2.97E+00	7.00E-01	5.72E-02	3.95E+00
1970		2.10E-01	1.27E-02	2.97E+00	7.00E-01	5.72E-02	3.95E+00
1971		2.10E-01	1.27E-02	2.97E+00	7.00E-01	5.72E-02	3.95E+00
1972		2.10E-01	1.27E-02	2.97E+00	7.00E-01	5.72E-02	3.95E+00
1973		2.10E-01	1.27E-02	2.97E+00	7.00E-01	5.72E-02	3.95E+00
1974		1.68E-01	1.02E-02	2.38E+00	5.61E-01	4.59E-02	3.17E+00
1975		1.39E-01	8.40E-03	1.96E+00	4.62E-01	3.78E-02	2.61E+00
1976		1.49E-01	9.00E-03	2.10E+00	4.95E-01	4.05E-02	2.79E+00
1977		1.39E-01	8.40E-03	1.96E+00	4.62E-01	3.78E-02	2.61E+00
1978		1.29E-01	7.80E-03	1.82E+00	4.29E-01	3.51E-02	2.42E+00
1979		1.29E-01	7.80E-03	1.82E+00	4.29E-01	3.51E-02	2.42E+00
1980		1.58E-01	9.60E-03	2.24E+00	5.28E-01	4.32E-02	2.98E+00
1981		1.58E-01	9.60E-03	2.24E+00	5.28E-01	4.32E-02	2.98E+00
1982		5.84E-02	3.54E-03	8.26E-01	1.95E-01	1.59E-02	1.10E+00
1983		4.06E-02	2.46E-03	5.74E-01	1.35E-01	1.11E-02	7.63E-01
1984		3.50E-02	2.12E-03	4.96E-01	1.17E-01	9.56E-03	6.59E-01
1985		6.44E-02	3.90E-03	9.10E-01	2.15E-01	1.76E-02	1.21E+00
1986		8.61E-02	5.22E-03	1.22E+00	2.87E-01	2.35E-02	1.62E+00
1987		7.13E-02	4.32E-03	1.01E+00	2.38E-01	1.94E-02	1.34E+00
1988		6.24E-02	3.78E-03	8.82E-01	2.08E-01	1.70E-02	1.17E+00
1989		5.14E-02	3.11E-03	7.27E-01	1.71E-01	1.40E-02	9.66E-01
1990		1.29E-02	7.80E-04	1.82E-01	4.29E-02	3.51E-03	2.42E-01
1991		1.00E-02	6.06E-04	1.41E-01	3.33E-02	2.73E-03	1.88E-01
1992		3.47E-03	2.10E-04	4.90E-02	1.16E-02	9.45E-04	6.52E-02
1993		4.91E-03	2.98E-04	6.94E-02	1.64E-02	1.34E-03	9.24E-02
1994		3.76E-03	2.28E-04	5.32E-02	1.25E-02	1.03E-03	7.08E-02
1995			2.82E-04	6.58E-02	1.55E-02	1.27E-03	8.29E-02
Totals		5.66E+00	3.43E-01	8.01E+01	1.89E+01	1.55E+00	1.07E+02
Percent		5.31%	0.32%	75.19%	17.72%	1.45%	

Table I-129. MEI Liquid-Pathway Doses

	Fish	Water	Shore	Swimming	Boating	Total Liquid Pathway
	(mrem)	(mrem)	(mrem)	(mrem)	(mrem)	(mrem)
1954						
1955						
1956						
1957						
1958						
1959						
1960						
1961						
1962						
1963						
1964						
1965						
1966						
1967						
1968						
1969						
1970						
1971						
1972						
1973						
1974						
1975						
1976						
1977						
1978						
1979						
1980	1.70E-04	4.40E-04	2.40E-06	2.40E-10	2.80E-10	6.12E-04
1981	1.87E-04	4.84E-04	2.64E-06	2.64E-10	3.08E-10	6.74E-04
1982	1.87E-04	4.84E-04	2.64E-06	2.64E-10	3.08E-10	6.74E-04
1983	1.87E-04	4.84E-04	2.64E-06	2.64E-10	3.08E-10	6.74E-04
1984	1.87E-04	4.84E-04	2.64E-06	2.64E-10	3.08E-10	6.74E-04
1985	1.87E-04	4.84E-04	2.64E-06	2.64E-10	3.08E-10	6.74E-04
1986	1.87E-04	4.84E-04	2.64E-06	2.64E-10	3.08E-10	6.74E-04
1987	1.87E-04	4.84E-04	2.64E-06	2.64E-10	3.08E-10	6.74E-04
1988	1.87E-04	4.84E-04	2.64E-06	2.64E-10	3.08E-10	6.74E-04
1989	1.87E-04	4.84E-04	2.64E-06	2.64E-10	3.08E-10	6.74E-04
1990	1.87E-04	4.84E-04	2.64E-06	2.64E-10	3.08E-10	6.74E-04
1991	1.87E-04	4.84E-04	2.64E-06	2.64E-10	3.08E-10	6.74E-04
1992	1.87E-04	4.84E-04	2.64E-06	2.64E-10	3.08E-10	6.74E-04
1993	1.87E-04	4.84E-04	2.64E-06	2.64E-10	3.08E-10	6.74E-04
1994	6.28E-04	1.63E-03	8.87E-06	8.87E-10	1.03E-09	2.26E-03
1995	8.07E-05	2.09E-04	1.14E-06	1.14E-10	1.33E-10	2.91E-04
Totals	3.31E-03	8.57E-03	4.67E-05	4.67E-09	5.45E-09	1.19E-02
Percent	27.76%	71.85%	0.39%	0.00%	0.00%	

Table I-129. Population Liquid-Pathway Doses

	Aquatic Food	Water	Shore	Swimming	Boating	Total Liquid Pathway
	(per.-rem)	(per.-rem)	(per.-rem)	(per.-rem)	(per.-rem)	(per.-rem)
1954						
1955						
1956						
1957						
1958						
1959						
1960						
1961						
1962						
1963						
1964						
1965						
1966						
1967						
1968						
1969						
1970						
1971						
1972						
1973						
1974						
1975						
1976						
1977						
1978						
1979						
1980	3.86E-03	1.24E-02	1.04E-04	4.20E-09	1.44E-08	1.64E-02
1981	4.25E-03	1.36E-02	1.14E-04	4.62E-09	1.58E-08	1.80E-02
1982	4.25E-03	1.36E-02	1.14E-04	4.62E-09	1.58E-08	1.80E-02
1983	4.25E-03	1.36E-02	1.14E-04	4.62E-09	1.58E-08	1.80E-02
1984	4.25E-03	1.36E-02	1.14E-04	4.62E-09	1.58E-08	1.80E-02
1985	4.25E-03	1.36E-02	1.14E-04	4.62E-09	1.58E-08	1.80E-02
1986	4.25E-03	1.36E-02	1.14E-04	4.62E-09	1.58E-08	1.80E-02
1987	4.25E-03	1.36E-02	1.14E-04	4.62E-09	1.58E-08	1.80E-02
1988	4.25E-03	1.36E-02	1.14E-04	4.62E-09	1.58E-08	1.80E-02
1989	4.25E-03	1.36E-02	1.14E-04	4.62E-09	1.58E-08	1.80E-02
1990	4.25E-03	1.36E-02	1.14E-04	4.62E-09	1.58E-08	1.80E-02
1991	4.25E-03	1.36E-02	1.14E-04	4.62E-09	1.58E-08	1.80E-02
1992	4.25E-03	1.36E-02	1.14E-04	4.62E-09	1.58E-08	1.80E-02
1993	4.25E-03	1.36E-02	1.14E-04	4.62E-09	1.58E-08	1.80E-02
1994	1.43E-02	4.58E-02	3.84E-04	1.55E-08	5.32E-08	6.05E-02
1995	1.83E-03	5.88E-03	4.93E-05	1.99E-09	6.83E-09	7.76E-03
Totals	7.52E-02	2.41E-01	2.02E-03	8.18E-08	2.80E-07	3.19E-01
Percent	23.59%	75.78%	0.64%	0.00%	0.00%	

Table I-129 Air. I-129 Atmospheric Releases and Maximally Exposed Individual Doses 1954 - 1995

Table I-129 Liquid. I-129 Liquid Releases and Maximally Exposed Individual Doses 1954 - 1995

I-131

Half-Life

I-132 - 8.04 days

Total Curies Released (1954-1995)

Air - $2.52\text{E}+03$

Streams - $3.02\text{E}+02$

Basins (Decay Corrected) - $<1.00\text{E}-12$

Total Cumulative Risks (1954-1995)

MEI Air Pathway - $1.56\text{E}-05$

MEI Liquid Pathway - $1.10\text{E}-06$

Population Air - $6.15\text{E}-01$

Population Liquid - $2.12\text{E}-02$

Projected 30-year Risks Using Recent Annual Doses (average of years 1991-1995)

MEI Air Pathway - $7.75\text{E}-10$

MEI Liquid Pathway - 0.0

Population Air - $3.01\text{E}-05$

Population Liquid - 0.0

Critical Pathways

MEI Air Pathway - Vegetation Consumption = 75%, Milk = 20%

MEI Liquid Pathway - Water Consumption = 72%, Fish Consumption = 28%

Population Air Pathway - Vegetation Consumption = 78%, Milk = 16%

Population Liquid Pathway - Water Consumption = 87%, Aquatic Food = 13%

Discussion

I-131 is an abundant, but short-lived, fission product. On a cumulative MEI and population risk basis, I-131 was the 7th and 8th most important liquid pathway radionuclide, respectively. Also, on a cumulative MEI and population risk basis, I-131 was the 1st and 2nd most important air pathway radionuclide, respectively. Because it was released to the atmosphere in relatively large quantities (prior to the implementation of stringent emission controls in the early 1960's) and because of its high mobility in the vegetation and milk pathways, I-131 accounted for about 31% of the site's cumulative air pathway MEI risk and about 24% of the population risk. The projected 30-year MEI air pathway risk is estimated to be $7.8\text{E}-10$, which is the 12th most important. Future liquid releases of I-131 are expected to remain nil.

Refer to Kantelo, 1993 for a more complete assessment of I-131 at SRS.

Table I-131. Effluent Releases

	I-131	I-131	I-131	I-131-Basin
	Air (Curies)	Streams (Curies)	Basins (Curies)	Decay Corrected (Ci)
1954				
1955	6.92E+01		4.89E+02	
1956	1.58E+03		9.39E+02	
1957	2.92E+02	6.50E+01	8.70E+02	
1958	1.99E+01		2.48E+01	
1959	1.62E+02		6.01E+01	
1960	7.30E+00	2.43E+01	5.42E+00	
1961	1.62E+02	2.88E+01	1.58E+02	
1962	1.67E+01	8.71E+01	7.18E+00	
1963	4.82E+00	4.65E+01	2.91E+00	
1964	1.16E+01	8.70E+00	1.24E+01	
1965	1.81E+01	5.39E+00	8.56E+00	
1966	3.16E+01	3.02E+00	1.71E+01	
1967	2.01E+01	1.36E+01	5.78E+00	
1968	2.21E+01	9.49E+00	4.14E+00	
1969	3.60E+01	5.02E+00	1.59E+01	
1970	3.44E+01	2.17E+00	9.22E+00	
1971	2.66E+01	1.53E+00	2.82E+00	
1972	2.74E+00	9.30E-01	3.04E+00	
1973	1.86E+00	1.55E-01	3.05E+00	
1974	1.91E+00	1.40E-02	3.51E-01	
1975	1.23E-01		2.26E-01	
1976	1.55E-01	2.00E-03	1.17E-01	
1977	6.09E-02	1.24E-02	2.91E-02	
1978	6.54E-02	7.26E-04	3.72E-02	
1979	8.43E-02		6.48E-02	
1980	2.51E-02		1.73E-02	
1981	4.70E-02		2.07E-02	
1982	1.06E-01		8.13E-02	
1983	8.41E-02		4.09E-02	
1984	2.82E-01		1.20E-01	
1985	6.05E-02		3.24E-02	
1986	2.63E-02		7.60E-03	
1987	1.26E-02		3.27E-02	
1988	2.62E-03		2.16E-03	
1989	3.45E-03			
1990	1.24E-04			
1991	2.97E-05			
1992	9.99E-05			
1993	1.48E-04			
1994	7.00E-05			
1995	2.06E-02			
Totals	2.52E+03	3.02E+02	2.64E+03	

Table I-131. MEI Air-Pathway Doses

	Plume	Ground	Inhalation	Vegetation	Milk	Meat	Total Air Pathway
	(mrem)	(mrem)	(mrem)	(mrem)	(mrem)	(mrem)	(mrem)
1954							
1955		6.30E-03	6.09E-03	4.36E-01	1.18E-01	1.87E-02	5.85E-01
1956		1.44E-01	1.39E-01	9.95E+00	2.69E+00	4.27E-01	1.33E+01
1957		2.66E-02	2.57E-02	1.84E+00	4.96E-01	7.88E-02	2.47E+00
1958		1.81E-03	1.75E-03	1.25E-01	3.38E-02	5.37E-03	1.68E-01
1959		1.47E-02	1.43E-02	1.02E+00	2.75E-01	4.37E-02	1.37E+00
1960		6.64E-04	6.42E-04	4.60E-02	1.24E-02	1.97E-03	6.17E-02
1961		1.47E-02	1.43E-02	1.02E+00	2.75E-01	4.37E-02	1.37E+00
1962		1.52E-03	1.47E-03	1.05E-01	2.84E-02	4.51E-03	1.41E-01
1963		4.39E-04	4.24E-04	3.04E-02	8.19E-03	1.30E-03	4.07E-02
1964		1.06E-03	1.02E-03	7.31E-02	1.97E-02	3.13E-03	9.80E-02
1965		1.65E-03	1.59E-03	1.14E-01	3.08E-02	4.89E-03	1.53E-01
1966		2.88E-03	2.78E-03	1.99E-01	5.37E-02	8.53E-03	2.67E-01
1967		1.83E-03	1.77E-03	1.27E-01	3.42E-02	5.43E-03	1.70E-01
1968		2.01E-03	1.94E-03	1.39E-01	3.76E-02	5.97E-03	1.87E-01
1969		3.28E-03	3.17E-03	2.27E-01	6.12E-02	9.72E-03	3.04E-01
1970		3.13E-03	3.03E-03	2.17E-01	5.85E-02	9.29E-03	2.91E-01
1971		2.42E-03	2.34E-03	1.68E-01	4.52E-02	7.18E-03	2.25E-01
1972		2.49E-04	2.41E-04	1.73E-02	4.66E-03	7.40E-04	2.32E-02
1973		1.69E-04	1.64E-04	1.17E-02	3.16E-03	5.02E-04	1.57E-02
1974		1.74E-04	1.68E-04	1.20E-02	3.25E-03	5.16E-04	1.61E-02
1975		1.12E-05	1.08E-05	7.75E-04	2.09E-04	3.32E-05	1.04E-03
1976		1.41E-05	1.36E-05	9.77E-04	2.64E-04	4.19E-05	1.31E-03
1977		5.54E-06	5.36E-06	3.84E-04	1.04E-04	1.64E-05	5.15E-04
1978		5.95E-06	5.76E-06	4.12E-04	1.11E-04	1.77E-05	5.53E-04
1979		7.67E-06	7.42E-06	5.31E-04	1.43E-04	2.28E-05	7.12E-04
1980		2.28E-06	2.21E-06	1.58E-04	4.27E-05	6.78E-06	2.12E-04
1981		4.28E-06	4.14E-06	2.96E-04	7.99E-05	1.27E-05	3.97E-04
1982		9.65E-06	9.33E-06	6.68E-04	1.80E-04	2.86E-05	8.96E-04
1983		7.65E-06	7.40E-06	5.30E-04	1.43E-04	2.27E-05	7.11E-04
1984		2.57E-05	2.48E-05	1.78E-03	4.79E-04	7.61E-05	2.38E-03
1985		5.51E-06	5.32E-06	3.81E-04	1.03E-04	1.63E-05	5.11E-04
1986		2.39E-06	2.31E-06	1.66E-04	4.47E-05	7.10E-06	2.22E-04
1987		1.15E-06	1.11E-06	7.94E-05	2.14E-05	3.40E-06	1.06E-04
1988		2.38E-07	2.31E-07	1.65E-05	4.45E-06	7.07E-07	2.21E-05
1989		3.14E-07	3.04E-07	2.17E-05	5.87E-06	9.32E-07	2.91E-05
1990		1.13E-08	1.09E-08	7.81E-07	2.11E-07	3.35E-08	1.05E-06
1991		2.70E-09	2.61E-09	1.87E-07	5.05E-08	8.02E-09	2.51E-07
1992		9.09E-09	8.79E-09	6.29E-07	1.70E-07	2.70E-08	8.44E-07
1993		1.35E-08	1.30E-08	9.32E-07	2.52E-07	4.00E-08	1.25E-06
1994		6.37E-09	6.16E-09	4.41E-07	1.19E-07	1.89E-08	5.91E-07
1995		1.87E-06	1.81E-06	1.30E-04	3.50E-05	5.56E-06	1.74E-04
Totals		2.30E-01	2.22E-01	1.59E+01	4.29E+00	6.81E-01	2.13E+01
Percent		1.08%	1.04%	74.57%	20.12%	3.20%	

Table I-131. Population Air-Pathway Doses

	Plume	Ground	Inhalation	Vegetation	Milk	Meat	Total Air Pathway
	(per.-rem)	(per.-rem)	(per.-rem)	(per.-rem)	(per.-rem)	(per.-rem)	(per.-rem)
1954							
1955		3.94E-01	6.92E-01	1.80E+01	3.67E+00	3.81E-01	2.31E+01
1956		9.01E+00	1.58E+01	4.11E+02	8.37E+01	8.69E+00	5.28E+02
1957		1.66E+00	2.92E+00	7.59E+01	1.55E+01	1.61E+00	9.76E+01
1958		1.13E-01	1.99E-01	5.17E+00	1.05E+00	1.09E-01	6.65E+00
1959		9.23E-01	1.62E+00	4.21E+01	8.59E+00	8.91E-01	5.41E+01
1960		4.16E-02	7.30E-02	1.90E+00	3.87E-01	4.02E-02	2.44E+00
1961		9.23E-01	1.62E+00	4.21E+01	8.59E+00	8.91E-01	5.41E+01
1962		9.52E-02	1.67E-01	4.34E+00	8.85E-01	9.19E-02	5.58E+00
1963		2.75E-02	4.82E-02	1.25E+00	2.55E-01	2.65E-02	1.61E+00
1964		6.61E-02	1.16E-01	3.02E+00	6.15E-01	6.38E-02	3.88E+00
1965		1.03E-01	1.81E-01	4.71E+00	9.59E-01	9.96E-02	6.05E+00
1966		1.80E-01	3.16E-01	8.22E+00	1.67E+00	1.74E-01	1.06E+01
1967		1.15E-01	2.01E-01	5.23E+00	1.07E+00	1.11E-01	6.72E+00
1968		1.26E-01	2.21E-01	5.75E+00	1.17E+00	1.22E-01	7.39E+00
1969		2.05E-01	3.60E-01	9.36E+00	1.91E+00	1.98E-01	1.20E+01
1970		1.96E-01	3.44E-01	8.94E+00	1.82E+00	1.89E-01	1.15E+01
1971		1.52E-01	2.66E-01	6.92E+00	1.41E+00	1.46E-01	8.89E+00
1972		1.56E-02	2.74E-02	7.12E-01	1.45E-01	1.51E-02	9.16E-01
1973		1.06E-02	1.86E-02	4.84E-01	9.86E-02	1.02E-02	6.22E-01
1974		1.09E-02	1.91E-02	4.97E-01	1.01E-01	1.05E-02	6.38E-01
1975		7.01E-04	1.23E-03	3.20E-02	6.52E-03	6.77E-04	4.11E-02
1976		8.84E-04	1.55E-03	4.03E-02	8.22E-03	8.53E-04	5.18E-02
1977		3.47E-04	6.09E-04	1.58E-02	3.23E-03	3.35E-04	2.04E-02
1978		3.73E-04	6.54E-04	1.70E-02	3.47E-03	3.60E-04	2.19E-02
1979		4.81E-04	8.43E-04	2.19E-02	4.47E-03	4.64E-04	2.82E-02
1980		1.43E-04	2.51E-04	6.53E-03	1.33E-03	1.38E-04	8.39E-03
1981		2.68E-04	4.70E-04	1.22E-02	2.49E-03	2.59E-04	1.57E-02
1982		6.04E-04	1.06E-03	2.76E-02	5.62E-03	5.83E-04	3.54E-02
1983		4.79E-04	8.41E-04	2.19E-02	4.46E-03	4.63E-04	2.81E-02
1984		1.61E-03	2.82E-03	7.33E-02	1.49E-02	1.55E-03	9.42E-02
1985		3.45E-04	6.05E-04	1.57E-02	3.21E-03	3.33E-04	2.02E-02
1986		1.50E-04	2.63E-04	6.84E-03	1.39E-03	1.45E-04	8.79E-03
1987		7.18E-05	1.26E-04	3.28E-03	6.68E-04	6.93E-05	4.21E-03
1988		1.49E-05	2.62E-05	6.81E-04	1.39E-04	1.44E-05	8.76E-04
1989		1.97E-05	3.45E-05	8.97E-04	1.83E-04	1.90E-05	1.15E-03
1990		7.07E-07	1.24E-06	3.22E-05	6.57E-06	6.82E-07	4.14E-05
1991		1.69E-07	2.97E-07	7.72E-06	1.57E-06	1.63E-07	9.93E-06
1992		5.69E-07	9.99E-07	2.60E-05	5.29E-06	5.49E-07	3.34E-05
1993		8.44E-07	1.48E-06	3.85E-05	7.84E-06	8.14E-07	4.95E-05
1994		3.99E-07	7.00E-07	1.82E-05	3.71E-06	3.85E-07	2.34E-05
1995			2.06E-04	5.36E-03	1.09E-03	1.13E-04	6.77E-03
Totals		1.44E+01	2.52E+01	6.56E+02	1.34E+02	1.39E+01	8.43E+02
Percent		1.71%	2.99%	77.80%	15.86%	1.65%	

Table I-131. MEI Liquid-Pathway Doses

	Fish	Water	Shore	Swimming	Boating	Total Liquid Pathway
	(mrem)	(mrem)	(mrem)	(mrem)	(mrem)	(mrem)
1954						
1955						
1956						
1957	9.10E-02	2.34E-01	1.11E-04	2.67E-05	3.19E-05	3.25E-01
1958						
1959						
1960	3.40E-02	8.75E-02	4.13E-05	9.96E-06	1.19E-05	1.22E-01
1961	4.03E-02	1.04E-01	4.90E-05	1.18E-05	1.41E-05	1.44E-01
1962	1.22E-01	3.14E-01	1.48E-04	3.57E-05	4.27E-05	4.36E-01
1963	6.51E-02	1.67E-01	7.91E-05	1.91E-05	2.28E-05	2.33E-01
1964	1.22E-02	3.13E-02	1.48E-05	3.57E-06	4.26E-06	4.35E-02
1965	7.55E-03	1.94E-02	9.16E-06	2.21E-06	2.64E-06	2.70E-02
1966	4.23E-03	1.09E-02	5.13E-06	1.24E-06	1.48E-06	1.51E-02
1967	1.90E-02	4.90E-02	2.31E-05	5.58E-06	6.66E-06	6.80E-02
1968	1.33E-02	3.42E-02	1.61E-05	3.89E-06	4.65E-06	4.75E-02
1969	7.03E-03	1.81E-02	8.53E-06	2.06E-06	2.46E-06	2.51E-02
1970	3.04E-03	7.81E-03	3.69E-06	8.90E-07	1.06E-06	1.09E-02
1971	2.14E-03	5.51E-03	2.60E-06	6.27E-07	7.50E-07	7.65E-03
1972	1.30E-03	3.35E-03	1.58E-06	3.81E-07	4.56E-07	4.65E-03
1973	2.17E-04	5.58E-04	2.64E-07	6.36E-08	7.60E-08	7.75E-04
1974	1.96E-05	5.04E-05	2.38E-08	5.74E-09	6.86E-09	7.00E-05
1975						
1976	2.80E-06	7.20E-06	3.40E-09	8.20E-10	9.80E-10	1.00E-05
1977	1.74E-05	4.46E-05	2.11E-08	5.08E-09	6.08E-09	6.20E-05
1978	1.02E-06	2.61E-06	1.23E-09	2.98E-10	3.56E-10	3.63E-06
1979						
1980						
1981						
1982						
1983						
1984						
1985						
1986						
1987						
1988						
1989						
1990						
1991						
1992						
1993						
1994						
1995						
Totals	4.22E-01	1.09E+00	5.13E-04	1.24E-04	1.48E-04	1.51E+00
Percent	27.99%	71.96%	0.03%	0.01%	0.01%	

Table I-131. Population Liquid-Pathway Doses

	Aquatic Food	Water	Shore	Swimming	Boating	Total Liquid Pathway
	(per.-rem)	(per.-rem)	(per.-rem)	(per.-rem)	(per.-rem)	(per.-rem)
1954						
1955						
1956						
1957	7.93E-01	5.46E+00	4.55E-03	4.88E-04	1.69E-03	6.26E+00
1958						
1959						
1960	2.96E-01	2.04E+00	1.70E-03	1.82E-04	6.32E-04	2.34E+00
1961	3.51E-01	2.42E+00	2.02E-03	2.16E-04	7.49E-04	2.77E+00
1962	1.06E+00	7.32E+00	6.10E-03	6.53E-04	2.26E-03	8.39E+00
1963	5.67E-01	3.91E+00	3.26E-03	3.49E-04	1.21E-03	4.48E+00
1964	1.06E-01	7.31E-01	6.09E-04	6.53E-05	2.26E-04	8.38E-01
1965	6.58E-02	4.53E-01	3.77E-04	4.04E-05	1.40E-04	5.19E-01
1966	3.68E-02	2.54E-01	2.11E-04	2.27E-05	7.85E-05	2.91E-01
1967	1.66E-01	1.14E+00	9.52E-04	1.02E-04	3.54E-04	1.31E+00
1968	1.16E-01	7.97E-01	6.64E-04	7.12E-05	2.47E-04	9.14E-01
1969	6.12E-02	4.22E-01	3.51E-04	3.77E-05	1.31E-04	4.83E-01
1970	2.65E-02	1.82E-01	1.52E-04	1.63E-05	5.64E-05	2.09E-01
1971	1.87E-02	1.29E-01	1.07E-04	1.15E-05	3.98E-05	1.47E-01
1972	1.13E-02	7.81E-02	6.51E-05	6.98E-06	2.42E-05	8.96E-02
1973	1.89E-03	1.30E-02	1.09E-05	1.16E-06	4.03E-06	1.49E-02
1974	1.71E-04	1.18E-03	9.80E-07	1.05E-07	3.64E-07	1.35E-03
1975						
1976	2.44E-05	1.68E-04	1.40E-07	1.50E-08	5.20E-08	1.93E-04
1977	1.51E-04	1.04E-03	8.68E-07	9.30E-08	3.22E-07	1.19E-03
1978	8.86E-06	6.10E-05	5.08E-08	5.45E-09	1.89E-08	6.99E-05
1979						
1980						
1981						
1982						
1983						
1984						
1985						
1986						
1987						
1988						
1989						
1990						
1991						
1992						
1993						
1994						
1995						
Totals	3.68E+00	2.53E+01	2.11E-02	2.26E-03	7.85E-03	2.91E+01
Percent	12.67%	87.22%	0.07%	0.01%	0.03%	

Table I-131 Air. I-131 Atmospheric Releases and Maximally Exposed Individual Doses 1954 - 1995

Table I-131 Liquid. I-131 Liquid Releases and Maximally Exposed Individual Doses 1954 - 1995

I-133/135

Half-Life

I-133 - 20.8 hours

I-135 - 6.57 hours

Total Curies Released (1954-1995)

Air - 2.28E-01

Streams - 0.0

Basins (Decay Corrected) - 0.0

Total Cumulative Risks (1954-1995)

MEI Air Pathway - 2.13E-11

MEI Liquid Pathway - 0.0

Population Air - 3.75E-07

Population Liquid - 0.0

Projected 30-year Risks Using Recent Annual Doses (average of years 1991-1995)

MEI Air Pathway - 1.21E-10

MEI Liquid Pathway - 0.0

Population Air - 2.11E-06

Population Liquid - 0.0

Critical Pathways

MEI Air Pathway - Vegetation Consumption = 67%, Ground = 12%

MEI Liquid Pathway - N/A

Population Air Pathway - Inhalation = 66%, Ground = 26%

Population Liquid Pathway - N/A

Discussion

I-133/135 are very short-lived fission products that have been measured only in airborne effluents from SRTC. They occur because of the spontaneous fissioning of Cf-252 stored at SRTC (Kantelo and Crandall, 1993). The cumulative MEI air pathway risk from I-133/135 releases is much less than 1.0E-06. Future releases of I-133/135 are expected to remain negligible.

Table I-133/135. Effluent Releases

	I-133,135	I-133,135	I-133,135	I-133,135-Basin
	Air (Curies)	Streams (Curies)	Basins (Curies)	Decay Corrected (Ci)
1954				
1955				
1956				
1957				
1958				
1959				
1960				
1961				
1962				
1963				
1964				
1965				
1966				
1967				
1968				
1969				
1970				
1971				
1972				
1973	1.02E-02			
1974				
1975				
1976				
1977				
1978				
1979				
1980				
1981				
1982				
1983				
1984				
1985				
1986				
1987				
1988				
1989				
1990	2.73E-03			
1991	7.92E-05			
1992	1.35E-01			
1993	1.96E-03			
1994	4.01E-03			
1995	7.36E-02			
Totals	2.28E-01			

Table I-133/135. MEI Air-Pathway Doses

	Plume	Ground	Inhalation	Vegetation	Milk	Meat	Total Air Pathway
	(mrem)	(mrem)	(mrem)	(mrem)	(mrem)	(mrem)	(mrem)
1954							
1955							
1956							
1957							
1958							
1959							
1960							
1961							
1962							
1963							
1964							
1965							
1966							
1967							
1968							
1969							
1970							
1971							
1972							
1973		1.63E-07	1.43E-07	8.77E-07	1.22E-07	1.12E-09	1.31E-06
1974							
1975							
1976							
1977							
1978							
1979							
1980							
1981							
1982							
1983							
1984							
1985							
1986							
1987							
1988							
1989							
1990		4.37E-08	3.82E-08	2.35E-07	3.28E-08	3.00E-10	3.50E-07
1991		1.27E-09	1.11E-09	6.81E-09	9.50E-10	8.71E-12	1.01E-08
1992		2.16E-06	1.89E-06	1.16E-05	1.62E-06	1.49E-08	1.73E-05
1993		3.14E-08	2.74E-08	1.69E-07	2.35E-08	2.16E-10	2.51E-07
1994		6.42E-08	5.61E-08	3.45E-07	4.81E-08	4.41E-10	5.14E-07
1995		1.18E-06	1.03E-06	6.33E-06	8.83E-07	8.10E-09	9.43E-06
Totals		3.64E-06	3.19E-06	1.96E-05	2.73E-06	2.51E-08	2.92E-05
Percent		12.49%	10.93%	67.13%	9.37%	0.09%	

Table I-133/135. Population Air-Pathway Doses

	Plume	Ground	Inhalation	Vegetation	Milk	Meat	Total Air Pathway
	(per.-rem)	(per.-rem)	(per.-rem)	(per.-rem)	(per.-rem)	(per.-rem)	(per.-rem)
1954							
1955							
1956							
1957							
1958							
1959							
1960							
1961							
1962							
1963							
1964							
1965							
1966							
1967							
1968							
1969							
1970							
1971							
1972							
1973		8.98E-06	1.53E-05	3.26E-09	1.63E-06	2.04E-08	2.59E-05
1974							
1975							
1976							
1977							
1978							
1979							
1980							
1981							
1982							
1983							
1984							
1985							
1986							
1987							
1988							
1989							
1990		2.40E-06	4.10E-06	8.74E-10	4.37E-07	5.46E-09	6.94E-06
1991		6.97E-08	1.19E-07	2.53E-11	1.27E-08	1.58E-10	2.01E-07
1992		1.19E-04	2.03E-04	4.32E-08	2.16E-05	2.70E-07	3.44E-04
1993		1.72E-06	2.94E-06	6.27E-10	3.14E-07	3.92E-09	4.98E-06
1994		3.53E-06	6.02E-06	1.28E-09	6.42E-07	8.02E-09	1.02E-05
1995			1.10E-04	2.36E-08	1.18E-05	1.47E-07	1.22E-04
Totals		1.36E-04	3.42E-04	7.29E-08	3.64E-05	4.55E-07	5.14E-04
Percent		26.38%	66.43%	0.01%	7.09%	0.09%	

Table I-133/135 Air. I-133/135 Atmospheric Releases and Maximally Exposed Individual Doses 1954 - 1995

Kr-85

Half-Life

Kr-85 - 10.72 years

Total Curies Released (1954-1995)

Air - $2.05\text{E}+07$

Streams - 0.0

Basins (Decay Corrected) - 0.0

Total Cumulative Risks (1954-1995)

MEI Air Pathway - $4.49\text{E}-08$

MEI Liquid Pathway - 0.0

Population Air - $4.35\text{E}-03$

Population Liquid - 0.0

Projected 30-year Risks Using Recent Annual Doses (average of years 1991-1995)

MEI Air Pathway - $1.32\text{E}-10$

MEI Liquid Pathway - 0.0

Population Air - $1.28\text{E}-05$

Population Liquid - 0.0

Critical Pathways

MEI Air Pathway - Plume = 100%

MEI Liquid Pathway - N/A

Population Air Pathway - Plume = 100%

Population Liquid Pathway - N/A

Discussion

Kr-85 is a medium-lived, gaseous fission product. On a cumulative risk basis, Kr-85 was the 14th most important airborne radionuclide, but accounted for much less than 1% of the total cumulative MEI and population air pathway risks. Because the spent fuel rods stored at SRS still contain large quantities of Kr-85, it will continue to be of concern as long as dissolution processes continue in the Separations areas. The projected 30-year MEI air pathway risk is estimated to be much less than $1.0\text{E}-06$ and is much less than 1% of the site total. However, if dissolution processing increases as compared to the past 5 years, Kr-85 may assume greater importance, on a percentage-of-risk basis. Releases of Kr-85 prior to 1971 are not yet available in the open literature; so for purposes of dose calculations, they were estimated by assuming that each year's release was equal to the 1971-1986 average. Refer to Carlton, 1995 for a more complete assessment of noble gases, including Kr-85, at SRS.

Table Kr-85. Effluent Releases, and Air-Pathway MEI and Population Doses

	Kr-85	Max. Exp. Ind. Dose	Population Dose
	Air (Curies)	(mrem)	(person-rem)
1954			
1955	6.20E+05	1.86E-03	1.80E-01
1956	6.20E+05	1.86E-03	1.80E-01
1957	6.20E+05	1.86E-03	1.80E-01
1958	6.20E+05	1.86E-03	1.80E-01
1959	6.20E+05	1.86E-03	1.80E-01
1960	6.20E+05	1.86E-03	1.80E-01
1961	6.20E+05	1.86E-03	1.80E-01
1962	6.20E+05	1.86E-03	1.80E-01
1963	6.20E+05	1.86E-03	1.80E-01
1964	6.20E+05	1.86E-03	1.80E-01
1965	6.20E+05	1.86E-03	1.80E-01
1966	6.20E+05	1.86E-03	1.80E-01
1967	6.20E+05	1.86E-03	1.80E-01
1968	6.20E+05	1.86E-03	1.80E-01
1969	6.20E+05	1.86E-03	1.80E-01
1970	6.20E+05	1.86E-03	1.80E-01
1971	6.40E+05	1.92E-03	1.86E-01
1972	6.00E+05	1.80E-03	1.74E-01
1973	7.60E+05	2.28E-03	2.20E-01
1974	5.00E+05	1.50E-03	1.45E-01
1975	5.20E+05	1.56E-03	1.51E-01
1976	7.40E+05	2.22E-03	2.15E-01
1977	4.40E+05	1.32E-03	1.28E-01
1978	5.30E+05	1.59E-03	1.54E-01
1979	4.80E+05	1.44E-03	1.39E-01
1980	5.80E+05	1.74E-03	1.68E-01
1981	8.40E+05	2.52E-03	2.44E-01
1982	5.10E+05	1.53E-03	1.48E-01
1983	5.70E+05	1.71E-03	1.65E-01
1984	8.40E+05	2.52E-03	2.44E-01
1985	6.50E+05	1.95E-03	1.89E-01
1986	7.10E+05	2.13E-03	2.06E-01
1987	4.00E+05	1.20E-03	1.16E-01
1988	2.40E+05	7.20E-04	6.96E-02
1989	4.20E+04	1.26E-04	1.22E-02
1990	3.00E+03	9.00E-06	8.70E-04
1991	1.00E+04	3.00E-05	2.90E-03
1992	5.00E+01	1.50E-07	1.45E-05
1993			
1994			
1995			
Totals	2.05E+07	6.16E-02	5.95E+00

Table Kr-85 Air. Krypton-85 Atmospheric Releases and Maximally Exposed Individual Doses 1954 - 1995

Kr-85m

Half-Life

Kr-85m - 4.48 hours

Total Curies Released (1954-1995)

Air - 1.17E+05

Streams - 0.0

Basins (Decay Corrected) - 0.0

Total Cumulative Risks (1954-1995)

MEI Air Pathway - 1.58E-08

MEI Liquid Pathway - 0.0

Population Air - 9.40E-04

Population Liquid - 0.0

Projected 30-year Risks Using Recent Annual Doses (average of years 1991-1995)

MEI Air Pathway - 0.0

MEI Liquid Pathway - 0.0

Population Air - 0.0

Population Liquid - 0.0

Critical Pathways

MEI Air Pathway - Plume = 100%

MEI Liquid Pathway - N/A

Population Air Pathway - Plume = 100%

Population Liquid Pathway - N/A

Discussion

Kr-85m is a short-lived, gaseous fission product. On a cumulative risk basis, Kr-85m accounted for much less than 1% of the total cumulative MEI and population air pathway risks and was the 19th and 20th most important airborne radionuclide, respectively. Because all SRS reactors are now shut down, projected releases of, and risks from, Kr-85m are expected to remain nil. Refer to Carlton, 1995 for a more complete assessment of noble gases, including Kr-85m, at SRS.

Table Kr-85m. Effluent Releases and Air-Pathway MEI and Population Doses

	Kr-85m	Max. Exp. Ind. Dose	Population Dose
	Air (Curies)	(mrem)	(person-rem)
1954	4.00E+01	7.20E-06	4.40E-04
1955	1.00E+02	1.80E-05	1.10E-03
1956	3.00E+02	5.40E-05	3.30E-03
1957	7.00E+02	1.26E-04	7.70E-03
1958	1.80E+03	3.24E-04	1.98E-02
1959	3.40E+03	6.12E-04	3.74E-02
1960	4.60E+03	8.28E-04	5.06E-02
1961	2.40E+03	4.32E-04	2.64E-02
1962	1.80E+03	3.24E-04	1.98E-02
1963	7.00E+03	1.26E-03	7.70E-02
1964	9.00E+02	1.62E-04	9.90E-03
1965	2.00E+03	3.60E-04	2.20E-02
1966	2.40E+03	4.32E-04	2.64E-02
1967	3.30E+04	5.94E-03	3.63E-01
1968	1.30E+04	2.34E-03	1.43E-01
1969	5.40E+03	9.72E-04	5.94E-02
1970	2.40E+03	4.32E-04	2.64E-02
1971	3.10E+03	5.58E-04	3.41E-02
1972	7.40E+03	1.33E-03	8.14E-02
1973	6.60E+03	1.19E-03	7.26E-02
1974	1.30E+03	2.34E-04	1.43E-02
1975	3.70E+02	6.66E-05	4.07E-03
1976	3.80E+02	6.84E-05	4.18E-03
1977	8.40E+02	1.51E-04	9.24E-03
1978	9.00E+02	1.62E-04	9.90E-03
1979	1.80E+03	3.24E-04	1.98E-02
1980	3.20E+03	5.76E-04	3.52E-02
1981	1.30E+03	2.34E-04	1.43E-02
1982	1.30E+03	2.34E-04	1.43E-02
1983	1.20E+03	2.16E-04	1.32E-02
1984	1.20E+03	2.16E-04	1.32E-02
1985	1.30E+03	2.34E-04	1.43E-02
1986	2.00E+03	3.60E-04	2.20E-02
1987	1.50E+03	2.70E-04	1.65E-02
1988	1.80E+02	3.24E-05	1.98E-03
1989			
1990			
1991			
1992			
1993			
1994			
1995			
Totals	1.17E+05	2.11E-02	1.29E+00

Table Kr-85m Air. Kr-85m Atmospheric Releases and Maximally Exposed Individual Doses 1954 - 1995

Kr-87

Half-Life

Kr-87 - 76.3 minutes

Total Curies Released (1954-1995)

Air - 1.99E+04

Streams - 0.0

Basins (Decay Corrected) - 0.0

Total Cumulative Risks (1954-1995)

MEI Air Pathway - 8.29E-09

MEI Liquid Pathway - 0.0

Population Air - 1.89E-04

Population Liquid - 0.0

Projected 30-year Risks Using Recent Annual Doses (average of years 1991-1995)

MEI Air Pathway - 0.0

MEI Liquid Pathway - 0.0

Population Air - 0.0

Population Liquid - 0.0

Critical Pathways

MEI Air Pathway - Plume = 100%

MEI Liquid Pathway - N/A

Population Air Pathway - Plume = 100%

Population Liquid Pathway - N/A

Discussion

Kr-87 is a short-lived, gaseous fission product. On a cumulative risk basis, Kr-87 accounted for much less than 1% of the total cumulative MEI and population air pathway risks and was the 23rd and 22nd most important airborne radionuclide, respectively. Because all SRS reactors are now shut down, projected releases of, and risks from, Kr-87 are expected to remain nil. Refer to Carlton, 1995 for a more complete assessment of noble gases, including Kr-87, at SRS.

Table Kr-87. Effluent Releases and Air-Pathway MEI and Population Doses

	Kr-87	Max. Exp. Ind. Dose	Population Dose
	Air (Curies)	(mrem)	(person-rem)
1954			
1955			
1956			
1957			
1958			
1959			
1960			
1961			
1962			
1963			
1964			
1965			
1966			
1967			
1968			
1969			
1970			
1971			
1972	2.47E+03	1.41E-03	3.21E-02
1973	2.03E+03	1.16E-03	2.64E-02
1974	6.38E+02	3.64E-04	8.29E-03
1975	1.17E+03	6.67E-04	1.52E-02
1976	4.22E+02	2.41E-04	5.49E-03
1977	6.02E+02	3.43E-04	7.83E-03
1978	5.55E+02	3.16E-04	7.22E-03
1979	1.51E+03	8.61E-04	1.96E-02
1980	2.79E+03	1.59E-03	3.63E-02
1981	8.69E+02	4.95E-04	1.13E-02
1982	6.87E+02	3.92E-04	8.93E-03
1983	8.02E+02	4.57E-04	1.04E-02
1984	5.99E+02	3.41E-04	7.79E-03
1985	1.05E+03	5.99E-04	1.37E-02
1986	1.38E+03	7.87E-04	1.79E-02
1987	1.00E+03	5.70E-04	1.30E-02
1988	1.36E+03	7.75E-04	1.77E-02
1989			
1990			
1991			
1992			
1993			
1994			
1995			
Totals	1.99E+04	1.14E-02	2.59E-01

Table Kr-87 Air. Kr-87 Atmospheric Releases and Maximally Exposed Individual Doses 1954 - 1995

Kr-88

Half-Life

Kr-88 - 2.84 hours

Total Curies Released (1954-1995)

Air - 9.38E+04

Streams - 0.0

Basins (Decay Corrected) - 0.0

Total Cumulative Risks (1954-1995)

MEI Air Pathway - 1.99E-07

MEI Liquid Pathway - 0.0

Population Air - 8.90E-03

Population Liquid - 0.0

Projected 30-year Risks Using Recent Annual Doses (average of years 1991-1995)

MEI Air Pathway - 0.0

MEI Liquid Pathway - 0.0

Population Air - 0.0

Population Liquid - 0.0

Critical Pathways

MEI Air Pathway - Plume = 100%

MEI Liquid Pathway - N/A

Population Air Pathway - Plume = 100%

Population Liquid Pathway - N/A

Discussion

Kr-88 is a short-lived, gaseous fission product. On a cumulative risk basis, Kr-88 accounted for much less than 1% of the total cumulative MEI and population air pathway risks, but was the 12th most important airborne radionuclide. Because all SRS reactors are now shut down, projected releases of, and risks from, Kr-88 are expected to remain nil. Refer to Carlton, 1995 for a more complete assessment of noble gases, including Kr-88, at SRS.

Table Kr-88. Effluent Releases and Air-Pathway MEI and Population Doses

	Kr-88	Max. Exp. Ind. Dose	Population Dose
	Air (Curies)	(mrem)	(person-rem)
1954	4.00E+01	1.16E-04	5.20E-03
1955	1.00E+02	2.90E-04	1.30E-02
1956	2.00E+02	5.80E-04	2.60E-02
1957	6.00E+02	1.74E-03	7.80E-02
1958	1.70E+03	4.93E-03	2.21E-01
1959	3.20E+03	9.28E-03	4.16E-01
1960	4.80E+03	1.39E-02	6.24E-01
1961	2.30E+03	6.67E-03	2.99E-01
1962	1.70E+03	4.93E-03	2.21E-01
1963	6.30E+03	1.83E-02	8.19E-01
1964	5.00E+02	1.45E-03	6.50E-02
1965	1.20E+03	3.48E-03	1.56E-01
1966	1.50E+03	4.35E-03	1.95E-01
1967	2.04E+04	5.92E-02	2.65E+00
1968	8.10E+03	2.35E-02	1.05E+00
1969	3.50E+03	1.02E-02	4.55E-01
1970	1.60E+03	4.64E-03	2.08E-01
1971	1.73E+03	5.02E-03	2.25E-01
1972	4.21E+03	1.22E-02	5.47E-01
1973	7.38E+03	2.14E-02	9.59E-01
1974	1.41E+03	4.09E-03	1.83E-01
1975	8.58E+02	2.49E-03	1.12E-01
1976	5.08E+02	1.47E-03	6.60E-02
1977	6.71E+02	1.95E-03	8.72E-02
1978	8.40E+02	2.44E-03	1.09E-01
1979	2.25E+03	6.53E-03	2.93E-01
1980	3.98E+03	1.15E-02	5.17E-01
1981	1.48E+03	4.29E-03	1.92E-01
1982	1.20E+03	3.48E-03	1.56E-01
1983	1.29E+03	3.74E-03	1.68E-01
1984	9.23E+02	2.68E-03	1.20E-01
1985	1.28E+03	3.71E-03	1.66E-01
1986	2.43E+03	7.05E-03	3.16E-01
1987	2.01E+03	5.83E-03	2.61E-01
1988	1.61E+03	4.67E-03	2.09E-01
1989			
1990			
1991			
1992			
1993			
1994			
1995			
Totals	9.38E+04	2.72E-01	1.22E+01

Table Kr-88 Air. Kr-88 Atmospheric Releases and Maximally Exposed Individual Doses 1954 - 1995

Mn-54

Half-Life

Mn-54 - 312.5 days

Total Curies Released (1954-1995)

Air - 0.0

Streams - 6.41E-01

Basins (Decay Corrected) - 2.93E-10

Total Cumulative Risks (1954-1995)

MEI Air Pathway - 0.0

MEI Liquid Pathway - 1.20E-09

Population Air - 0.0

Population Liquid - 1.39E-05

Projected 30-year Risks Using Recent Annual Doses (average of years 1991-1995)

MEI Air Pathway - 0.0

MEI Liquid Pathway - 0.0

Population Air - 0.0

Population Liquid - 0.0

Critical Pathways

MEI Air Pathway - N/A

MEI Liquid Pathway - Fish Consumption = 86%, Water Consumption = 8%

Population Air Pathway - N/A

Population Liquid Pathway - Aquatic Food = 59%, Shore = 21%, Water = 20%

Discussion

Mn-54 is a medium-lived activation product that was released to site streams during just 2 years (1964 and 1977). The cumulative liquid pathway MEI risk from Mn-54 is less than 1.0E-06 and the cumulative MEI and population risks are much less than 1% of the site's total. Future releases of Mn-54 are expected to remain nil.

Table Mn-54. Effluent Releases

	Mn-54 to Air	Mn-54 to Streams	Mn-54 to Basins	Mn-54 to Basins
	Curies	Curies	Curies	Decay Corrected (Ci)
1954				
1955				
1956				
1957				
1958				
1959				
1960				
1961				
1962				
1963				
1964		6.20E-01		
1965				
1966				
1967				
1968				
1969				
1970				
1971				
1972				
1973				
1974				
1975				
1976				
1977		2.10E-02		
1978				
1979				
1980				
1981				
1982			1.10E-05	2.93E-10
1983				
1984				
1985				
1986				
1987				
1988				
1989				
1990				
1991				
1992				
1993				
1994				
1995				
Totals		6.41E-01	1.10E-05	2.93E-10

Table Mn-54. MEI Liquid-Pathway Doses

	Fish	Water	Shore	Swimming	Boating	Total Liquid Pathway
	(mrem)	(mrem)	(mrem)	(mrem)	(mrem)	(mrem)
1954						
1955						
1956						
1957						
1958						
1959						
1960						
1961						
1962						
1963						
1964	1.36E-03	1.30E-04	9.30E-05	6.20E-07	7.44E-07	1.59E-03
1965						
1966						
1967						
1968						
1969						
1970						
1971						
1972						
1973						
1974						
1975						
1976						
1977	4.62E-05	4.41E-06	3.15E-06	2.10E-08	2.52E-08	5.38E-05
1978						
1979						
1980						
1981						
1982						
1983						
1984						
1985						
1986						
1987						
1988						
1989						
1990						
1991						
1992						
1993						
1994						
1995						
Totals	1.41E-03	1.35E-04	9.62E-05	6.41E-07	7.69E-07	1.64E-03
Percent	85.86%	8.20%	5.85%	0.04%	0.05%	

Table Mn-54. Population Liquid-Pathway Doses

	Aquatic Food	Water	Shore	Swimming	Boating	Total Liquid Pathway
	(per.-rem)	(per.-rem)	(per.-rem)	(per.-rem)	(per.-rem)	(per.-rem)
1954						
1955						
1956						
1957						
1958						
1959						
1960						
1961						
1962						
1963						
1964	1.09E-02	3.72E-03	3.78E-03	1.12E-05	3.91E-05	1.84E-02
1965						
1966						
1967						
1968						
1969						
1970						
1971						
1972						
1973						
1974						
1975						
1976						
1977	3.68E-04	1.26E-04	1.28E-04	3.78E-07	1.32E-06	6.23E-04
1978						
1979						
1980						
1981						
1982						
1983						
1984						
1985						
1986						
1987						
1988						
1989						
1990						
1991						
1992						
1993						
1994						
1995						
Totals	1.12E-02	3.85E-03	3.91E-03	1.15E-05	4.04E-05	1.90E-02
Percent	58.96%	20.21%	20.55%	0.06%	0.21%	

Table Mn-54 Liquid. Mn-54 Liquid Releases and Maximally Exposed Individual Doses 1954 - 1995

Mo-99

Half-Life

Mo-99 - 66.0 hours

Total Curies Released (1954-1995)

Air - 0.0

Streams - 2.29E+01

Basins (Decay Corrected) - 0.0

Total Cumulative Risks (1954-1995)

MEI Air Pathway - 0.0

MEI Liquid Pathway - 4.76E-09

Population Air - 0.0

Population Liquid - 6.13E-05

Projected 30-year Risks Using Recent Annual Doses (average of years 1991-1995)

MEI Air Pathway - 0.0

MEI Liquid Pathway - 0.0

Population Air - 0.0

Population Liquid - 0.0

Critical Pathways

MEI Air Pathway - N/A

MEI Liquid Pathway - Water Consumption = 81%, Fish Consumption = 19%

Population Air Pathway - N/A

Population Liquid Pathway - Water Consumption = 99%, Aquatic Food = 1%

Discussion

Mo-99 is a short-lived fission product that was measured to have been released to site streams during just 3 years (1960, 1961 and 1962). The cumulative liquid pathway MEI risk from Mo-99 is less than 1.0E-06 and the cumulative MEI and population risks are much less than 1% of the site's total. Future releases of Mo-99 are expected to remain nil.

Table Mo-99. Effluent Releases

	Mo-99 - Air	Mo-99 - Streams	Mo-99 - Basins	Mo-99 - Basins
	Curies	Curies	Curies	Decay Corrected (Ci)
1954				
1955				
1956				
1957				
1958				
1959				
1960		1.03E+01		
1961		9.31E+00		
1962		3.26E+00		
1963				
1964				
1965				
1966				
1967				
1968				
1969				
1970				
1971				
1972				
1973				
1974				
1975				
1976				
1977				
1978				
1979				
1980				
1981				
1982				
1983				
1984				
1985				
1986				
1987				
1988				
1989				
1990				
1991				
1992				
1993				
1994				
1995				
Totals		2.29E+01		

Table Mo-99. MEI Liquid-Pathway Doses

	Fish	Water	Shore	Swimming	Boating	Total Liquid Pathway
	(mrem)	(mrem)	(mrem)	(mrem)	(mrem)	(mrem)
1954						
1955						
1956						
1957						
1958						
1959						
1960	5.56E-04	2.37E-03	3.61E-06	2.68E-06	3.09E-06	2.93E-03
1961	5.03E-04	2.14E-03	3.26E-06	2.42E-06	2.79E-06	2.65E-03
1962	1.76E-04	7.50E-04	1.14E-06	8.48E-07	9.78E-07	9.29E-04
1963						
1964						
1965						
1966						
1967						
1968						
1969						
1970						
1971						
1972						
1973						
1974						
1975						
1976						
1977						
1978						
1979						
1980						
1981						
1982						
1983						
1984						
1985						
1986						
1987						
1988						
1989						
1990						
1991						
1992						
1993						
1994						
1995						
Totals	1.23E-03	5.26E-03	8.00E-06	5.95E-06	6.86E-06	6.52E-03
Percent	18.95%	80.73%	0.12%	0.09%	0.11%	

Table Mo-99. Population Liquid-Pathway Doses

	Aquatic Food	Water	Shore	Swimming	Boating	Total Liquid Pathway
	(per.-rem)	(per.-rem)	(per.-rem)	(per.-rem)	(per.-rem)	(per.-rem)
1954						
1955						
1956						
1957						
1958						
1959						
1960	3.56E-04	3.71E-02	1.55E-04	4.74E-05	1.65E-04	3.78E-02
1961	3.22E-04	3.35E-02	1.40E-04	4.28E-05	1.49E-04	3.42E-02
1962	1.13E-04	1.17E-02	4.89E-05	1.50E-05	5.22E-05	1.20E-02
1963						
1964						
1965						
1966						
1967						
1968						
1969						
1970						
1971						
1972						
1973						
1974						
1975						
1976						
1977						
1978						
1979						
1980						
1981						
1982						
1983						
1984						
1985						
1986						
1987						
1988						
1989						
1990						
1991						
1992						
1993						
1994						
1995						
Totals	7.91E-04	8.23E-02	3.43E-04	1.05E-04	3.66E-04	8.39E-02
Percent	0.94%	98.09%	0.41%	0.13%	0.44%	

Table Mo-99 Liquid. Mo-99 Liquid Releases and Maximally Exposed Individual Doses 1954 - 1995

Nb-95

Half-Life

Nb-95 - 34.97 days

Total Curies Released (1954-1995)

Air - $1.08\text{E}+00$

Streams - $1.27\text{E}+02$

Basins (Decay Corrected) - $<1.00\text{E}-12$

Total Cumulative Risks (1954-1995)

MEI Air Pathway - $1.35\text{E}-09$

MEI Liquid Pathway - $1.21\text{E}-05$

Population Air - $5.83\text{E}-05$

Population Liquid - $2.08\text{E}-02$

Projected 30-year Risks Using Recent Annual Doses (average of years 1991-1995)

MEI Air Pathway - 0.0

MEI Liquid Pathway - 0.0

Population Air - 0.0

Population Liquid - 0.0

Critical Pathways

MEI Air Pathway - Ground = 44%, Meat = 38%

MEI Liquid Pathway - Fish Consumption = 99+%

Population Air Pathway - Ground = 65%, Meat = 18%

Population Liquid Pathway - Aquatic Food = 98%, Water Consumption = 2%

Discussion

Nb-95 is a short-lived, but abundant, fission product. On a cumulative MEI and population risk basis, Nb-95 was the 25th and 24th most important air pathway radionuclide, respectively and the 3rd and 9th most important liquid pathway radionuclide, respectively. The fish consumption and aquatic food pathways are the most critical for Nb-95 due to its very high (30,000) bioaccumulation factor in freshwater fish (NRC, 1977a). Because Nb-95 has a much greater liquid pathway dose factor than Zr-95, measured liquid releases of Zr-Nb-95 are conservatively added with Nb-95 releases for dose and risk calculations. Future releases of Nb-95 are expected to remain nil.

Table Nb-95. Effluent Releases

	Nb-95 - Air	Zr/Nb-95 - Streams	Zr/Nb-95 - Basins	Zr/Nb-95 - Basins
	Curies	Curies	Curies	Decay Corrected (Ci)
1954				
1955				
1956				
1957				
1958				
1959				
1960		7.43E+00	1.84E+02	<1.00E-12
1961		6.98E+00	6.39E+01	<1.00E-12
1962		1.71E+01	2.95E+01	<1.00E-12
1963		3.21E+01	6.88E+01	<1.00E-12
1964		1.97E+01	1.57E+02	<1.00E-12
1965		6.13E+00	3.97E+01	<1.00E-12
1966		7.94E+00	3.85E+01	<1.00E-12
1967		1.38E+01	3.79E+01	<1.00E-12
1968		8.11E+00	2.09E+01	<1.00E-12
1969		3.58E+00	1.67E+01	<1.00E-12
1970		2.81E+00	3.21E+01	<1.00E-12
1971	3.46E-01	8.93E-01	4.52E+00	<1.00E-12
1972	2.02E-01	9.90E-02	9.86E+00	<1.00E-12
1973	7.55E-02	1.92E-01	1.39E+01	<1.00E-12
1974	1.23E-01	2.36E-01	4.95E+00	<1.00E-12
1975	2.42E-02	3.90E-02	9.03E-01	<1.00E-12
1976	2.69E-02	1.70E-02	3.52E+00	<1.00E-12
1977	3.74E-02	9.38E-02	1.52E+00	<1.00E-12
1978	1.97E-02	3.47E-04	1.53E+00	<1.00E-12
1979	2.65E-02		1.40E+00	<1.00E-12
1980	1.79E-02		1.94E+00	<1.00E-12
1981	6.36E-02		4.11E+00	<1.00E-12
1982	1.59E-02		4.07E+00	<1.00E-12
1983	1.80E-02		3.25E+00	<1.00E-12
1984	1.91E-02		4.84E+00	<1.00E-12
1985	4.87E-02		8.73E+00	<1.00E-12
1986	9.18E-03		9.72E-01	<1.00E-12
1987	3.29E-03		1.87E-01	<1.00E-12
1988	2.22E-03		2.44E-02	<1.00E-12
1989	1.28E-04	1.40E-05	2.59E-06	<1.00E-12
1990				
1991				
1992				
1993				
1994				
1995				
Totals	1.08E+00	1.27E+02	7.59E+02	<1.00E-12

Table Nb-95. MEI Air-Pathway Doses

	Plume (mrem)	Ground (mrem)	Inhalation (mrem)	Vegetation (mrem)	Milk (mrem)	Meat (mrem)	Total Air Pathway (mrem)
1954							
1955							
1956							
1957							
1958							
1959							
1960							
1961							
1962							
1963							
1964							
1965							
1966							
1967							
1968							
1969							
1970							
1971		2.63E-04	4.15E-06	9.34E-05	5.54E-06	2.28E-04	5.94E-04
1972		1.54E-04	2.42E-06	5.45E-05	3.23E-06	1.33E-04	3.47E-04
1973		5.74E-05	9.06E-07	2.04E-05	1.21E-06	4.98E-05	1.30E-04
1974		9.35E-05	1.48E-06	3.32E-05	1.97E-06	8.12E-05	2.11E-04
1975		1.84E-05	2.90E-07	6.53E-06	3.87E-07	1.60E-05	4.16E-05
1976		2.04E-05	3.23E-07	7.26E-06	4.30E-07	1.78E-05	4.62E-05
1977		2.84E-05	4.49E-07	1.01E-05	5.98E-07	2.47E-05	6.43E-05
1978		1.50E-05	2.36E-07	5.32E-06	3.15E-07	1.30E-05	3.38E-05
1979		2.01E-05	3.18E-07	7.16E-06	4.24E-07	1.75E-05	4.55E-05
1980		1.36E-05	2.15E-07	4.83E-06	2.86E-07	1.18E-05	3.08E-05
1981		4.83E-05	7.63E-07	1.72E-05	1.02E-06	4.20E-05	1.09E-04
1982		1.21E-05	1.91E-07	4.29E-06	2.54E-07	1.05E-05	2.73E-05
1983		1.37E-05	2.16E-07	4.86E-06	2.88E-07	1.19E-05	3.09E-05
1984		1.45E-05	2.29E-07	5.16E-06	3.06E-07	1.26E-05	3.28E-05
1985		3.70E-05	5.84E-07	1.31E-05	7.79E-07	3.21E-05	8.37E-05
1986		6.98E-06	1.10E-07	2.48E-06	1.47E-07	6.06E-06	1.58E-05
1987		2.50E-06	3.95E-08	8.88E-07	5.26E-08	2.17E-06	5.65E-06
1988		1.69E-06	2.66E-08	5.99E-07	3.55E-08	1.47E-06	3.81E-06
1989		9.73E-08	1.54E-09	3.46E-08	2.05E-09	8.45E-08	2.20E-07
1990							
1991							
1992							
1993							
1994							
1995							
Totals		8.20E-04	1.30E-05	2.91E-04	1.73E-05	7.12E-04	1.85E-03
Percent		44.24%	0.70%	15.72%	0.93%	38.42%	

Table Nb-95. Population Air-Pathway Doses

	Plume	Ground	Inhalation	Vegetation	Milk	Meat	Total Air Pathway
	(per.-rem)	(per.-rem)	(per.-rem)	(per.-rem)	(per.-rem)	(per.-rem)	(per.-rem)
1954							
1955							
1956							
1957							
1958							
1959							
1960							
1961							
1962							
1963							
1964							
1965							
1966							
1967							
1968							
1969							
1970							
1971		1.66E-02	5.19E-04	3.81E-03	1.90E-04	4.50E-03	2.56E-02
1972		9.70E-03	3.03E-04	2.22E-03	1.11E-04	2.63E-03	1.50E-02
1973		3.62E-03	1.13E-04	8.31E-04	4.15E-05	9.82E-04	5.59E-03
1974		5.90E-03	1.85E-04	1.35E-03	6.77E-05	1.60E-03	9.11E-03
1975		1.16E-03	3.63E-05	2.66E-04	1.33E-05	3.15E-04	1.79E-03
1976		1.29E-03	4.04E-05	2.96E-04	1.48E-05	3.50E-04	1.99E-03
1977		1.80E-03	5.61E-05	4.11E-04	2.06E-05	4.86E-04	2.77E-03
1978		9.46E-04	2.96E-05	2.17E-04	1.08E-05	2.56E-04	1.46E-03
1979		1.27E-03	3.98E-05	2.92E-04	1.46E-05	3.45E-04	1.96E-03
1980		8.59E-04	2.69E-05	1.97E-04	9.85E-06	2.33E-04	1.33E-03
1981		3.05E-03	9.54E-05	7.00E-04	3.50E-05	8.27E-04	4.71E-03
1982		7.63E-04	2.39E-05	1.75E-04	8.75E-06	2.07E-04	1.18E-03
1983		8.64E-04	2.70E-05	1.98E-04	9.90E-06	2.34E-04	1.33E-03
1984		9.17E-04	2.87E-05	2.10E-04	1.05E-05	2.48E-04	1.41E-03
1985		2.34E-03	7.31E-05	5.36E-04	2.68E-05	6.33E-04	3.61E-03
1986		4.41E-04	1.38E-05	1.01E-04	5.05E-06	1.19E-04	6.80E-04
1987		1.58E-04	4.94E-06	3.62E-05	1.81E-06	4.28E-05	2.44E-04
1988		1.07E-04	3.33E-06	2.44E-05	1.22E-06	2.89E-05	1.64E-04
1989		6.14E-06	1.92E-07	1.41E-06	7.04E-08	1.66E-06	9.48E-06
1990							
1991							
1992							
1993							
1994							
1995							
Totals		5.18E-02	1.62E-03	1.19E-02	5.94E-04	1.40E-02	7.99E-02
Percent		64.82%	2.03%	14.85%	0.74%	17.56%	

Table Nb-95. MEI Liquid-Pathway Doses

	Fish	Water	Shore	Swimming	Boating	Total Liquid Pathway
	(mrem)	(mrem)	(mrem)	(mrem)	(mrem)	(mrem)
1954						
1955						
1956						
1957						
1958						
1959						
1960	9.66E-01	1.26E-03	1.11E-04	6.76E-06	8.17E-06	9.67E-01
1961	9.07E-01	1.19E-03	1.05E-04	6.35E-06	7.68E-06	9.09E-01
1962	2.22E+00	2.91E-03	2.57E-04	1.56E-05	1.88E-05	2.23E+00
1963	4.17E+00	5.46E-03	4.82E-04	2.92E-05	3.53E-05	4.18E+00
1964	2.56E+00	3.35E-03	2.96E-04	1.79E-05	2.17E-05	2.56E+00
1965	7.97E-01	1.04E-03	9.20E-05	5.58E-06	6.74E-06	7.98E-01
1966	1.03E+00	1.35E-03	1.19E-04	7.23E-06	8.73E-06	1.03E+00
1967	1.79E+00	2.35E-03	2.07E-04	1.26E-05	1.52E-05	1.80E+00
1968	1.05E+00	1.38E-03	1.22E-04	7.38E-06	8.92E-06	1.06E+00
1969	4.65E-01	6.09E-04	5.37E-05	3.26E-06	3.94E-06	4.66E-01
1970	3.65E-01	4.78E-04	4.22E-05	2.56E-06	3.09E-06	3.66E-01
1971	1.16E-01	1.52E-04	1.34E-05	8.13E-07	9.82E-07	1.16E-01
1972	1.29E-02	1.68E-05	1.49E-06	9.01E-08	1.09E-07	1.29E-02
1973	2.50E-02	3.26E-05	2.88E-06	1.75E-07	2.11E-07	2.50E-02
1974	3.07E-02	4.01E-05	3.54E-06	2.15E-07	2.60E-07	3.07E-02
1975	5.07E-03	6.63E-06	5.85E-07	3.55E-08	4.29E-08	5.08E-03
1976	2.21E-03	2.89E-06	2.55E-07	1.55E-08	1.87E-08	2.21E-03
1977	1.22E-02	1.59E-05	1.41E-06	8.54E-08	1.03E-07	1.22E-02
1978	4.51E-05	5.90E-08	5.21E-09	3.16E-10	3.82E-10	4.52E-05
1979						
1980						
1981						
1982						
1983						
1984						
1985						
1986						
1987						
1988						
1989	1.82E-06	2.38E-09	2.10E-10	1.27E-11	1.54E-11	1.82E-06
1990						
1991						
1992						
1993						
1994						
1995						
Totals	1.65E+01	2.16E-02	1.91E-03	1.16E-04	1.40E-04	1.66E+01
Percent	99.86%	0.13%	0.01%	0.00%	0.00%	

Table Nb-95 Air. Nb-95 Atmospheric Releases and Maximally Exposed Individual Doses 1954 - 1995

Table Nb-Zr-95 Liquid. Nb-Zr-95 Liquid Releases and Maximally Exposed Individual Doses 1954 - 1995

Np-239

Half-Life

Np-239 - 2.35 days

Total Curies Released (1954-1995)

Air - 0.0

Streams - $1.43\text{E}+03$

Basins (Decay Corrected) - $<1.00\text{E}-12$

Total Cumulative Risks (1954-1995)

MEI Air Pathway - 0.0

MEI Liquid Pathway - $1.91\text{E}-07$

Population Air - 0.0

Population Liquid - $2.12\text{E}-03$

Projected 30-year Risks Using Recent Annual Doses (average of years 1991-1995)

MEI Air Pathway - 0.0

MEI Liquid Pathway - 0.0

Population Air - 0.0

Population Liquid - 0.0

Critical Pathways

MEI Air Pathway - N/A

MEI Liquid Pathway - Water Consumption = 82%, Fish Consumption = 18%

Population Air Pathway - N/A

Population Liquid Pathway - Water Consumption = 98%, Aquatic Food = 1%

Discussion

Np-239 is a short-lived activation product that has not been measured in site stream or basin effluents since 1976. The cumulative liquid pathway MEI risk from Np-239 releases is less than $2.0\text{E}-07$ and the cumulative MEI and population risks are much less than 1% of the site's total. Future releases of Np-239 are expected to remain nil.

Table Np-239. Effluent Releases

	Np-239	Np-239	Np-239	Np-239-Basin
	Air (Curies)	Streams (Curies)	Basins (Curies)	Decay Corrected (Ci)
1954				
1955				
1956				
1957				
1958				
1959				
1960		5.50E+01		
1961		1.31E+02		
1962		9.09E+01		
1963		7.84E+02		
1964		1.81E+02	1.10E-01	
1965		7.43E+01	1.10E-01	
1966		2.79E+01		
1967		3.64E+01	5.00E-03	
1968		2.02E+01	8.76E+00	
1969		2.57E+01	1.02E+00	
1970		4.70E-01	2.40E-01	
1971		1.63E+00		
1972		3.00E-02		
1973		1.10E-02	1.00E-03	
1974		8.00E-03	1.00E-03	
1975		8.00E-03		
1976			1.00E-03	
1977				
1978				
1979				
1980				
1981				
1982				
1983				
1984				
1985				
1986				
1987				
1988				
1989				
1990				
1991				
1992				
1993				
1994				
1995				
Totals		1.43E+03	1.02E+01	

Table Np-239. MEI Liquid-Pathway Doses

	Fish	Water	Shore	Swimming	Boating	Total Liquid Pathway
	(mrem)	(mrem)	(mrem)	(mrem)	(mrem)	(mrem)
1954						
1955						
1956						
1957						
1958						
1959						
1960	1.82E-03	8.25E-03	1.05E-05	8.25E-06	9.90E-06	1.01E-02
1961	4.32E-03	1.97E-02	2.49E-05	1.97E-05	2.36E-05	2.40E-02
1962	3.00E-03	1.36E-02	1.73E-05	1.36E-05	1.64E-05	1.67E-02
1963	2.59E-02	1.18E-01	1.49E-04	1.18E-04	1.41E-04	1.44E-01
1964	5.97E-03	2.72E-02	3.44E-05	2.72E-05	3.26E-05	3.32E-02
1965	2.45E-03	1.11E-02	1.41E-05	1.11E-05	1.34E-05	1.36E-02
1966	9.21E-04	4.19E-03	5.30E-06	4.19E-06	5.02E-06	5.12E-03
1967	1.20E-03	5.46E-03	6.92E-06	5.46E-06	6.55E-06	6.68E-03
1968	6.67E-04	3.03E-03	3.84E-06	3.03E-06	3.64E-06	3.71E-03
1969	8.48E-04	3.86E-03	4.88E-06	3.86E-06	4.63E-06	4.72E-03
1970	1.55E-05	7.05E-05	8.93E-08	7.05E-08	8.46E-08	8.63E-05
1971	5.38E-05	2.45E-04	3.10E-07	2.45E-07	2.93E-07	2.99E-04
1972	9.90E-07	4.50E-06	5.70E-09	4.50E-09	5.40E-09	5.51E-06
1973	3.63E-07	1.65E-06	2.09E-09	1.65E-09	1.98E-09	2.02E-06
1974	2.64E-07	1.20E-06	1.52E-09	1.20E-09	1.44E-09	1.47E-06
1975	2.64E-07	1.20E-06	1.52E-09	1.20E-09	1.44E-09	1.47E-06
1976						
1977						
1978						
1979						
1980						
1981						
1982						
1983						
1984						
1985						
1986						
1987						
1988						
1989						
1990						
1991						
1992						
1993						
1994						
1995						
Totals	4.71E-02	2.14E-01	2.71E-04	2.14E-04	2.57E-04	2.62E-01
Percent	17.98%	81.73%	0.10%	0.08%	0.10%	

Table Np-239. Population Liquid-Pathway Doses

	Aquatic Food	Water	Shore	Swimming	Boating	Total Liquid Pathway
	(per.-rem)	(per.-rem)	(per.-rem)	(per.-rem)	(per.-rem)	(per.-rem)
1954						
1955						
1956						
1957						
1958						
1959						
1960	7.54E-04	1.10E-01	4.29E-04	1.49E-04	5.17E-04	1.12E-01
1961	1.79E-03	2.62E-01	1.02E-03	3.54E-04	1.23E-03	2.66E-01
1962	1.25E-03	1.82E-01	7.09E-04	2.45E-04	8.54E-04	1.85E-01
1963	1.07E-02	1.57E+00	6.12E-03	2.12E-03	7.37E-03	1.59E+00
1964	2.48E-03	3.62E-01	1.41E-03	4.89E-04	1.70E-03	3.68E-01
1965	1.02E-03	1.49E-01	5.80E-04	2.01E-04	6.98E-04	1.51E-01
1966	3.82E-04	5.58E-02	2.18E-04	7.53E-05	2.62E-04	5.67E-02
1967	4.99E-04	7.28E-02	2.84E-04	9.83E-05	3.42E-04	7.40E-02
1968	2.77E-04	4.04E-02	1.58E-04	5.45E-05	1.90E-04	4.11E-02
1969	3.52E-04	5.14E-02	2.00E-04	6.94E-05	2.42E-04	5.23E-02
1970	6.44E-06	9.40E-04	3.67E-06	1.27E-06	4.42E-06	9.56E-04
1971	2.23E-05	3.26E-03	1.27E-05	4.40E-06	1.53E-05	3.31E-03
1972	4.11E-07	6.00E-05	2.34E-07	8.10E-08	2.82E-07	6.10E-05
1973	1.51E-07	2.20E-05	8.58E-08	2.97E-08	1.03E-07	2.24E-05
1974	1.10E-07	1.60E-05	6.24E-08	2.16E-08	7.52E-08	1.63E-05
1975	1.10E-07	1.60E-05	6.24E-08	2.16E-08	7.52E-08	1.63E-05
1976						
1977						
1978						
1979						
1980						
1981						
1982						
1983						
1984						
1985						
1986						
1987						
1988						
1989						
1990						
1991						
1992						
1993						
1994						
1995						
Totals	1.96E-02	2.86E+00	1.11E-02	3.86E-03	1.34E-02	2.91E+00
Percent	0.67%	98.35%	0.38%	0.13%	0.46%	

Table Np-239 Liquid. Np-239 Liquid Releases and Maximally Exposed Individual Doses 1954 - 1995

Os-185

Half-Life

Os-185 - 93.6 days

Total Curies Released (1954-1995)

Air - 1.77E-03

Streams - 0.0

Basins (Decay Corrected) - 0.0

Total Cumulative Risks (1954-1995)

MEI Air Pathway -	Not Calculated	MEI Liquid Pathway -	0.0
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Population Air -	Not Calculated	Population Liquid -	0.0
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Projected 30-year Risks Using Recent Annual Doses (average of years 1991-1995)

MEI Air Pathway -	Not Calculated	MEI Liquid Pathway -	0.0
-------------------	----------------	----------------------	-----

Population Air -	Not Calculated	Population Liquid -	0.0
------------------	----------------	---------------------	-----

Critical Pathways

MEI Air Pathway - N/A

MEI Liquid Pathway - N/A

Population Air Pathway - N/A

Population Liquid Pathway - N/A

Discussion

Os-185 is a short-lived fission product that was measured to have been released to the atmosphere only during six years (1983-1988). The MAXIGASP dosimetry code does not have Os-185 in its radionuclide library, therefore, doses and risks were not calculated. However, because of the small amount released and its relatively short half-life, Os-185 is not of concern on a cumulative or projected risk basis.

Table Os-185. Effluent Releases

	Os-185	Os-185	Os-185	Os-185 - Basin
	Air (Curies)	Streams (Curies)	Basins (Curies)	Decay Corrected (Ci)
1954				
1955				
1956				
1957				
1958				
1959				
1960				
1961				
1962				
1963				
1964				
1965				
1966				
1967				
1968				
1969				
1970				
1971				
1972				
1973				
1974				
1975				
1976				
1977				
1978				
1979				
1980				
1981				
1982				
1983	5.50E-04			
1984	4.00E-04			
1985	5.80E-04			
1986	1.40E-04			
1987	7.00E-05			
1988	3.00E-05			
1989				
1990				
1991				
1992				
1993				
1994				
1995				

P-32

Half-Life

P-32 14.29 days

Total Curies Released (1954-1995)

Air - 0.0

Streams - $3.63\text{E}+01$

Basins (Decay Corrected) - $<1.00\text{E}-12$

Total Cumulative Risks (1954-1995)

MEI Air Pathway - 0.0

MEI Liquid Pathway - $3.72\text{E}-05$

Population Air - 0.0

Population Liquid - $9.16\text{E}-02$

Projected 30-year Risks Using Recent Annual Doses (average of years 1991-1995)

MEI Air Pathway - 0.0

MEI Liquid Pathway - 0.0

Population Air - 0.0

Population Liquid - 0.0

Critical Pathways

MEI Air Pathway - N/A

MEI Liquid Pathway - Fish Consumption = 100%

Population Air Pathway - N/A

Population Liquid Pathway - Aquatic Food = 100%

Discussion

P-32 is a short-lived activation product that has not been measured in site airborne effluents and has not been measured in liquid effluents to site streams since 1990. However, on a cumulative MEI and population risk basis, P-32 was the 2nd and 4th most important liquid pathway radionuclide, respectively. The cumulative MEI risk was estimated to be $3.7\text{E}-05$, which is 18% of the site total.

The fish consumption and aquatic food pathways are the most critical for P-32 due to its very high bioaccumulation factor in freshwater fish (100,000) and saltwater invertebrates (30,000) (NRC, 1977a). Future releases of P-32 are expected to remain nil. Refer to Carlton, 1996 for a more complete assessment of P-32 at SRS.

Table P-32. Effluent Releases

	P-32 to Air Curies	P-32 to Streams Curies	P-32 to Basins Curies	P-32 to Basins Decay Corrected (Ci)
1954				
1955				
1956				
1957				
1958				
1959				
1960				
1961				
1962				
1963				
1964		3.07E+00		
1965		1.36E+01	3.70E+01	8.42E-230
1966		1.02E+01	1.14E+02	1.26E-221
1967		4.13E+00	9.00E+00	4.87E-215
1968		2.44E+00		
1969		7.30E-01		
1970		7.70E-01		
1971		9.20E-01		
1972		3.00E-01		
1973		1.33E-01	1.80E-02	1.31E-171
1974		1.40E-02	2.20E-02	7.80E-164
1975		2.00E-03	8.00E-03	1.38E-156
1976		1.70E-02	9.00E-03	7.59E-149
1977		6.44E-03	2.20E-02	9.05E-141
1978		2.66E-05	3.65E-03	7.32E-134
1979		4.00E-03	2.02E-03	1.98E-126
1980			1.87E-03	8.92E-119
1981			3.70E-03	8.61E-111
1982			6.86E-03	7.78E-103
1983			1.59E-02	8.78E-95
1984			3.03E-03	8.17E-88
1985			6.11E-04	8.04E-81
1986			8.50E-05	5.45E-74
1987			1.27E-05	3.97E-67
1988			9.82E-06	1.50E-59
1989			2.07E-04	1.54E-50
1990		1.52E-05	2.60E-03	9.43E-42
1991				
1992				
1993				
1994				
1995				
Totals		3.63E+01	1.60E+02	9.43E-42

Table P-32. MEI Liquid-Pathway Doses

	Fish	Water	Shore	Swimming	Boating	Total Liquid Pathway
	(mrem)	(mrem)	(mrem)	(mrem)	(mrem)	(mrem)
1954						
1955						
1956						
1957						
1958						
1959						
1960						
1961						
1962						
1963						
1964	4.30E+00	1.72E-03				4.30E+00
1965	1.90E+01	7.62E-03				1.90E+01
1966	1.43E+01	5.71E-03				1.43E+01
1967	5.78E+00	2.31E-03				5.78E+00
1968	3.42E+00	1.37E-03				3.42E+00
1969	1.02E+00	4.09E-04				1.02E+00
1970	1.08E+00	4.31E-04				1.08E+00
1971	1.29E+00	5.15E-04				1.29E+00
1972	4.20E-01	1.68E-04				4.20E-01
1973	1.86E-01	7.45E-05				1.86E-01
1974	1.96E-02	7.84E-06				1.96E-02
1975	2.80E-03	1.12E-06				2.80E-03
1976	2.38E-02	9.52E-06				2.38E-02
1977	9.02E-03	3.61E-06				9.02E-03
1978	3.72E-05	1.49E-08				3.73E-05
1979	5.60E-03	2.24E-06				5.60E-03
1980						
1981						
1982						
1983						
1984						
1985						
1986						
1987						
1988						
1989						
1990	2.13E-05	8.51E-09				2.13E-05
1991						
1992						
1993						
1994						
1995						
Totals	5.09E+01	2.03E-02				5.09E+01
Percent	99.96%	0.04%				

Table P-32. Population Liquid-Pathway Doses

	Aquatic Food	Water	Shore	Swimming	Boating	Total Liquid Pathway
	(per.-rem)	(per.-rem)	(per.-rem)	(per.-rem)	(per.-rem)	(per.-rem)
1954						
1955						
1956						
1957						
1958						
1959						
1960						
1961						
1962						
1963						
1964	1.06E+01	4.30E-02				1.06E+01
1965	4.68E+01	1.90E-01				4.70E+01
1966	3.51E+01	1.43E-01				3.52E+01
1967	1.42E+01	5.78E-02				1.43E+01
1968	8.39E+00	3.42E-02				8.43E+00
1969	2.51E+00	1.02E-02				2.52E+00
1970	2.65E+00	1.08E-02				2.66E+00
1971	3.16E+00	1.29E-02				3.18E+00
1972	1.03E+00	4.20E-03				1.04E+00
1973	4.58E-01	1.86E-03				4.59E-01
1974	4.82E-02	1.96E-04				4.84E-02
1975	6.88E-03	2.80E-05				6.91E-03
1976	5.85E-02	2.38E-04				5.87E-02
1977	2.22E-02	9.02E-05				2.22E-02
1978	9.15E-05	3.72E-07				9.19E-05
1979	1.38E-02	5.60E-05				1.38E-02
1980						
1981						
1982						
1983						
1984						
1985						
1986						
1987						
1988						
1989						
1990	5.23E-05	2.13E-07				5.25E-05
1991						
1992						
1993						
1994						
1995						
Totals	1.25E+02	5.09E-01				1.26E+02
Percent	99.59%	0.41%				

Table P-32 Liquid. P-32 Liquid Releases and Maximally Exposed Individual Doses 1954 - 1995

Pm-147

Half-Life

Pm-147 - 2.62 years

Total Curies Released (1954-1995)

Air - 0.0

Streams - 1.10E+02

Basins (Decay Corrected) - 3.80E-01

Total Cumulative Risks (1954-1995)

MEI Air Pathway - 0.0

MEI Liquid Pathway - 9.78E-09

Population Air - 0.0

Population Liquid - 1.13E-03

Projected 30-year Risks Using Recent Annual Doses (average of years 1991-1995)

MEI Air Pathway - 0.0

MEI Liquid Pathway - 9.66E-12

Population Air - 0.0

Population Liquid - 1.12E-06

Critical Pathways

MEI Air Pathway - N/A

MEI Liquid Pathway - Water Consumption = 60%, Fish Consumption = 40%

Population Air Pathway - N/A

Population Liquid Pathway - Aquatic Food = 85%, Water Consumption = 15%

Discussion

Pm-147 is a medium-lived fission product that has been measured only in liquid effluents. On a cumulative MEI and population risk basis, Pm-147 was the 22nd and 21st most important liquid pathway radionuclide, respectively. The cumulative and projected 30-year MEI liquid pathway risks are estimated to be much less than 1.0E-06 and are much less than 1% of the site total. Estimated residual inventories (3.9E+05 Ci) of Pm-147 are relatively high. However, because Pm-147 is a weak beta emitter with a subsequently low internal dose factor (DOE, 1988b), and because of its relatively short half-life, it should remain of low importance, on a percentage-of-risk basis, in the future.

Table Pm-147. Effluent Releases

	Pm-147	Pm-147	Pm-147	Pm-147-Basin
	Air (Curies)	Streams (Curies)	Basins (Curies)	Decay Corrected (Ci)
1954		6.00E-03		
1955		2.24E-01	1.38E+00	3.54E-05
1956		6.06E-01	3.56E+00	1.19E-04
1957		1.64E+00	4.81E+00	2.09E-04
1958		1.07E+00	4.08E+00	2.31E-04
1959		2.65E+00	1.41E+01	1.04E-03
1960		7.79E+00	2.13E+01	2.05E-03
1961		6.33E+00	6.57E+00	8.23E-04
1962		1.27E+01	1.42E+01	2.32E-03
1963		5.07E+00	1.46E+01	3.10E-03
1964		3.11E+00	3.37E+01	9.33E-03
1965		1.21E+01	1.31E+01	4.72E-03
1966		8.46E+00	4.90E+00	2.30E-03
1967		1.59E+01	2.39E+00	1.46E-03
1968		1.15E+01	7.08E+00	5.64E-03
1969		1.46E+01	6.56E+00	6.81E-03
1970		4.50E+00	3.59E+00	4.85E-03
1971		1.20E+00	2.18E+00	3.84E-03
1972		7.00E-03	1.90E+00	4.36E-03
1973		6.87E-02	2.05E+00	6.12E-03
1974		5.30E-02	1.15E+00	4.47E-03
1975		3.40E-02	1.36E+00	6.89E-03
1976		9.40E-02	8.43E-01	5.56E-03
1977		2.90E-02	2.95E-01	2.54E-03
1978		3.17E-03	5.55E-01	6.21E-03
1979			2.91E-01	4.24E-03
1980			1.23E-01	2.34E-03
1981			5.64E-01	1.39E-02
1982			4.76E-01	1.53E-02
1983			6.65E-02	2.79E-03
1984			3.54E-01	1.93E-02
1985			4.34E-01	3.09E-02
1986			1.39E+00	1.29E-01
1987			5.02E-01	6.06E-02
1988		1.97E-02	1.06E-01	1.67E-02
1989		3.30E-02	1.60E-04	3.28E-05
1990		2.13E-02	1.63E-05	4.35E-06
1991		6.63E-03	5.84E-04	2.03E-04
1992		2.45E-04		
1993		7.03E-03		
1994		1.54E-03		
1995		2.63E-03		
Totals		1.10E+02	1.71E+02	3.80E-01

Table Pm-147. MEI Liquid-Pathway Doses

	Fish	Water	Shore	Swimming	Boating	Total Liquid Pathway
	(mrem)	(mrem)	(mrem)	(mrem)	(mrem)	(mrem)
1954	2.88E-07	4.44E-07	1.32E-11	2.70E-14	3.18E-14	7.32E-07
1955	1.08E-05	1.66E-05	4.93E-10	1.01E-12	1.19E-12	2.73E-05
1956	2.91E-05	4.48E-05	1.33E-09	2.73E-12	3.21E-12	7.39E-05
1957	7.87E-05	1.21E-04	3.61E-09	7.38E-12	8.69E-12	2.00E-04
1958	5.14E-05	7.92E-05	2.35E-09	4.82E-12	5.67E-12	1.31E-04
1959	1.27E-04	1.96E-04	5.83E-09	1.19E-11	1.40E-11	3.23E-04
1960	3.74E-04	5.76E-04	1.71E-08	3.51E-11	4.13E-11	9.50E-04
1961	3.04E-04	4.68E-04	1.39E-08	2.85E-11	3.35E-11	7.72E-04
1962	6.10E-04	9.40E-04	2.79E-08	5.72E-11	6.73E-11	1.55E-03
1963	2.43E-04	3.75E-04	1.12E-08	2.28E-11	2.69E-11	6.19E-04
1964	1.49E-04	2.30E-04	6.84E-09	1.40E-11	1.65E-11	3.79E-04
1965	5.81E-04	8.95E-04	2.66E-08	5.45E-11	6.41E-11	1.48E-03
1966	4.06E-04	6.26E-04	1.86E-08	3.81E-11	4.48E-11	1.03E-03
1967	7.63E-04	1.18E-03	3.50E-08	7.16E-11	8.43E-11	1.94E-03
1968	5.52E-04	8.51E-04	2.53E-08	5.18E-11	6.10E-11	1.40E-03
1969	7.01E-04	1.08E-03	3.21E-08	6.57E-11	7.74E-11	1.78E-03
1970	2.16E-04	3.33E-04	9.90E-09	2.03E-11	2.39E-11	5.49E-04
1971	5.76E-05	8.88E-05	2.64E-09	5.40E-12	6.36E-12	1.46E-04
1972	3.36E-07	5.18E-07	1.54E-11	3.15E-14	3.71E-14	8.54E-07
1973	3.30E-06	5.08E-06	1.51E-10	3.09E-13	3.64E-13	8.38E-06
1974	2.54E-06	3.92E-06	1.17E-10	2.39E-13	2.81E-13	6.47E-06
1975	1.63E-06	2.52E-06	7.48E-11	1.53E-13	1.80E-13	4.15E-06
1976	4.51E-06	6.96E-06	2.07E-10	4.23E-13	4.98E-13	1.15E-05
1977	1.39E-06	2.15E-06	6.38E-11	1.31E-13	1.54E-13	3.54E-06
1978	1.52E-07	2.35E-07	6.97E-12	1.43E-14	1.68E-14	3.87E-07
1979						
1980						
1981						
1982						
1983						
1984						
1985						
1986						
1987						
1988	9.46E-07	1.46E-06	4.33E-11	8.87E-14	1.04E-13	2.40E-06
1989	1.58E-06	2.44E-06	7.26E-11	1.49E-13	1.75E-13	4.03E-06
1990	1.02E-06	1.58E-06	4.69E-11	9.59E-14	1.13E-13	2.60E-06
1991	3.18E-07	4.91E-07	1.46E-11	2.98E-14	3.51E-14	8.09E-07
1992	1.18E-08	1.81E-08	5.39E-13	1.10E-15	1.30E-15	2.99E-08
1993	3.37E-07	5.20E-07	1.55E-11	3.16E-14	3.73E-14	8.58E-07
1994	7.39E-08	1.14E-07	3.39E-12	6.93E-15	8.16E-15	1.88E-07
1995	1.26E-07	1.95E-07	5.79E-12	1.18E-14	1.39E-14	3.21E-07
Totals	5.27E-03	8.13E-03	2.42E-07	4.94E-10	5.82E-10	1.34E-02
Percent	39.34%	60.65%	0.00%	0.00%	0.00%	

Table Pm-147. Population Liquid-Pathway Doses

	Aquatic Food	Water	Shore	Swimming	Boating	Total Liquid Pathway
	(per.-rem)	(per.-rem)	(per.-rem)	(per.-rem)	(per.-rem)	(per.-rem)
1954	7.20E-05	1.26E-05	5.52E-10	4.86E-13	1.68E-12	8.46E-05
1955	2.69E-03	4.70E-04	2.06E-08	1.81E-11	6.27E-11	3.16E-03
1956	7.27E-03	1.27E-03	5.58E-08	4.91E-11	1.70E-10	8.54E-03
1957	1.97E-02	3.44E-03	1.51E-07	1.33E-10	4.59E-10	2.31E-02
1958	1.28E-02	2.25E-03	9.84E-08	8.67E-11	3.00E-10	1.51E-02
1959	3.18E-02	5.57E-03	2.44E-07	2.15E-10	7.42E-10	3.74E-02
1960	9.35E-02	1.64E-02	7.17E-07	6.31E-10	2.18E-09	1.10E-01
1961	7.60E-02	1.33E-02	5.82E-07	5.13E-10	1.77E-09	8.93E-02
1962	1.52E-01	2.67E-02	1.17E-06	1.03E-09	3.56E-09	1.79E-01
1963	6.08E-02	1.06E-02	4.66E-07	4.11E-10	1.42E-09	7.15E-02
1964	3.73E-02	6.53E-03	2.86E-07	2.52E-10	8.71E-10	4.39E-02
1965	1.45E-01	2.54E-02	1.11E-06	9.80E-10	3.39E-09	1.71E-01
1966	1.02E-01	1.78E-02	7.78E-07	6.85E-10	2.37E-09	1.19E-01
1967	1.91E-01	3.34E-02	1.46E-06	1.29E-09	4.45E-09	2.24E-01
1968	1.38E-01	2.42E-02	1.06E-06	9.32E-10	3.22E-09	1.62E-01
1969	1.75E-01	3.07E-02	1.34E-06	1.18E-09	4.09E-09	2.06E-01
1970	5.40E-02	9.45E-03	4.14E-07	3.65E-10	1.26E-09	6.35E-02
1971	1.44E-02	2.52E-03	1.10E-07	9.72E-11	3.36E-10	1.69E-02
1972	8.40E-05	1.47E-05	6.44E-10	5.67E-13	1.96E-12	9.87E-05
1973	8.24E-04	1.44E-04	6.32E-09	5.56E-12	1.92E-11	9.69E-04
1974	6.36E-04	1.11E-04	4.88E-09	4.29E-12	1.48E-11	7.47E-04
1975	4.08E-04	7.14E-05	3.13E-09	2.75E-12	9.52E-12	4.79E-04
1976	1.13E-03	1.97E-04	8.65E-09	7.61E-12	2.63E-11	1.33E-03
1977	3.48E-04	6.09E-05	2.67E-09	2.35E-12	8.12E-12	4.09E-04
1978	3.80E-05	6.66E-06	2.92E-10	2.57E-13	8.88E-13	4.47E-05
1979						
1980						
1981						
1982						
1983						
1984						
1985						
1986						
1987						
1988	2.36E-04	4.14E-05	1.81E-09	1.60E-12	5.52E-12	2.78E-04
1989	3.96E-04	6.93E-05	3.04E-09	2.67E-12	9.24E-12	4.65E-04
1990	2.56E-04	4.47E-05	1.96E-09	1.73E-12	5.96E-12	3.00E-04
1991	7.96E-05	1.39E-05	6.10E-10	5.37E-13	1.86E-12	9.35E-05
1992	2.94E-06	5.15E-07	2.25E-11	1.98E-14	6.86E-14	3.45E-06
1993	8.44E-05	1.48E-05	6.47E-10	5.69E-13	1.97E-12	9.91E-05
1994	1.85E-05	3.23E-06	1.42E-10	1.25E-13	4.31E-13	2.17E-05
1995	3.16E-05	5.52E-06	2.42E-10	2.13E-13	7.36E-13	3.71E-05
Totals	1.32E+00	2.31E-01	1.01E-05	8.90E-09	3.08E-08	1.55E+00
Percent	85.11%	14.89%	0.00%	0.00%	0.00%	

Table Pm-147 Liquid. Pm-147 Liquid Releases and Maximally Exposed Individual Doses 1954 - 1995

Pu-238

Half-Life

Pu-238 - 87.7 years

Total Curies Released (1954-1995)

Air - 7.02E-01

Streams - 1.03E-01

Basins (Decay Corrected) - 3.29E+00

Total Cumulative Risks (1954-1995)

MEI Air Pathway - 1.44E-06

MEI Liquid Pathway - 2.45E-08

Population Air - 9.44E-02

Population Liquid - 1.36E-03

Projected 30-year Risks Using Recent Annual Doses (average of years 1991-1995)

MEI Air Pathway - 5.06E-08

MEI Liquid Pathway - 5.80E-11

Population Air - 3.32E-03

Population Liquid - 3.22E-06

Critical Pathways

MEI Air Pathway - Vegetation Consumption = 54%, Inhalation = 46%

MEI Liquid Pathway - Water Consumption = 92%, Fish Consumption = 8%

Population Air Pathway - Inhalation = 82%, Vegetation Consumption = 18%

Population Liquid Pathway - Aquatic Food = 53%, Water Consumption = 47%

Discussion

Pu-238 is a medium-lived alpha-emitting radionuclide with large ingestion and inhalation dose factors (DOE, 1988b). On a cumulative MEI and population risk basis, Pu-238 was the 8th and 5th most important air pathway radionuclide, respectively and the 20th most important liquid pathway radionuclide. The projected 30-year MEI air pathway risk from Pu-238 is estimated at 5.1E-08, which is the 4th most important. The projected 30-year MEI liquid pathway risk is estimated at 5.8E-11, which is the 6th most important. Estimated long-term residual inventories ($>5.8\text{E}+04$ Ci) may cause Pu-238 to remain of importance, on a percentage-of-risk basis, in the future.

Refer to Carlton, 1993c for a more complete assessment of Pu-238 at SRS.

Table Pu-238. Effluent Releases

	Pu-238	Pu-238	Pu-238	Pu-238-Basin
	Air (Curies)	Streams (Curies)	Basins (Curies)	Decay Corrected (Ci)
1954				
1955				
1956				
1957				
1958				
1959				
1960				
1961				
1962				
1963				
1964				
1965				
1966				
1967	2.60E-04		1.43E-01	1.15E-01
1968	1.00E-03		5.17E-01	4.18E-01
1969	5.58E-01		1.09E+00	8.88E-01
1970	2.08E-02		5.50E-01	4.52E-01
1971	2.14E-02	3.01E-02	3.33E-01	2.76E-01
1972	1.66E-02	5.04E-02	4.00E-01	3.34E-01
1973	2.21E-02	2.23E-02	1.92E-01	1.61E-01
1974	4.74E-03		9.73E-02	8.25E-02
1975	1.97E-03		1.54E-01	1.32E-01
1976	1.62E-02		8.80E-02	7.58E-02
1977	5.02E-03		6.60E-02	5.73E-02
1978	6.94E-03		6.40E-02	5.60E-02
1979	1.37E-03		3.51E-02	3.09E-02
1980	2.76E-03		1.31E-02	1.16E-02
1981	4.57E-03		5.87E-02	5.26E-02
1982	4.00E-03		2.76E-02	2.49E-02
1983	2.62E-03		3.70E-02	3.37E-02
1984	1.37E-03		2.40E-02	2.20E-02
1985	5.44E-04		2.60E-02	2.40E-02
1986	2.02E-03		2.50E-02	2.33E-02
1987	1.96E-03		1.26E-02	1.18E-02
1988	8.25E-04		5.65E-03	5.35E-03
1989	8.61E-04			
1990	3.35E-04			
1991	2.64E-04			
1992	4.46E-04			
1993	1.21E-03			
1994	1.61E-03			
1995	5.92E-04	4.05E-05		
Totals	7.02E-01	1.03E-01	3.96E+00	3.29E+00

Table Pu-238. MEI Air-Pathway Doses

	Plume (mrem)	Ground (mrem)	Inhalation (mrem)	Vegetation (mrem)	Milk (mrem)	Meat (mrem)	Total Air Pathway (mrem)
1954							
1955							
1956							
1957							
1958							
1959							
1960							
1961							
1962							
1963							
1964							
1965							
1966							
1967		5.46E-08	3.38E-04	3.90E-04	1.90E-08	3.64E-08	7.28E-04
1968		2.10E-07	1.30E-03	1.50E-03	7.30E-08	1.40E-07	2.80E-03
1969		1.17E-04	7.25E-01	8.37E-01	4.07E-05	7.81E-05	1.56E+00
1970		4.37E-06	2.70E-02	3.12E-02	1.52E-06	2.91E-06	5.82E-02
1971		4.49E-06	2.78E-02	3.21E-02	1.56E-06	3.00E-06	5.99E-02
1972		3.49E-06	2.16E-02	2.49E-02	1.21E-06	2.32E-06	4.65E-02
1973		4.64E-06	2.87E-02	3.32E-02	1.61E-06	3.09E-06	6.19E-02
1974		9.95E-07	6.16E-03	7.11E-03	3.46E-07	6.64E-07	1.33E-02
1975		4.14E-07	2.56E-03	2.96E-03	1.44E-07	2.76E-07	5.52E-03
1976		3.40E-06	2.11E-02	2.43E-02	1.18E-06	2.27E-06	4.54E-02
1977		1.05E-06	6.53E-03	7.53E-03	3.66E-07	7.03E-07	1.41E-02
1978		1.46E-06	9.02E-03	1.04E-02	5.07E-07	9.72E-07	1.94E-02
1979		2.88E-07	1.78E-03	2.06E-03	1.00E-07	1.92E-07	3.84E-03
1980		5.80E-07	3.59E-03	4.14E-03	2.01E-07	3.86E-07	7.73E-03
1981		9.60E-07	5.94E-03	6.86E-03	3.34E-07	6.40E-07	1.28E-02
1982		8.40E-07	5.20E-03	6.00E-03	2.92E-07	5.60E-07	1.12E-02
1983		5.50E-07	3.41E-03	3.93E-03	1.91E-07	3.67E-07	7.34E-03
1984		2.88E-07	1.78E-03	2.06E-03	1.00E-07	1.92E-07	3.84E-03
1985		1.14E-07	7.07E-04	8.16E-04	3.97E-08	7.62E-08	1.52E-03
1986		4.24E-07	2.63E-03	3.03E-03	1.47E-07	2.83E-07	5.66E-03
1987		4.12E-07	2.55E-03	2.94E-03	1.43E-07	2.74E-07	5.49E-03
1988		1.73E-07	1.07E-03	1.24E-03	6.02E-08	1.16E-07	2.31E-03
1989		1.81E-07	1.12E-03	1.29E-03	6.29E-08	1.21E-07	2.41E-03
1990		7.04E-08	4.36E-04	5.03E-04	2.45E-08	4.69E-08	9.38E-04
1991		5.54E-08	3.43E-04	3.96E-04	1.93E-08	3.70E-08	7.39E-04
1992		9.37E-08	5.80E-04	6.69E-04	3.26E-08	6.24E-08	1.25E-03
1993		2.54E-07	1.57E-03	1.82E-03	8.83E-08	1.69E-07	3.39E-03
1994		3.38E-07	2.09E-03	2.42E-03	1.18E-07	2.25E-07	4.51E-03
1995		1.24E-07	7.70E-04	8.88E-04	4.32E-08	8.29E-08	1.66E-03
Totals		1.48E-04	9.13E-01	1.05E+00	5.13E-05	9.83E-05	1.97E+00
Percent		0.01%	46.42%	53.56%	0.00%	0.00%	

Table Pu-238. Population Air-Pathway Doses

	Plume (per.-rem)	Ground (per.-rem)	Inhalation (per.-rem)	Vegetation (per.-rem)	Milk (per.-rem)	Meat (per.-rem)	Total Air Pathway (per.-rem)
1954							
1955							
1956							
1957							
1958							
1959							
1960							
1961							
1962							
1963							
1964							
1965							
1966							
1967		7.02E-06	3.90E-02	8.84E-03	6.50E-07	7.54E-07	4.78E-02
1968		2.70E-05	1.50E-01	3.40E-02	2.50E-06	2.90E-06	1.84E-01
1969		1.51E-02	8.37E+01	1.90E+01	1.40E-03	1.62E-03	1.03E+02
1970		5.62E-04	3.12E+00	7.07E-01	5.20E-05	6.03E-05	3.83E+00
1971		5.78E-04	3.21E+00	7.28E-01	5.35E-05	6.21E-05	3.94E+00
1972		4.48E-04	2.49E+00	5.64E-01	4.15E-05	4.81E-05	3.05E+00
1973		5.97E-04	3.32E+00	7.51E-01	5.53E-05	6.41E-05	4.07E+00
1974		1.28E-04	7.11E-01	1.61E-01	1.19E-05	1.37E-05	8.72E-01
1975		5.32E-05	2.96E-01	6.70E-02	4.93E-06	5.71E-06	3.63E-01
1976		4.37E-04	2.43E+00	5.51E-01	4.05E-05	4.70E-05	2.98E+00
1977		1.36E-04	7.53E-01	1.71E-01	1.26E-05	1.46E-05	9.24E-01
1978		1.87E-04	1.04E+00	2.36E-01	1.74E-05	2.01E-05	1.28E+00
1979		3.70E-05	2.06E-01	4.66E-02	3.43E-06	3.97E-06	2.52E-01
1980		7.45E-05	4.14E-01	9.38E-02	6.90E-06	8.00E-06	5.08E-01
1981		1.23E-04	6.86E-01	1.55E-01	1.14E-05	1.33E-05	8.41E-01
1982		1.08E-04	6.00E-01	1.36E-01	1.00E-05	1.16E-05	7.36E-01
1983		7.07E-05	3.93E-01	8.91E-02	6.55E-06	7.60E-06	4.82E-01
1984		3.70E-05	2.06E-01	4.66E-02	3.43E-06	3.97E-06	2.52E-01
1985		1.47E-05	8.16E-02	1.85E-02	1.36E-06	1.58E-06	1.00E-01
1986		5.45E-05	3.03E-01	6.87E-02	5.05E-06	5.86E-06	3.72E-01
1987		5.29E-05	2.94E-01	6.66E-02	4.90E-06	5.68E-06	3.61E-01
1988		2.23E-05	1.24E-01	2.81E-02	2.06E-06	2.39E-06	1.52E-01
1989		2.32E-05	1.29E-01	2.93E-02	2.15E-06	2.50E-06	1.58E-01
1990		9.05E-06	5.03E-02	1.14E-02	8.38E-07	9.72E-07	6.17E-02
1991		7.13E-06	3.96E-02	8.98E-03	6.60E-07	7.66E-07	4.86E-02
1992		1.20E-05	6.69E-02	1.52E-02	1.12E-06	1.29E-06	8.21E-02
1993		3.27E-05	1.82E-01	4.11E-02	3.03E-06	3.51E-06	2.23E-01
1994		4.35E-05	2.42E-01	5.47E-02	4.03E-06	4.67E-06	2.96E-01
1995		1.60E-05	8.88E-02	2.01E-02	1.48E-06	1.72E-06	1.09E-01
Totals		1.89E-02	1.05E+02	2.39E+01	1.76E-03	2.04E-03	1.29E+02
Percent		0.01%	81.51%	18.48%	0.00%	0.00%	

Table Pu-238. MEI Liquid-Pathway Doses

	Fish	Water	Shore	Swimming	Boating	Total Liquid Pathway
	(mrem)	(mrem)	(mrem)	(mrem)	(mrem)	(mrem)
1954						
1955						
1956						
1957						
1958						
1959						
1960						
1961						
1962						
1963						
1964						
1965						
1966						
1967						
1968						
1969						
1970						
1971	8.13E-04	9.03E-03	1.26E-07	3.61E-12	4.21E-12	9.84E-03
1972	1.36E-03	1.51E-02	2.12E-07	6.05E-12	7.06E-12	1.65E-02
1973	6.02E-04	6.69E-03	9.37E-08	2.68E-12	3.12E-12	7.29E-03
1974						
1975						
1976						
1977						
1978						
1979						
1980						
1981						
1982						
1983						
1984						
1985						
1986						
1987						
1988						
1989						
1990						
1991						
1992						
1993						
1994						
1995	1.09E-06	1.22E-05	1.70E-10	4.86E-15	5.67E-15	1.32E-05
Totals	2.78E-03	3.09E-02	4.32E-07	1.23E-11	1.44E-11	3.36E-02
Percent	8.26%	91.74%	0.00%	0.00%	0.00%	

Table Pu-238. Population Liquid-Pathway Doses

	Aquatic Food	Water	Shore	Swimming	Boating	Total Liquid Pathway
	(per.-rem)	(per.-rem)	(per.-rem)	(per.-rem)	(per.-rem)	(per.-rem)
1954						
1955						
1956						
1957						
1958						
1959						
1960						
1961						
1962						
1963						
1964						
1965						
1966						
1967						
1968						
1969						
1970						
1971	2.90E-01	2.56E-01	5.12E-06	6.62E-11	2.26E-10	5.46E-01
1972	4.85E-01	4.28E-01	8.57E-06	1.11E-10	3.78E-10	9.14E-01
1973	2.15E-01	1.90E-01	3.79E-06	4.91E-11	1.67E-10	4.04E-01
1974						
1975						
1976						
1977						
1978						
1979						
1980						
1981						
1982						
1983						
1984						
1985						
1986						
1987						
1988						
1989						
1990						
1991						
1992						
1993						
1994						
1995	3.90E-04	3.44E-04	6.89E-09	8.91E-14	3.04E-13	7.34E-04
Totals	9.90E-01	8.74E-01	1.75E-05	2.26E-10	7.71E-10	1.86E+00
Percent	53.12%	46.88%	0.00%	0.00%	0.00%	

Table Pu-238 Air. Pu-238 Atmospheric Releases and Maximally Exposed Individual Doses 1954 - 1995

Table Pu-238 Liquid. Pu-238 Liquid Releases and Maximally Exposed Individual Doses 1954 - 1955

Pu-239

(Including Unidentified Alpha)

Half-Life

Pu-239 - 2.41E+04 years

Total Curies Released (1954-1995)

Air - 3.10E+00

Streams - 6.15E-01

Basins (Decay Corrected) - 1.35E+01

Total Cumulative Risks (1954-1995)

MEI Air Pathway - 7.06E-06

MEI Liquid Pathway - 1.62E-07

Population Air - 4.72E-01

Population Liquid - 9.21E-03

Projected 30-year Risks Using Recent Annual Doses (average of years 1991-1995)

MEI Air Pathway - 5.08E-08

MEI Liquid Pathway - 1.18E-07

Population Air - 3.42E-03

Population Liquid - 6.72E-03

Critical Pathways

MEI Air Pathway - Vegetation Consumption = 55%, Inhalation = 45%

MEI Liquid Pathway - Water Consumption = 92%, Fish Consumption = 8%

Population Air Pathway - Inhalation = 81%, Vegetation Consumption = 19%

Population Liquid Pathway - Aquatic Food = 53%, Water Consumption = 47%

Discussion

Pu-239 is a long-lived alpha-emitting radionuclide with large ingestion and inhalation dose factors (DOE, 1988b). On a cumulative MEI and population risk basis, Pu-239 was the 3rd most important air pathway radionuclide and the 15th and 14th most important liquid pathway radionuclide, respectively. The projected 30-year MEI air pathway risk from Pu-239 is estimated at 5.1E-08, which is the 3rd most important. The projected 30-year MEI liquid pathway risk is estimated at 1.2E-07, which is the 4th most important. Estimated long-term residual inventories ($>3.5\text{E}+03$ Ci, which include Pu-240 plus other unidentified alpha emitters) may cause Pu-239 to remain of importance, on a percentage-of-risk basis, in the future.

Refer to Carlton, 1993c for a more complete assessment of Pu-239 at SRS.

**Table Pu-239.
Effluent Releases**

	Pu-239	Pu-239	Pu-239	Pu-239-Basin
	Air (Curies)	Streams (Curies)	Basins (Curies)	Decay Corrected (Ci)
1954		2.40E-03	2.80E-04	2.80E-04
1955	2.66E+00	5.76E-02	1.39E-01	1.39E-01
1956	3.10E-02	4.21E-02	6.39E-01	6.38E-01
1957	4.27E-02	4.00E-03	4.48E-01	4.47E-01
1958	2.09E-02	1.10E-02	5.34E-01	5.33E-01
1959	2.38E-02	1.30E-02	5.51E-01	5.51E-01
1960	7.10E-02	1.68E-02	2.89E-01	2.89E-01
1961	1.20E-02	1.68E-02	3.11E-01	3.11E-01
1962	3.00E-04	1.15E-02	6.39E-01	6.38E-01
1963	3.74E-03	1.60E-02	4.02E-01	4.01E-01
1964	5.60E-03	1.50E-02	1.95E-01	1.95E-01
1965	6.83E-02	1.10E-02	6.45E-01	6.44E-01
1966	3.07E-02	1.41E-02	6.69E-01	6.68E-01
1967	1.06E-02	1.57E-02	7.98E-01	7.98E-01
1968	6.17E-03	1.19E-02	6.56E-01	6.55E-01
1969	6.08E-02	1.06E-02	1.43E+00	1.43E+00
1970	9.49E-03	2.06E-02	1.49E+00	1.49E+00
1971	8.75E-03	1.18E-02	1.19E+00	1.19E+00
1972	3.79E-03	2.14E-02	3.15E-01	3.14E-01
1973	1.48E-03	1.84E-02	3.95E-01	3.94E-01
1974	3.01E-03	1.57E-02	1.01E-01	1.01E-01
1975	5.44E-04	1.86E-02	3.63E-02	3.63E-02
1976	2.60E-04	8.31E-03	1.55E-02	1.55E-02
1977	1.29E-04	8.30E-03	1.47E-02	1.47E-02
1978	2.43E-04	5.75E-03	1.75E-02	1.75E-02
1979	4.11E-04	8.82E-03	1.68E-02	1.68E-02
1980	1.26E-03	5.77E-03	1.75E-02	1.75E-02
1981	2.81E-03	7.64E-03	5.69E-02	5.69E-02
1982	1.71E-03	9.24E-03	3.24E-02	3.23E-02
1983	7.33E-04	6.74E-03	1.39E-02	1.39E-02
1984	4.72E-04	3.12E-02	2.24E-02	2.24E-02
1985	5.11E-04	7.00E-03	2.79E-02	2.79E-02
1986	3.36E-04	8.47E-03	1.24E+00	1.24E+00
1987	4.07E-04	1.82E-02	8.32E-02	8.32E-02
1988	7.40E-04	5.54E-03	3.73E-02	3.73E-02
1989	1.70E-03	1.18E-02	2.40E-03	2.40E-03
1990	5.62E-03	2.15E-02	1.64E-03	1.64E-03
1991	4.31E-04	1.91E-02	1.08E-03	1.08E-03
1992	7.45E-04	1.61E-02		
1993	1.08E-03	9.59E-03		
1994	7.59E-04	1.44E-02		
1995	7.26E-04	1.56E-02		
Totals	3.10E+00	6.15E-01	1.35E+01	1.35E+01

**Table Pu-239.
MEI Air-Pathway Doses**

	Plume	Ground	Inhalation	Vegetation	Milk	Meat	Total Air Pathway
	(mrem)	(mrem)	(mrem)	(mrem)	(mrem)	(mrem)	(mrem)
1954							
1955	2.93E-04	3.72E+00	4.52E+00	2.21E-04	4.26E-04	8.25E+00	
1956	3.41E-06	4.34E-02	5.27E-02	2.57E-06	4.96E-06	9.61E-02	
1957	4.70E-06	5.98E-02	7.26E-02	3.54E-06	6.83E-06	1.32E-01	
1958	2.30E-06	2.93E-02	3.55E-02	1.73E-06	3.34E-06	6.48E-02	
1959	2.62E-06	3.33E-02	4.05E-02	1.98E-06	3.81E-06	7.38E-02	
1960	7.81E-06	9.94E-02	1.21E-01	5.89E-06	1.14E-05	2.20E-01	
1961	1.32E-06	1.68E-02	2.04E-02	9.96E-07	1.92E-06	3.72E-02	
1962	3.30E-08	4.20E-04	5.10E-04	2.49E-08	4.80E-08	9.30E-04	
1963	4.12E-07	5.24E-03	6.36E-03	3.11E-07	5.99E-07	1.16E-02	
1964	6.16E-07	7.84E-03	9.52E-03	4.65E-07	8.96E-07	1.74E-02	
1965	7.51E-06	9.56E-02	1.16E-01	5.67E-06	1.09E-05	2.12E-01	
1966	3.38E-06	4.30E-02	5.22E-02	2.55E-06	4.91E-06	9.52E-02	
1967	1.17E-06	1.48E-02	1.80E-02	8.80E-07	1.70E-06	3.29E-02	
1968	6.79E-07	8.64E-03	1.05E-02	5.12E-07	9.87E-07	1.91E-02	
1969	6.69E-06	8.51E-02	1.03E-01	5.05E-06	9.73E-06	1.89E-01	
1970	1.04E-06	1.33E-02	1.61E-02	7.88E-07	1.52E-06	2.94E-02	
1971	9.63E-07	1.23E-02	1.49E-02	7.26E-07	1.40E-06	2.71E-02	
1972	4.17E-07	5.31E-03	6.44E-03	3.15E-07	6.06E-07	1.18E-02	
1973	1.63E-07	2.07E-03	2.51E-03	1.23E-07	2.36E-07	4.58E-03	
1974	3.32E-07	4.22E-03	5.12E-03	2.50E-07	4.82E-07	9.34E-03	
1975	5.99E-08	7.62E-04	9.25E-04	4.52E-08	8.71E-08	1.69E-03	
1976	2.86E-08	3.64E-04	4.42E-04	2.16E-08	4.16E-08	8.06E-04	
1977	1.42E-08	1.81E-04	2.20E-04	1.07E-08	2.07E-08	4.01E-04	
1978	2.67E-08	3.40E-04	4.13E-04	2.02E-08	3.89E-08	7.53E-04	
1979	4.52E-08	5.75E-04	6.98E-04	3.41E-08	6.57E-08	1.27E-03	
1980	1.38E-07	1.76E-03	2.14E-03	1.04E-07	2.01E-07	3.90E-03	
1981	3.09E-07	3.93E-03	4.78E-03	2.33E-07	4.50E-07	8.71E-03	
1982	1.88E-07	2.40E-03	2.91E-03	1.42E-07	2.74E-07	5.31E-03	
1983	8.06E-08	1.03E-03	1.25E-03	6.08E-08	1.17E-07	2.27E-03	
1984	5.20E-08	6.61E-04	8.03E-04	3.92E-08	7.56E-08	1.46E-03	
1985	5.62E-08	7.16E-04	8.69E-04	4.24E-08	8.18E-08	1.59E-03	
1986	3.69E-08	4.70E-04	5.71E-04	2.79E-08	5.37E-08	1.04E-03	
1987	4.48E-08	5.70E-04	6.92E-04	3.38E-08	6.51E-08	1.26E-03	
1988	8.14E-08	1.04E-03	1.26E-03	6.14E-08	1.18E-07	2.29E-03	
1989	1.87E-07	2.38E-03	2.89E-03	1.41E-07	2.72E-07	5.27E-03	
1990	6.18E-07	7.87E-03	9.55E-03	4.66E-07	8.99E-07	1.74E-02	
1991	4.74E-08	6.03E-04	7.33E-04	3.58E-08	6.90E-08	1.34E-03	
1992	8.20E-08	1.04E-03	1.27E-03	6.18E-08	1.19E-07	2.31E-03	
1993	1.19E-07	1.51E-03	1.84E-03	8.96E-08	1.73E-07	3.35E-03	
1994	8.35E-08	1.06E-03	1.29E-03	6.30E-08	1.21E-07	2.35E-03	
1995	7.99E-08	1.02E-03	1.23E-03	6.03E-08	1.16E-07	2.25E-03	
Totals	3.41E-04	4.33E+00	5.26E+00	2.57E-04	4.95E-04	9.60E+00	
Percent							

**Table Pu-239.
Population Air-Pathway Doses**

	Plume	Ground	Inhalation	Vegetation	Milk	Meat	Total Air Pathway
	(per.-rem)	(per.-rem)	(per.-rem)	(per.-rem)	(per.-rem)	(per.-rem)	(per.-rem)
1954							
1955		4.52E-02	4.52E+02	1.04E+02	7.71E-03	8.78E-03	5.56E+02
1956		5.27E-04	5.27E+00	1.21E+00	8.99E-05	1.02E-04	6.48E+00
1957		7.26E-04	7.26E+00	1.67E+00	1.24E-04	1.41E-04	8.93E+00
1958		3.55E-04	3.55E+00	8.15E-01	6.06E-05	6.90E-05	4.37E+00
1959		4.05E-04	4.05E+00	9.28E-01	6.90E-05	7.85E-05	4.97E+00
1960		1.21E-03	1.21E+01	2.77E+00	2.06E-04	2.34E-04	1.48E+01
1961		2.04E-04	2.04E+00	4.68E-01	3.48E-05	3.96E-05	2.51E+00
1962		5.10E-06	5.10E-02	1.17E-02	8.70E-07	9.90E-07	6.27E-02
1963		6.36E-05	6.36E-01	1.46E-01	1.09E-05	1.23E-05	7.82E-01
1964		9.52E-05	9.52E-01	2.18E-01	1.62E-05	1.85E-05	1.17E+00
1965		1.16E-03	1.16E+01	2.66E+00	1.98E-04	2.25E-04	1.43E+01
1966		5.22E-04	5.22E+00	1.20E+00	8.90E-05	1.01E-04	6.42E+00
1967		1.80E-04	1.80E+00	4.13E-01	3.07E-05	3.50E-05	2.22E+00
1968		1.05E-04	1.05E+00	2.41E-01	1.79E-05	2.04E-05	1.29E+00
1969		1.03E-03	1.03E+01	2.37E+00	1.76E-04	2.01E-04	1.27E+01
1970		1.61E-04	1.61E+00	3.70E-01	2.75E-05	3.13E-05	1.98E+00
1971		1.49E-04	1.49E+00	3.41E-01	2.54E-05	2.89E-05	1.83E+00
1972		6.44E-05	6.44E-01	1.48E-01	1.10E-05	1.25E-05	7.92E-01
1973		2.51E-05	2.51E-01	5.76E-02	4.29E-06	4.88E-06	3.09E-01
1974		5.12E-05	5.12E-01	1.18E-01	8.74E-06	9.95E-06	6.30E-01
1975		9.25E-06	9.25E-02	2.12E-02	1.58E-06	1.80E-06	1.14E-01
1976		4.42E-06	4.42E-02	1.01E-02	7.54E-07	8.58E-07	5.43E-02
1977		2.20E-06	2.20E-02	5.05E-03	3.75E-07	4.27E-07	2.70E-02
1978		4.13E-06	4.13E-02	9.47E-03	7.04E-07	8.02E-07	5.08E-02
1979		6.98E-06	6.98E-02	1.60E-02	1.19E-06	1.36E-06	8.58E-02
1980		2.14E-05	2.14E-01	4.91E-02	3.65E-06	4.15E-06	2.63E-01
1981		4.78E-05	4.78E-01	1.10E-01	8.15E-06	9.27E-06	5.87E-01
1982		2.91E-05	2.91E-01	6.67E-02	4.96E-06	5.65E-06	3.58E-01
1983		1.25E-05	1.25E-01	2.86E-02	2.13E-06	2.42E-06	1.53E-01
1984		8.03E-06	8.03E-02	1.84E-02	1.37E-06	1.56E-06	9.87E-02
1985		8.69E-06	8.69E-02	1.99E-02	1.48E-06	1.69E-06	1.07E-01
1986		5.71E-06	5.71E-02	1.31E-02	9.74E-07	1.11E-06	7.02E-02
1987		6.92E-06	6.92E-02	1.59E-02	1.18E-06	1.34E-06	8.51E-02
1988		1.26E-05	1.26E-01	2.89E-02	2.15E-06	2.44E-06	1.55E-01
1989		2.89E-05	2.89E-01	6.63E-02	4.93E-06	5.61E-06	3.55E-01
1990		9.55E-05	9.55E-01	2.19E-01	1.63E-05	1.85E-05	1.17E+00
1991		7.33E-06	7.33E-02	1.68E-02	1.25E-06	1.42E-06	9.01E-02
1992		1.27E-05	1.27E-01	2.91E-02	2.16E-06	2.46E-06	1.56E-01
1993		1.84E-05	1.84E-01	4.21E-02	3.13E-06	3.56E-06	2.26E-01
1994		1.29E-05	1.29E-01	2.96E-02	2.20E-06	2.50E-06	1.59E-01
1995		1.23E-05	1.23E-01	2.83E-02	2.11E-06	2.40E-06	1.52E-01
Totals		5.26E-02	5.26E+02	1.21E+02	8.98E-03	1.02E-02	6.47E+02
Percent		0.01%	81.33%	18.66%	0.00%	0.00%	

**Table Pu-239.
Population Liquid-Pathway Doses**

	Aquatic Food	Water	Shore	Swimming	Boating	Total Liquid Pathway
	(per.-rem)	(per.-rem)	(per.-rem)	(per.-rem)	(per.-rem)	(per.-rem)
1954	2.62E-02	2.30E-02	2.14E-07	4.56E-12	1.56E-11	4.92E-02
1955	6.28E-01	5.53E-01	5.13E-06	1.09E-10	3.74E-10	1.18E+00
1956	4.59E-01	4.04E-01	3.75E-06	8.00E-11	2.74E-10	8.63E-01
1957	4.36E-02	3.84E-02	3.56E-07	7.60E-12	2.60E-11	8.20E-02
1958	1.20E-01	1.06E-01	9.79E-07	2.09E-11	7.15E-11	2.26E-01
1959	1.42E-01	1.25E-01	1.16E-06	2.47E-11	8.45E-11	2.67E-01
1960	1.83E-01	1.61E-01	1.50E-06	3.19E-11	1.09E-10	3.44E-01
1961	1.83E-01	1.61E-01	1.50E-06	3.19E-11	1.09E-10	3.44E-01
1962	1.25E-01	1.10E-01	1.02E-06	2.19E-11	7.48E-11	2.36E-01
1963	1.74E-01	1.54E-01	1.42E-06	3.04E-11	1.04E-10	3.28E-01
1964	1.64E-01	1.44E-01	1.34E-06	2.85E-11	9.75E-11	3.08E-01
1965	1.20E-01	1.06E-01	9.79E-07	2.09E-11	7.15E-11	2.26E-01
1966	1.54E-01	1.35E-01	1.25E-06	2.68E-11	9.17E-11	2.89E-01
1967	1.71E-01	1.51E-01	1.40E-06	2.98E-11	1.02E-10	3.22E-01
1968	1.30E-01	1.14E-01	1.06E-06	2.26E-11	7.74E-11	2.44E-01
1969	1.16E-01	1.02E-01	9.43E-07	2.01E-11	6.89E-11	2.17E-01
1970	2.25E-01	1.98E-01	1.83E-06	3.91E-11	1.34E-10	4.22E-01
1971	1.29E-01	1.13E-01	1.05E-06	2.24E-11	7.67E-11	2.42E-01
1972	2.33E-01	2.05E-01	1.90E-06	4.07E-11	1.39E-10	4.39E-01
1973	2.01E-01	1.77E-01	1.64E-06	3.50E-11	1.20E-10	3.77E-01
1974	1.71E-01	1.51E-01	1.40E-06	2.98E-11	1.02E-10	3.22E-01
1975	2.03E-01	1.79E-01	1.66E-06	3.53E-11	1.21E-10	3.81E-01
1976	9.06E-02	7.98E-02	7.40E-07	1.58E-11	5.40E-11	1.70E-01
1977	9.05E-02	7.97E-02	7.39E-07	1.58E-11	5.40E-11	1.70E-01
1978	6.27E-02	5.52E-02	5.12E-07	1.09E-11	3.74E-11	1.18E-01
1979	9.61E-02	8.47E-02	7.85E-07	1.68E-11	5.73E-11	1.81E-01
1980	6.29E-02	5.54E-02	5.14E-07	1.10E-11	3.75E-11	1.18E-01
1981	8.33E-02	7.33E-02	6.80E-07	1.45E-11	4.97E-11	1.57E-01
1982	1.01E-01	8.87E-02	8.22E-07	1.76E-11	6.01E-11	1.89E-01
1983	7.35E-02	6.47E-02	6.00E-07	1.28E-11	4.38E-11	1.38E-01
1984	3.40E-01	3.00E-01	2.78E-06	5.93E-11	2.03E-10	6.40E-01
1985	7.63E-02	6.72E-02	6.23E-07	1.33E-11	4.55E-11	1.44E-01
1986	9.23E-02	8.13E-02	7.54E-07	1.61E-11	5.51E-11	1.74E-01
1987	1.98E-01	1.75E-01	1.62E-06	3.46E-11	1.18E-10	3.73E-01
1988	6.04E-02	5.32E-02	4.93E-07	1.05E-11	3.60E-11	1.14E-01
1989	1.29E-01	1.13E-01	1.05E-06	2.24E-11	7.67E-11	2.42E-01
1990	2.35E-01	2.07E-01	1.92E-06	4.09E-11	1.40E-10	4.41E-01
1991	2.08E-01	1.83E-01	1.70E-06	3.63E-11	1.24E-10	3.92E-01
1992	1.75E-01	1.55E-01	1.43E-06	3.06E-11	1.05E-10	3.30E-01
1993	1.05E-01	9.21E-02	8.54E-07	1.82E-11	6.23E-11	1.97E-01
1994	1.57E-01	1.38E-01	1.28E-06	2.74E-11	9.36E-11	2.95E-01
1995	1.70E-01	1.50E-01	1.39E-06	2.96E-11	1.01E-10	3.20E-01
Totals	6.70E+00	5.90E+00	5.47E-05	1.17E-09	4.00E-09	1.26E+01
Percent	53.17%	46.83%	0.00%	0.00%	0.00%	

Table Pu-239 Air. Pu-239 Atmospheric Releases and Maximally Exposed Individual Doses 1954 - 1995

Table Pu-239 Liquid. Pu-239 Liquid Releases and Maximally Exposed Individual Doses 1954 - 1995

Ru-103

Half-Life

Ru-103 - 39.27 days

Total Curies Released (1954-1995)

Air - $1.91\text{E}+01$

Streams - 0.0

Basins (Decay Corrected) - $<1.00\text{E}-12$

Total Cumulative Risks (1954-1995)

MEI Air Pathway - $3.13\text{E}-08$

MEI Liquid Pathway - 0.0

Population Air - $1.08\text{E}-03$

Population Liquid - 0.0

Projected 30-year Risks Using Recent Annual Doses (average of years 1991-1995)

MEI Air Pathway - $3.67\text{E}-13$

MEI Liquid Pathway - 0.0

Population Air - $6.94\text{E}-09$

Population Liquid - 0.0

Critical Pathways

MEI Air Pathway - Meat Consumption = 58%, Ground = 25%

MEI Liquid Pathway - N/A

Population Air Pathway - Ground = 45%, Meat Consumption = 34%

Population Liquid Pathway - N/A

Discussion

Ru-103 is a short-lived fission product that has been measured only in airborne effluents and in seepage basin discharges. On a cumulative MEI and population risk basis, Ru-103 was the 16th and 17th most important air pathway radionuclide, respectively. However, Ru-103 accounted for less than 1% of the site's cumulative air pathway risks. Because of its short half-life, future releases of Ru-103 are expected to remain essentially nil.

Table Ru-103. Effluent Releases

	Ru-103 - Air	Ru-103 - Streams	Ru-103 - Basins	Ru-103 - Basins
	Curies	Curies	Curies	Decay Corrected (Ci)
1954				
1955				
1956				
1957				
1958				
1959				
1960				
1961				
1962				
1963				
1964				
1965				
1966				
1967				
1968				
1969	9.62E+00			
1970				
1971	2.73E+00		7.02E+00	7.74E-67
1972	3.85E+00		6.41E+00	4.35E-64
1973	1.88E+00		4.14E+00	1.73E-61
1974	8.82E-03		1.59E+00	4.11E-59
1975	1.82E-03		2.80E-01	4.46E-57
1976	2.09E-02		1.85E+00	1.82E-53
1977	2.46E-02		1.27E+00	7.68E-51
1978	8.02E-01		1.30E+00	4.85E-48
1979	4.82E-03		1.55E+00	3.56E-45
1980	1.66E-03		1.25E+00	1.77E-42
1981	1.30E-02		2.05E+00	1.79E-39
1982	5.44E-02		2.27E+00	1.22E-36
1983	2.03E-02		4.31E-01	1.43E-34
1984	1.90E-02		3.83E-01	7.84E-32
1985	1.10E-02		7.68E-01	9.69E-29
1986	3.50E-03		4.05E-01	3.15E-26
1987	1.37E-03		3.17E-03	1.52E-25
1988	4.61E-04			
1989	7.00E-06			
1990				
1991				
1992				
1993				
1994				
1995	3.72E-05			
Totals	1.91E+01		3.30E+01	1.84E-25

Table Ru-103. MEI Air-Pathway Doses

	Plume (mrem)	Ground (mrem)	Inhalation (mrem)	Vegetation (mrem)	Milk (mrem)	Meat (mrem)	Total Air Pathway (mrem)
1954							
1955							
1956							
1957							
1958							
1959							
1960							
1961							
1962							
1963							
1964							
1965							
1966							
1967							
1968							
1969		5.39E-03	2.02E-04	3.56E-03	8.47E-08	1.25E-02	2.17E-02
1970							
1971		1.53E-03	5.73E-05	1.01E-03	2.40E-08	3.55E-03	6.15E-03
1972		2.16E-03	8.09E-05	1.42E-03	3.39E-08	5.01E-03	8.67E-03
1973		1.05E-03	3.95E-05	6.96E-04	1.65E-08	2.44E-03	4.23E-03
1974		4.94E-06	1.85E-07	3.26E-06	7.76E-11	1.15E-05	1.99E-05
1975		1.02E-06	3.82E-08	6.73E-07	1.60E-11	2.37E-06	4.10E-06
1976		1.17E-05	4.39E-07	7.73E-06	1.84E-10	2.72E-05	4.70E-05
1977		1.38E-05	5.17E-07	9.10E-06	2.16E-10	3.20E-05	5.54E-05
1978		4.49E-04	1.68E-05	2.97E-04	7.06E-09	1.04E-03	1.81E-03
1979		2.70E-06	1.01E-07	1.78E-06	4.24E-11	6.27E-06	1.08E-05
1980		9.30E-07	3.49E-08	6.14E-07	1.46E-11	2.16E-06	3.74E-06
1981		7.28E-06	2.73E-07	4.81E-06	1.14E-10	1.69E-05	2.93E-05
1982		3.05E-05	1.14E-06	2.01E-05	4.79E-10	7.07E-05	1.22E-04
1983		1.14E-05	4.26E-07	7.51E-06	1.79E-10	2.64E-05	4.57E-05
1984		1.06E-05	3.99E-07	7.03E-06	1.67E-10	2.47E-05	4.28E-05
1985		6.16E-06	2.31E-07	4.07E-06	9.68E-11	1.43E-05	2.48E-05
1986		1.96E-06	7.35E-08	1.30E-06	3.08E-11	4.55E-06	7.88E-06
1987		7.67E-07	2.88E-08	5.07E-07	1.21E-11	1.78E-06	3.08E-06
1988		2.58E-07	9.68E-09	1.71E-07	4.06E-12	5.99E-07	1.04E-06
1989		3.92E-09	1.47E-10	2.59E-09	6.16E-14	9.10E-09	1.58E-08
1990							
1991							
1992							
1993							
1994							
1995		2.08E-08	7.81E-10	1.38E-08	3.27E-13	4.84E-08	8.37E-08
Totals		1.07E-02	4.00E-04	7.06E-03	1.68E-07	2.48E-02	4.29E-02
Percent		24.88%	0.93%	16.44%	0.00%	57.75%	

Table Ru-103. Population Air-Pathway Doses

	Plume	Ground	Inhalation	Vegetation	Milk	Meat	Total Air Pathway
	(per.-rem)	(per.-rem)	(per.-rem)	(per.-rem)	(per.-rem)	(per.-rem)	(per.-rem)
1954							
1955							
1956							
1957							
1958							
1959							
1960							
1961							
1962							
1963							
1964							
1965							
1966							
1967							
1968							
1969		3.37E-01	2.50E-02	1.35E-01	2.89E-06	2.50E-01	7.47E-01
1970							
1971		9.56E-02	7.10E-03	3.82E-02	8.19E-07	7.10E-02	2.12E-01
1972		1.35E-01	1.00E-02	5.39E-02	1.16E-06	1.00E-01	2.99E-01
1973		6.58E-02	4.89E-03	2.63E-02	5.64E-07	4.89E-02	1.46E-01
1974		3.09E-04	2.29E-05	1.23E-04	2.65E-09	2.29E-04	6.84E-04
1975		6.37E-05	4.73E-06	2.55E-05	5.46E-10	4.73E-05	1.41E-04
1976		7.32E-04	5.43E-05	2.93E-04	6.27E-09	5.43E-04	1.62E-03
1977		8.61E-04	6.40E-05	3.44E-04	7.38E-09	6.40E-04	1.91E-03
1978		2.81E-02	2.09E-03	1.12E-02	2.41E-07	2.09E-02	6.22E-02
1979		1.69E-04	1.25E-05	6.75E-05	1.45E-09	1.25E-04	3.74E-04
1980		5.81E-05	4.32E-06	2.32E-05	4.98E-10	4.32E-05	1.29E-04
1981		4.55E-04	3.38E-05	1.82E-04	3.90E-09	3.38E-04	1.01E-03
1982		1.90E-03	1.41E-04	7.62E-04	1.63E-08	1.41E-03	4.22E-03
1983		7.11E-04	5.28E-05	2.84E-04	6.09E-09	5.28E-04	1.58E-03
1984		6.65E-04	4.94E-05	2.66E-04	5.70E-09	4.94E-04	1.47E-03
1985		3.85E-04	2.86E-05	1.54E-04	3.30E-09	2.86E-04	8.54E-04
1986		1.23E-04	9.10E-06	4.90E-05	1.05E-09	9.10E-05	2.72E-04
1987		4.80E-05	3.56E-06	1.92E-05	4.11E-10	3.56E-05	1.06E-04
1988		1.61E-05	1.20E-06	6.45E-06	1.38E-10	1.20E-05	3.58E-05
1989		2.45E-07	1.82E-08	9.80E-08	2.10E-12	1.82E-07	5.43E-07
1990							
1991							
1992							
1993							
1994							
1995			9.67E-08	5.21E-07	1.12E-11	9.67E-07	1.58E-06
Totals		6.67E-01	4.96E-02	2.67E-01	5.72E-06	4.96E-01	1.48E+00
Percent		45.10%	3.35%	18.04%	0.00%	33.51%	

Table Ru-103 Air. Ru-103 Atmospheric Releases and Maximally Exposed Individual Doses 1954 - 1995

Ru-103/106

Half-Life

Ru-103 - 39.27 days

Ru-106 - 1.02 years

Total Curies Released (1954-1995)

Air - $1.39\text{E}+02$

Streams - $5.86\text{E}+01$

Basins (Decay Corrected) - $3.56\text{E}-02$

Total Cumulative Risks (1954-1995)

MEI Air Pathway - $3.23\text{E}-06$

MEI Liquid Pathway - $8.83\text{E}-08$

Population Air - $9.04\text{E}-02$

Population Liquid - $1.31\text{E}-02$

Projected 30-year Risks Using Recent Annual Doses (average of years 1991-1995)

MEI Air Pathway - $8.79\text{E}-11$

MEI Liquid Pathway - 0.0

Population Air - $2.35\text{E}-06$

Population Liquid - 0.0

Critical Pathways

MEI Air Pathway - Meat Consumption = 66%, Vegetation Consumption = 23%

MEI Liquid Pathway - Water Consumption = 78%, Fish Consumption = 20%

Population Air Pathway - Meat Consumption = 47%, Vegetation Consumption = 20%

Population Liquid Pathway - Aquatic Food = 84%, Water Consumption = 15%

Discussion

Ru-103/106 are relatively short-lived fission products. Because Ru-106 has larger inhalation and ingestion dose factors than Ru-103 (DOE, 1988), measured airborne and liquid releases of Ru-103/106 are conservatively added with Ru-106 releases for dose and risk calculations. On a cumulative MEI and population risk basis, Ru-103/106 were the 5th and 6th most important air pathway radionuclides, respectively and the 18th and 10th most important liquid pathway radionuclides, respectively. The projected 30-year MEI air and liquid pathway risks from Ru-103/106 emissions are $8.8\text{E}-11$ and 0.0, respectively. Estimated residual inventories of Ru-106 ($>7.5\text{E}+03$ Ci) may cause it to assume greater importance, on a percentage-of-risk basis, in the near (0-30 years) future.

Table Ru-103/106. Effluent Releases

	Ru-103,106	Ru-103,106	Ru-103,106	Ru-103,106-Basin
	Air (Curies)	Streams (Curies)	Basins (Curies)	Decay Corrected (Ci)
1954		4.50E-02		
1955	2.51E+01	1.68E-01	1.40E+01	1.68E-11
1956	6.34E+00	4.55E-01	2.32E+01	5.53E-11
1957	1.24E+00	2.15E+00	6.59E+01	3.12E-10
1958	6.17E-01	8.06E-01	2.89E+01	2.72E-10
1959	9.99E+00	1.98E+00	1.37E+02	2.57E-09
1960	8.85E+00	9.04E+00	1.57E+02	5.83E-09
1961	3.91E+00	7.01E+00	5.33E+01	3.93E-09
1962	2.78E+00	6.90E+00	1.16E+02	1.70E-08
1963	3.89E+00	1.25E+01	1.24E+02	3.59E-08
1964	2.62E+00	7.86E+00	2.39E+02	1.38E-07
1965	2.76E+00	3.84E+00	1.33E+02	1.53E-07
1966	4.59E+00	1.27E+00	9.72E+01	2.21E-07
1967	4.18E-01	1.94E+00	6.13E+01	2.77E-07
1968	2.01E+01	1.87E+00	9.97E+01	8.96E-07
1969	4.11E+00	5.20E-01	5.45E+01	9.73E-07
1970	6.78E-01	6.10E-02	5.30E+01	1.88E-06
1971	2.95E+00	3.45E-02	3.23E+01	2.28E-06
1972	3.47E+00	3.90E-02	2.88E+01	4.03E-06
1973	1.31E+00	4.84E-02	3.47E+01	9.64E-06
1974	1.42E-01	4.00E-03	2.40E+01	1.32E-05
1975	3.66E-02	5.40E-02	6.23E+00	6.83E-06
1976	2.64E-01	1.00E-03	1.31E+01	2.85E-05
1977	1.40E-01	1.02E-03	7.76E+00	3.36E-05
1978	3.21E+01		1.90E+01	1.63E-04
1979	5.46E-02		1.59E+01	2.71E-04
1980	5.98E-02		1.98E+01	6.71E-04
1981	7.83E-02		2.15E+01	1.45E-03
1982	1.88E-01		6.61E+00	8.83E-04
1983	8.12E-02		2.68E+00	7.11E-04
1984	1.48E-01		1.28E+00	6.76E-04
1985	4.33E-02		7.96E+00	8.34E-03
1986	5.90E-02		8.08E+00	1.68E-02
1987	4.53E-02		9.77E-01	4.03E-03
1988	3.02E-02		1.83E-01	1.50E-03
1989	3.26E-03	4.61E-03		
1990	1.18E-03			
1991	4.44E-04			
1992	1.81E-06			
1993	4.00E-06			
1994	1.39E-08			
1995	1.81E-04			
Totals	1.39E+02	5.86E+01	1.71E+03	3.56E-02

Table Ru-103/106. MEI Air-Pathway Doses

	Plume	Ground	Inhalation	Vegetation	Milk	Meat	Total Air Pathway
	(mrem)	(mrem)	(mrem)	(mrem)	(mrem)	(mrem)	(mrem)
1954							
1955		5.52E-02	3.01E-02	1.86E-01	4.52E-06	5.27E-01	7.98E-01
1956		1.39E-02	7.61E-03	4.69E-02	1.14E-06	1.33E-01	2.02E-01
1957		2.73E-03	1.49E-03	9.18E-03	2.23E-07	2.60E-02	3.94E-02
1958		1.36E-03	7.40E-04	4.57E-03	1.11E-07	1.30E-02	1.96E-02
1959		2.20E-02	1.20E-02	7.39E-02	1.80E-06	2.10E-01	3.18E-01
1960		1.95E-02	1.06E-02	6.55E-02	1.59E-06	1.86E-01	2.81E-01
1961		8.60E-03	4.69E-03	2.89E-02	7.04E-07	8.21E-02	1.24E-01
1962		6.12E-03	3.34E-03	2.06E-02	5.00E-07	5.84E-02	8.84E-02
1963		8.56E-03	4.67E-03	2.88E-02	7.00E-07	8.17E-02	1.24E-01
1964		5.76E-03	3.14E-03	1.94E-02	4.72E-07	5.50E-02	8.33E-02
1965		6.07E-03	3.31E-03	2.04E-02	4.97E-07	5.80E-02	8.78E-02
1966		1.01E-02	5.51E-03	3.40E-02	8.26E-07	9.64E-02	1.46E-01
1967		9.20E-04	5.02E-04	3.09E-03	7.52E-08	8.78E-03	1.33E-02
1968		4.42E-02	2.41E-02	1.49E-01	3.62E-06	4.22E-01	6.39E-01
1969		9.04E-03	4.93E-03	3.04E-02	7.40E-07	8.63E-02	1.31E-01
1970		1.49E-03	8.14E-04	5.02E-03	1.22E-07	1.42E-02	2.16E-02
1971		6.49E-03	3.54E-03	2.18E-02	5.31E-07	6.20E-02	9.38E-02
1972		7.63E-03	4.16E-03	2.57E-02	6.25E-07	7.29E-02	1.10E-01
1973		2.88E-03	1.57E-03	9.69E-03	2.36E-07	2.75E-02	4.17E-02
1974		3.12E-04	1.70E-04	1.05E-03	2.56E-08	2.98E-03	4.52E-03
1975		8.05E-05	4.39E-05	2.71E-04	6.59E-09	7.69E-04	1.16E-03
1976		5.81E-04	3.17E-04	1.95E-03	4.75E-08	5.54E-03	8.40E-03
1977		3.08E-04	1.68E-04	1.04E-03	2.52E-08	2.94E-03	4.45E-03
1978		7.06E-02	3.85E-02	2.38E-01	5.78E-06	6.74E-01	1.02E+00
1979		1.20E-04	6.55E-05	4.04E-04	9.83E-09	1.15E-03	1.74E-03
1980		1.32E-04	7.18E-05	4.43E-04	1.08E-08	1.26E-03	1.90E-03
1981		1.72E-04	9.40E-05	5.79E-04	1.41E-08	1.64E-03	2.49E-03
1982		4.14E-04	2.26E-04	1.39E-03	3.38E-08	3.95E-03	5.98E-03
1983		1.79E-04	9.74E-05	6.01E-04	1.46E-08	1.71E-03	2.58E-03
1984		3.26E-04	1.78E-04	1.10E-03	2.66E-08	3.11E-03	4.71E-03
1985		9.53E-05	5.20E-05	3.20E-04	7.79E-09	9.09E-04	1.38E-03
1986		1.30E-04	7.08E-05	4.37E-04	1.06E-08	1.24E-03	1.88E-03
1987		9.97E-05	5.44E-05	3.35E-04	8.15E-09	9.51E-04	1.44E-03
1988		6.64E-05	3.62E-05	2.23E-04	5.44E-09	6.34E-04	9.60E-04
1989		7.17E-06	3.91E-06	2.41E-05	5.87E-10	6.85E-05	1.04E-04
1990		2.60E-06	1.42E-06	8.73E-06	2.12E-10	2.48E-05	3.75E-05
1991		9.77E-07	5.33E-07	3.29E-06	7.99E-11	9.32E-06	1.41E-05
1992		3.98E-09	2.17E-09	1.34E-08	3.26E-13	3.80E-08	5.76E-08
1993		8.80E-09	4.80E-09	2.96E-08	7.20E-13	8.40E-08	1.27E-07
1994		3.06E-11	1.67E-11	1.03E-10	2.50E-15	2.92E-10	4.42E-10
1995		3.98E-07	2.17E-07	1.34E-06	3.26E-11	3.80E-06	5.76E-06
Totals		3.06E-01	1.67E-01	1.03E+00	2.51E-05	2.92E+00	4.43E+00
Percent		6.92%	3.77%	23.27%	0.00%	66.04%	

Table Ru-103/106. Population Air-Pathway Doses

	Plume	Ground	Inhalation	Vegetation	Milk	Meat	Total Air Pathway
	(per.-rem)	(per.-rem)	(per.-rem)	(per.-rem)	(per.-rem)	(per.-rem)	(per.-rem)
1954							
1955		3.51E+00	3.77E+00	4.52E+00	1.56E-04	1.05E+01	2.23E+01
1956		8.88E-01	9.51E-01	1.14E+00	3.93E-05	2.66E+00	5.64E+00
1957		1.74E-01	1.86E-01	2.23E-01	7.69E-06	5.21E-01	1.10E+00
1958		8.64E-02	9.26E-02	1.11E-01	3.83E-06	2.59E-01	5.49E-01
1959		1.40E+00	1.50E+00	1.80E+00	6.19E-05	4.20E+00	8.89E+00
1960		1.24E+00	1.33E+00	1.59E+00	5.49E-05	3.72E+00	7.88E+00
1961		5.47E-01	5.87E-01	7.04E-01	2.42E-05	1.64E+00	3.48E+00
1962		3.89E-01	4.17E-01	5.00E-01	1.72E-05	1.17E+00	2.47E+00
1963		5.45E-01	5.84E-01	7.00E-01	2.41E-05	1.63E+00	3.46E+00
1964		3.67E-01	3.93E-01	4.72E-01	1.62E-05	1.10E+00	2.33E+00
1965		3.86E-01	4.14E-01	4.97E-01	1.71E-05	1.16E+00	2.46E+00
1966		6.43E-01	6.89E-01	8.26E-01	2.85E-05	1.93E+00	4.09E+00
1967		5.85E-02	6.27E-02	7.52E-02	2.59E-06	1.76E-01	3.72E-01
1968		2.81E+00	3.02E+00	3.62E+00	1.25E-04	8.44E+00	1.79E+01
1969		5.75E-01	6.17E-01	7.40E-01	2.55E-05	1.73E+00	3.66E+00
1970		9.49E-02	1.02E-01	1.22E-01	4.20E-06	2.85E-01	6.03E-01
1971		4.13E-01	4.43E-01	5.31E-01	1.83E-05	1.24E+00	2.63E+00
1972		4.86E-01	5.21E-01	6.25E-01	2.15E-05	1.46E+00	3.09E+00
1973		1.83E-01	1.97E-01	2.36E-01	8.12E-06	5.50E-01	1.17E+00
1974		1.99E-02	2.13E-02	2.56E-02	8.80E-07	5.96E-02	1.26E-01
1975		5.12E-03	5.49E-03	6.59E-03	2.27E-07	1.54E-02	3.26E-02
1976		3.70E-02	3.96E-02	4.75E-02	1.64E-06	1.11E-01	2.35E-01
1977		1.96E-02	2.10E-02	2.52E-02	8.68E-07	5.88E-02	1.25E-01
1978		4.49E+00	4.82E+00	5.78E+00	1.99E-04	1.35E+01	2.86E+01
1979		7.64E-03	8.19E-03	9.83E-03	3.39E-07	2.29E-02	4.86E-02
1980		8.37E-03	8.97E-03	1.08E-02	3.71E-07	2.51E-02	5.32E-02
1981		1.10E-02	1.17E-02	1.41E-02	4.85E-07	3.29E-02	6.97E-02
1982		2.63E-02	2.82E-02	3.38E-02	1.17E-06	7.90E-02	1.67E-01
1983		1.14E-02	1.22E-02	1.46E-02	5.03E-07	3.41E-02	7.23E-02
1984		2.07E-02	2.22E-02	2.66E-02	9.18E-07	6.22E-02	1.32E-01
1985		6.06E-03	6.50E-03	7.79E-03	2.68E-07	1.82E-02	3.85E-02
1986		8.26E-03	8.85E-03	1.06E-02	3.66E-07	2.48E-02	5.25E-02
1987		6.34E-03	6.80E-03	8.15E-03	2.81E-07	1.90E-02	4.03E-02
1988		4.23E-03	4.53E-03	5.44E-03	1.87E-07	1.27E-02	2.69E-02
1989		4.56E-04	4.89E-04	5.87E-04	2.02E-08	1.37E-03	2.90E-03
1990		1.65E-04	1.77E-04	2.12E-04	7.32E-09	4.96E-04	1.05E-03
1991		6.22E-05	6.66E-05	7.99E-05	2.75E-09	1.86E-04	3.95E-04
1992		2.53E-07	2.72E-07	3.26E-07	1.12E-11	7.60E-07	1.61E-06
1993		5.60E-07	6.00E-07	7.20E-07	2.48E-11	1.68E-06	3.56E-06
1994		1.95E-09	2.09E-09	2.50E-09	8.62E-14	5.84E-09	1.24E-08
1995			2.72E-05	3.26E-05	1.12E-09	7.60E-05	1.36E-04
Totals		1.95E+01	2.09E+01	2.51E+01	8.63E-04	5.85E+01	1.24E+02
Percent		15.73%	16.85%	20.22%	0.00%	47.19%	

Table Ru-103/106. MEI Liquid-Pathway Doses

	Fish	Water	Shore	Swimming	Boating	Total Liquid Pathway
	(mrem)	(mrem)	(mrem)	(mrem)	(mrem)	(mrem)
1954	1.89E-05	7.20E-05	1.94E-06	1.13E-08	1.31E-08	9.29E-05
1955	7.06E-05	2.69E-04	7.22E-06	4.20E-08	4.87E-08	3.47E-04
1956	1.91E-04	7.28E-04	1.96E-05	1.14E-07	1.32E-07	9.39E-04
1957	9.03E-04	3.44E-03	9.25E-05	5.38E-07	6.24E-07	4.44E-03
1958	3.39E-04	1.29E-03	3.47E-05	2.02E-07	2.34E-07	1.66E-03
1959	8.32E-04	3.17E-03	8.51E-05	4.95E-07	5.74E-07	4.09E-03
1960	3.80E-03	1.45E-02	3.89E-04	2.26E-06	2.62E-06	1.87E-02
1961	2.94E-03	1.12E-02	3.01E-04	1.75E-06	2.03E-06	1.45E-02
1962	2.90E-03	1.10E-02	2.97E-04	1.73E-06	2.00E-06	1.42E-02
1963	5.25E-03	2.00E-02	5.38E-04	3.13E-06	3.63E-06	2.58E-02
1964	3.30E-03	1.26E-02	3.38E-04	1.97E-06	2.28E-06	1.62E-02
1965	1.61E-03	6.14E-03	1.65E-04	9.60E-07	1.11E-06	7.92E-03
1966	5.33E-04	2.03E-03	5.46E-05	3.18E-07	3.68E-07	2.62E-03
1967	8.15E-04	3.10E-03	8.34E-05	4.85E-07	5.63E-07	4.00E-03
1968	7.85E-04	2.99E-03	8.04E-05	4.68E-07	5.42E-07	3.86E-03
1969	2.18E-04	8.32E-04	2.24E-05	1.30E-07	1.51E-07	1.07E-03
1970	2.56E-05	9.76E-05	2.62E-06	1.53E-08	1.77E-08	1.26E-04
1971	1.45E-05	5.52E-05	1.48E-06	8.63E-09	1.00E-08	7.12E-05
1972	1.64E-05	6.24E-05	1.68E-06	9.75E-09	1.13E-08	8.05E-05
1973	2.03E-05	7.74E-05	2.08E-06	1.21E-08	1.40E-08	9.99E-05
1974	1.68E-06	6.40E-06	1.72E-07	1.00E-09	1.16E-09	8.25E-06
1975	2.27E-05	8.64E-05	2.32E-06	1.35E-08	1.57E-08	1.11E-04
1976	4.20E-07	1.60E-06	4.30E-08	2.50E-10	2.90E-10	2.06E-06
1977	4.28E-07	1.63E-06	4.39E-08	2.55E-10	2.96E-10	2.10E-06
1978						
1979						
1980						
1981						
1982						
1983						
1984						
1985						
1986						
1987						
1988						
1989	1.94E-06	7.38E-06	1.98E-07	1.15E-09	1.34E-09	9.51E-06
1990						
1991						
1992						
1993						
1994						
1995						
Totals	2.46E-02	9.38E-02	2.52E-03	1.47E-05	1.70E-05	1.21E-01
Percent	20.35%	77.54%	2.08%	0.01%	0.01%	

Table Ru-103/106. Population Liquid-Pathway Doses

	Aquatic Food	Water	Shore	Swimming	Boating	Total Liquid Pathway
	(per.-rem)	(per.-rem)	(per.-rem)	(per.-rem)	(per.-rem)	(per.-rem)
1954	1.17E-02	2.07E-03	8.10E-05	1.98E-07	6.75E-07	1.38E-02
1955	4.35E-02	7.73E-03	3.02E-04	7.39E-07	2.52E-06	5.15E-02
1956	1.18E-01	2.09E-02	8.19E-04	2.00E-06	6.83E-06	1.40E-01
1957	5.57E-01	9.89E-02	3.87E-03	9.46E-06	3.23E-05	6.60E-01
1958	2.09E-01	3.71E-02	1.45E-03	3.55E-06	1.21E-05	2.47E-01
1959	5.13E-01	9.11E-02	3.56E-03	8.71E-06	2.97E-05	6.08E-01
1960	2.34E+00	4.16E-01	1.63E-02	3.98E-05	1.36E-04	2.77E+00
1961	1.82E+00	3.22E-01	1.26E-02	3.08E-05	1.05E-04	2.15E+00
1962	1.79E+00	3.17E-01	1.24E-02	3.04E-05	1.04E-04	2.12E+00
1963	3.24E+00	5.75E-01	2.25E-02	5.50E-05	1.88E-04	3.84E+00
1964	2.04E+00	3.62E-01	1.41E-02	3.46E-05	1.18E-04	2.41E+00
1965	9.95E-01	1.77E-01	6.91E-03	1.69E-05	5.76E-05	1.18E+00
1966	3.29E-01	5.84E-02	2.29E-03	5.59E-06	1.91E-05	3.90E-01
1967	5.02E-01	8.92E-02	3.49E-03	8.54E-06	2.91E-05	5.95E-01
1968	4.84E-01	8.60E-02	3.37E-03	8.23E-06	2.81E-05	5.74E-01
1969	1.35E-01	2.39E-02	9.36E-04	2.29E-06	7.80E-06	1.60E-01
1970	1.58E-02	2.81E-03	1.10E-04	2.68E-07	9.15E-07	1.87E-02
1971	8.94E-03	1.59E-03	6.21E-05	1.52E-07	5.18E-07	1.06E-02
1972	1.01E-02	1.79E-03	7.02E-05	1.72E-07	5.85E-07	1.20E-02
1973	1.25E-02	2.23E-03	8.71E-05	2.13E-07	7.26E-07	1.49E-02
1974	1.04E-03	1.84E-04	7.20E-06	1.76E-08	6.00E-08	1.23E-03
1975	1.40E-02	2.48E-03	9.72E-05	2.38E-07	8.10E-07	1.66E-02
1976	2.59E-04	4.60E-05	1.80E-06	4.40E-09	1.50E-08	3.07E-04
1977	2.64E-04	4.69E-05	1.84E-06	4.49E-09	1.53E-08	3.13E-04
1978						
1979						
1980						
1981						
1982						
1983						
1984						
1985						
1986						
1987						
1988						
1989	1.19E-03	2.12E-04	8.30E-06	2.03E-08	6.92E-08	1.41E-03
1990						
1991						
1992						
1993						
1994						
1995						
Totals	1.52E+01	2.70E+00	1.05E-01	2.58E-04	8.79E-04	1.80E+01
Percent	84.41%	14.99%	0.59%	0.00%	0.00%	

Table Ru-103/106 Air. Ru-103/106 Atmospheric Releases and Maximally Exposed Individual Doses 1954 - 1995

Table Ru-103/106 Liquid. Ru-103/106 Liquid Releases and Maximally Exposed Individual Doses 1954 - 1995

S-35

Half-Life

S-35 - 87.44 days

Total Curies Released (1954-1995)

Air - 0.0

Streams - $1.47\text{E}+03$

Basins (Decay Corrected) - $7.78\text{E}-09$

Total Cumulative Risks (1954-1995)

MEI Air Pathway - 0.0

MEI Liquid Pathway - $1.09\text{E}-06$

Population Air - 0.0

Population Liquid - $3.44\text{E}-03$

Projected 30-year Risks Using Recent Annual Doses (average of years 1991-1995)

MEI Air Pathway - 0.0

MEI Liquid Pathway - 0.0

Population Air - 0.0

Population Liquid - 0.0

Critical Pathways

MEI Air Pathway - N/A

MEI Liquid Pathway - Fish Consumption = 95%, Water Consumption = 5%

Population Air Pathway - N/A

Population Liquid Pathway - Aquatic Food = 56%, Water Consumption = 44%

Discussion

S-35 is a short-lived activation product that has not been measured in site airborne effluents and has not been measured in liquid effluents to site streams since 1990. However, on a cumulative MEI and population risk basis, S-35 was the 8th and 16th most important liquid pathway radionuclide, respectively. The cumulative MEI risk was estimated to be $1.1\text{E}-06$.

The fish consumption and aquatic food pathways are the most critical for S-35 due to its relatively high bioaccumulation factor in freshwater fish (750) (NRC, 1977a). Future releases of S-35 are expected to remain nil. Refer to Carlton, 1996 for a more complete assessment of S-35 at SRS.

Table S-35. Effluent Releases

	S-35 to Air	S-35 to Streams	S-35 to Basins	S-35 to Basins
	Curies	Curies	Curies	Decay Corrected (Ci)
1954				
1955				
1956				
1957				
1958				
1959				
1960				
1961		6.60E+01		
1962		5.12E+02		
1963		1.56E+02		
1964		9.13E+01		
1965		8.58E+01		
1966		1.21E+02		
1967		1.53E+02		
1968		1.71E+02	1.85E+02	1.74E-32
1969		6.43E+01	7.65E+01	1.31E-31
1970		2.57E+01	1.80E+01	5.62E-31
1971		1.15E+01	3.09E+00	1.76E-30
1972		1.50E+00	9.70E-01	1.00E-29
1973		1.70E+00	1.67E-01	3.15E-29
1974		4.97E+00	7.30E-01	2.51E-27
1975		2.91E-01	5.10E-02	3.19E-27
1976		3.44E-01	3.09E-01	3.51E-25
1977		6.19E-01	5.13E-02	1.06E-24
1978		1.54E-02	1.29E-02	4.86E-24
1979		1.07E-01	1.94E-01	1.33E-21
1980			1.09E-02	1.36E-21
1981			7.41E-02	1.69E-19
1982			7.10E-02	2.94E-18
1983			1.02E-01	7.69E-17
1984			1.47E-02	2.02E-16
1985			4.31E-02	1.08E-14
1986			2.70E-02	1.23E-13
1987			2.30E-02	1.91E-12
1988			2.43E-03	3.67E-12
1989			2.14E-03	5.88E-11
1990		3.32E-02	1.53E-02	7.65E-09
1991			7.59E-06	6.91E-11
1992				
1993				
1994				
1995				
Totals		1.47E+03	2.85E+02	7.78E-09

Table S-35. MEI Liquid-Pathway Doses

	Fish	Water	Shore	Swimming	Boating	Total Liquid Pathway
	(mrem)	(mrem)	(mrem)	(mrem)	(mrem)	(mrem)
1954						
1955						
1956						
1957						
1958						
1959						
1960						
1961	6.40E-02	3.30E-03				6.73E-02
1962	4.97E-01	2.56E-02				5.22E-01
1963	1.51E-01	7.80E-03				1.59E-01
1964	8.86E-02	4.57E-03				9.31E-02
1965	8.32E-02	4.29E-03				8.75E-02
1966	1.17E-01	6.05E-03				1.23E-01
1967	1.48E-01	7.65E-03				1.56E-01
1968	1.66E-01	8.55E-03				1.74E-01
1969	6.24E-02	3.22E-03				6.56E-02
1970	2.49E-02	1.29E-03				2.62E-02
1971	1.12E-02	5.75E-04				1.17E-02
1972	1.46E-03	7.50E-05				1.53E-03
1973	1.65E-03	8.50E-05				1.73E-03
1974	4.82E-03	2.49E-04				5.07E-03
1975	2.82E-04	1.46E-05				2.97E-04
1976	3.34E-04	1.72E-05				3.51E-04
1977	6.00E-04	3.10E-05				6.31E-04
1978	1.49E-05	7.70E-07				1.57E-05
1979	1.04E-04	5.35E-06				1.09E-04
1980						
1981						
1982						
1983						
1984						
1985						
1986						
1987						
1988						
1989						
1990	3.22E-05	1.66E-06				3.38E-05
1991						
1992						
1993						
1994						
1995						
Totals	1.42E+00	7.34E-02				1.50E+00
Percent	95.10%	4.90%				

Table S-35. Population Liquid-Pathway Doses

	Aquatic Food	Water	Shore	Swimming	Boating	Total Liquid Pathway
	(per.-rem)	(per.-rem)	(per.-rem)	(per.-rem)	(per.-rem)	(per.-rem)
1954						
1955						
1956						
1957						
1958						
1959						
1960						
1961	1.19E-01	9.24E-02				2.12E-01
1962	9.27E-01	7.17E-01				1.64E+00
1963	2.82E-01	2.18E-01				5.01E-01
1964	1.65E-01	1.28E-01				2.93E-01
1965	1.55E-01	1.20E-01				2.75E-01
1966	2.19E-01	1.69E-01				3.88E-01
1967	2.77E-01	2.14E-01				4.91E-01
1968	3.10E-01	2.39E-01				5.49E-01
1969	1.16E-01	9.00E-02				2.06E-01
1970	4.65E-02	3.60E-02				8.25E-02
1971	2.08E-02	1.61E-02				3.69E-02
1972	2.72E-03	2.10E-03				4.82E-03
1973	3.08E-03	2.38E-03				5.46E-03
1974	9.00E-03	6.96E-03				1.60E-02
1975	5.27E-04	4.07E-04				9.34E-04
1976	6.23E-04	4.82E-04				1.10E-03
1977	1.12E-03	8.67E-04				1.99E-03
1978	2.79E-05	2.16E-05				4.94E-05
1979	1.94E-04	1.50E-04				3.43E-04
1980						
1981						
1982						
1983						
1984						
1985						
1986						
1987						
1988						
1989						
1990	6.00E-05	4.64E-05				1.06E-04
1991						
1992						
1993						
1994						
1995						
Totals	2.66E+00	2.05E+00				4.71E+00
Percent	56.39%	43.61%				

Table S-35 Liquid. S-35 Liquid Releases and Maximally Exposed Individual Doses 1954 - 1995

Sb-124/125

Half-Life

Sb-124 - 60.2 days

Sb-125 - 2.758 years

Total Curies Released (1954-1995)

Air - 0.0

Streams - 7.56E+00

Basins (Decay Corrected) - 7.15E-12

Total Cumulative Risks (1954-1995)

MEI Air Pathway - 0.0

MEI Liquid Pathway - 4.37E-09

Population Air - 0.0

Population Liquid - 1.28E-04

Projected 30-year Risks Using Recent Annual Doses (average of years 1991-1995)

MEI Air Pathway - 0.0

MEI Liquid Pathway - 0.0

Population Air - 0.0

Population Liquid - 0.0

Critical Pathways

MEI Air Pathway - N/A

MEI Liquid Pathway - Water Consumption = 90%, Shore = 7%

Population Air Pathway - N/A

Population Liquid Pathway - Water Consumption = 86%, Shore = 11%

Discussion

Sb-124/125 are short and medium-lived activation/fission products that were measured only in liquid effluents. Because Sb-124 has a larger ingestion dose factor than Sb-125 (DOE, 1988), measured liquid releases of Sb-124/125 are conservatively added with Sb-124 releases for dose and risk calculations. On a cumulative MEI and population risk basis, Sb-124/125 were the 25th and 24th most important liquid pathway radionuclides, respectively. Future liquid releases of Sb-124/125 are expected to remain essentially nil.

Table Sb-124/125. Effluent Releases

	Sb-124,125	Sb-124,125	Sb-124,125	Sb-124,125-Basin
	Air (Curies)	Streams (Curies)	Basins (Curies)	Decay Corrected (Ci)
1954				
1955				
1956				
1957				
1958				
1959				
1960				
1961				
1962				
1963				
1964		7.50E+00		
1965				
1966				
1967				
1968				
1969				
1970			1.60E+00	4.27E-46
1971		4.04E-02	8.05E+00	1.43E-43
1972			7.10E-01	8.38E-43
1973		2.10E-02	5.53E-01	4.34E-41
1974			4.18E-01	2.18E-39
1975		1.00E-03	1.08E-01	3.75E-38
1976			2.22E-01	5.13E-36
1977		8.82E-04	6.27E-02	9.64E-35
1978			6.25E-02	6.39E-33
1979			6.95E-02	4.73E-31
1980			1.68E-02	7.60E-30
1981			1.29E-01	3.88E-27
1982			7.10E-02	1.42E-25
1983			7.25E-02	9.66E-24
1984			2.84E-02	2.52E-22
1985			1.07E-02	6.31E-21
1986			9.21E-03	3.61E-19
1987			1.78E-04	4.64E-19
1988				
1989			3.04E-04	3.51E-15
1990				
1991			1.40E-04	7.15E-12
1992				
1993				
1994				
1995				
Totals		7.56E+00	1.22E+01	7.15E-12

Table Sb-124/125. MEI Liquid Pathway Doses

	Fish	Water	Shore	Swimming	Boating	Total Liquid Pathway
	(mrem)	(mrem)	(mrem)	(mrem)	(mrem)	(mrem)
1954						
1955						
1956						
1957						
1958						
1959						
1960						
1961						
1962						
1963						
1964	1.35E-04	5.33E-03	4.43E-04	1.73E-05	2.03E-05	5.94E-03
1965						
1966						
1967						
1968						
1969						
1970						
1971	7.27E-07	2.87E-05	2.38E-06	9.29E-08	1.09E-07	3.20E-05
1972						
1973	3.78E-07	1.49E-05	1.24E-06	4.83E-08	5.67E-08	1.66E-05
1974						
1975	1.80E-08	7.10E-07	5.90E-08	2.30E-09	2.70E-09	7.92E-07
1976						
1977	1.59E-08	6.26E-07	5.20E-08	2.03E-09	2.38E-09	6.99E-07
1978						
1979						
1980						
1981						
1982						
1983						
1984						
1985						
1986						
1987						
1988						
1989						
1990						
1991						
1992						
1993						
1994						
1995						
Totals	1.36E-04	5.37E-03	4.46E-04	1.74E-05	2.04E-05	5.99E-03
Percent	2.27%	89.65%	7.45%	0.29%	0.34%	

Table Sb-124/125. Population Liquid Pathway Doses

	Aquatic Food	Water	Shore	Swimming	Boating	Total Liquid Pathway
	(per.-rem)	(per.-rem)	(per.-rem)	(per.-rem)	(per.-rem)	(per.-rem)
1954						
1955						
1956						
1957						
1958						
1959						
1960						
1961						
1962						
1963						
1964	4.04E-03	1.50E-01	1.88E-02	3.08E-04	1.05E-03	1.74E-01
1965						
1966						
1967						
1968						
1969						
1970						
1971	2.17E-05	8.08E-04	1.01E-04	1.66E-06	5.66E-06	9.38E-04
1972						
1973	1.13E-05	4.20E-04	5.25E-05	8.61E-07	2.94E-06	4.88E-04
1974						
1975	5.38E-07	2.00E-05	2.50E-06	4.10E-08	1.40E-07	2.32E-05
1976						
1977	4.75E-07	1.76E-05	2.21E-06	3.62E-08	1.23E-07	2.05E-05
1978						
1979						
1980						
1981						
1982						
1983						
1984						
1985						
1986						
1987						
1988						
1989						
1990						
1991						
1992						
1993						
1994						
1995						
Totals	4.07E-03	1.51E-01	1.89E-02	3.10E-04	1.06E-03	1.76E-01
Percent	2.32%	86.14%	10.77%	0.18%	0.60%	

Table Sb-124/125 Liquid. Sb-124/125 Liquid Releases and Maximally Exposed Individual Doses 1954 - 1995

Sb-125

Half-Life

Sb-125 - 2.785 years

Total Curies Released (1954-1995)

Air - 6.63E-07

Streams - 0.0

Basins (Decay Corrected) - 4.94E-02

Total Cumulative Risks (1954-1995)

MEI Air Pathway - 6.81E-15

MEI Liquid Pathway - 0.0

Population Air - 4.01E-10

Population Liquid - 0.0

Projected 30-year Risks Using Recent Annual Doses (average of years 1991-1995)

MEI Air Pathway - 5.26E-15

MEI Liquid Pathway - 0.0

Population Air - 3.10E-10

Population Liquid - 0.0

Critical Pathways

MEI Air Pathway - Ground = 92%, Vegetation Consumption = 7%

MEI Liquid Pathway - N/A

Population Air Pathway - Ground = 97%, Vegetation Consumption = 3%

Population Liquid Pathway - N/A

Discussion

Sb-125 is a medium-lived activation/fission product that was measured only in air effluents during two years (1990 and 1991). On a cumulative MEI and population risk basis, Sb-125 was the 29th most important air pathway radionuclide. This was the lowest of all measured radionuclides. Future airborne and liquid releases of Sb-125 are expected to remain essentially nil. However, estimated residual inventories ($>1.6\text{E}+05$ Ci) of Sb-125 are relatively high and may cause it to assume greater importance, on a percentage-of-risk basis, in the near (0-30 years) future.

Table Sb-125. Effluent Releases

	Sb-125	Sb-125	Sb-125	Sb-125-Basin
	Air (Curies)	Streams (Curies)	Basins (Curies)	Decay Corrected (Ci)
1954				
1955				
1956				
1957				
1958				
1959				
1960				
1961				
1962				
1963			1.00E-01	2.78E-05
1964			1.00E-01	3.59E-05
1965				
1966				
1967				
1968				
1969				
1970				
1971			1.11E+00	2.39E-03
1972			8.60E-01	2.39E-03
1973				
1974				
1975				
1976				
1977				
1978				
1979				
1980				
1981			1.60E+00	4.45E-02
1982				
1983				
1984				
1985				
1986				
1987				
1988				
1989				
1990	5.78E-07			
1991	8.54E-08			
1992				
1993				
1994				
1995				
Totals	6.63E-07		3.77E+00	4.94E-02

Table Sb-125. MEI Air-Pathway Doses

	Plume	Ground	Inhalation	Vegetation	Milk	Meat	Total Air Pathway
	(mrem)	(mrem)	(mrem)	(mrem)	(mrem)	(mrem)	(mrem)
1954							
1955							
1956							
1957							
1958							
1959							
1960							
1961							
1962							
1963							
1964							
1965							
1966							
1967							
1968							
1969							
1970							
1971							
1972							
1973							
1974							
1975							
1976							
1977							
1978							
1979							
1980							
1981							
1982							
1983							
1984							
1985							
1986							
1987							
1988							
1989							
1990		7.51E-09	1.56E-11	5.66E-10	2.08E-11	1.56E-11	8.13E-09
1991		1.11E-09	2.31E-12	8.37E-11	3.07E-12	2.31E-12	1.20E-09
1992							
1993							
1994							
1995							
Totals		8.62E-09	1.79E-11	6.50E-10	2.39E-11	1.79E-11	9.33E-09
Percent		92.40%	0.19%	6.97%	0.26%	0.19%	

Table Sb-125. Population Air-Pathway Doses

	Plume	Ground	Inhalation	Vegetation	Milk	Meat	Total Air Pathway
	(per.-rem)	(per.-rem)	(per.-rem)	(per.-rem)	(per.-rem)	(per.-rem)	(per.-rem)
1954							
1955							
1956							
1957							
1958							
1959							
1960							
1961							
1962							
1963							
1964							
1965							
1966							
1967							
1968							
1969							
1970							
1971							
1972							
1973							
1974							
1975							
1976							
1977							
1978							
1979							
1980							
1981							
1982							
1983							
1984							
1985							
1986							
1987							
1988							
1989							
1990		4.62E-07	1.85E-09	1.33E-08	7.51E-10	3.18E-10	4.79E-07
1991		6.83E-08	2.73E-10	1.96E-09	1.11E-10	4.70E-11	7.07E-08
1992							
1993							
1994							
1995							
Totals		5.31E-07	2.12E-09	1.53E-08	8.62E-10	3.65E-10	5.49E-07
Percent		96.61%	0.39%	2.78%	0.16%	0.07%	

Table Sb-125 Air. Sb-125 Atmospheric Releases and Maximally Exposed Individual Doses 1954 - 1995

Se-75

Half-Life

Se-75 - 119.8 days

Total Curies Released (1954-1995)

Air - 1.87E-04

Streams - 0.0

Basins (Decay Corrected) - 0.0

Total Cumulative Risks (1954-1995)

MEI Air Pathway - Not Calculated

MEI Liquid Pathway - 0.0

Population Air - Not Calculated

Population Liquid - 0.0

Projected 30-year Risks Using Recent Annual Doses (average of years 1991-1995)

MEI Air Pathway - Not Calculated

MEI Liquid Pathway - 0.0

Population Air - Not Calculated

Population Liquid - 0.0

Critical Pathways

MEI Air Pathway - N/A

MEI Liquid Pathway - N/A

Population Air Pathway - N/A

Population Liquid Pathway - N/A

Discussion

Se-75 is a short-lived fission/activation product that was measured to have been released to the atmosphere only during six years (1983-1988). The MAXIGASP dosimetry code does not have Se-75 in its radionuclide library, therefore, doses and risks were not calculated. However, because of the small amount released and its relatively short half-life, Se-75 is not of concern on a cumulative or projected risk basis.

Table Se-75. Effluent Releases

	Se-75 to Air Curies	Se-75 to Streams Curies	Se-75 to Basins Curies	Se-75 to Basins Decay Corrected (Ci)
1954				
1955				
1956				
1957				
1958				
1959				
1960				
1961				
1962				
1963				
1964				
1965				
1966				
1967				
1968				
1969				
1970				
1971				
1972				
1973				
1974				
1975				
1976				
1977				
1978				
1979				
1980				
1981				
1982				
1983	5.50E-05			
1984	4.20E-05			
1985	9.30E-06			
1986	2.10E-05			
1987	4.00E-05			
1988	2.00E-05			
1989				
1990				
1991				
1992				
1993				
1994				
1995				
Totals	1.87E-04			

Sr-89

Half-Life

Sr-89 - 50.52 days

Total Curies Released (1954-1995)

Air - 0.0

Streams - 2.16E+02

Basins (Decay Corrected) - <1.00E-12

Total Cumulative Risks (1954-1995)

MEI Air Pathway - 0.0

MEI Liquid Pathway - 1.85E-07

Population Air - 0.0

Population Liquid - 3.28E-03

Projected 30-year Risks Using Recent Annual Doses (average of years 1991-1995)

MEI Air Pathway - 0.0

MEI Liquid Pathway - 0.0

Population Air - 0.0

Population Liquid - 0.0

Critical Pathways

MEI Air Pathway - N/A

MEI Liquid Pathway - Water Consumption = 56%, Fish Consumption = 44%

Population Air Pathway - N/A

Population Liquid Pathway - Water Consumption = 87%, Aquatic Food = 13%

Discussion

Sr-89 is a short-lived fission product that has not been measured in site streams, separately from Sr-90, since 1977. On a cumulative MEI and population risk basis, Sr-89 was the 18th and 14th most important liquid pathway radionuclide, respectively. Future releases of Sr-89 are expected to remain nil.

Refer to Carlton, 1994 for a more complete assessment of Sr-89 at SRS.

Table Sr-89. Effluent Releases

	Sr-89 to Air	Sr-89 to Streams	Sr-89 to Basins	Sr-89 to Basins
	Curies	Curies	Curies	Decay Corrected (Ci)
1954				
1955				
1956				
1957				
1958				
1959				
1960				
1961		1.14E+01		
1962		3.43E+01		
1963		3.37E+01	5.69E+00	<1.00E-12
1964		6.20E+01	1.31E+00	<1.00E-12
1965		6.88E+00	1.24E+00	<1.00E-12
1966		6.09E+00	6.60E-01	<1.00E-12
1967		1.30E+01	7.30E-01	<1.00E-12
1968		2.90E+01	4.60E-01	<1.00E-12
1969		8.82E+00	4.61E+01	<1.00E-12
1970		8.32E+00	3.88E+01	<1.00E-12
1971		1.90E+00	3.47E+00	<1.00E-12
1972		4.50E-01	2.33E+00	<1.00E-12
1973		1.57E-01	1.86E+00	<1.00E-12
1974		1.46E-01	3.06E-01	<1.00E-12
1975		1.40E-02	4.00E-01	<1.00E-12
1976		4.00E-03	1.93E-01	<1.00E-12
1977		2.28E-01	6.16E-02	<1.00E-12
1978			3.51E-01	<1.00E-12
1979			8.32E-02	<1.00E-12
1980			4.50E-02	<1.00E-12
1981			1.21E-01	<1.00E-12
1982			6.74E-02	<1.00E-12
1983			8.73E-02	<1.00E-12
1984			1.64E-02	<1.00E-12
1985			1.38E-02	<1.00E-12
1986			1.07E-02	<1.00E-12
1987			8.96E-03	<1.00E-12
1988			2.76E-02	<1.00E-12
1989				
1990				
1991				
1992				
1993				
1994				
1995				
Totals		2.16E+02	1.04E+02	<1.00E-12

Table Sr-89. MEI Liquid-Pathway Doses

	Fish	Water	Shore	Swimming	Boating	Total Liquid Pathway
	(mrem)	(mrem)	(mrem)	(mrem)	(mrem)	(mrem)
1954						
1955						
1956						
1957						
1958						
1959						
1960						
1961	5.81E-03	7.52E-03	4.33E-08	1.94E-09	2.28E-09	1.33E-02
1962	1.75E-02	2.26E-02	1.30E-07	5.83E-09	6.86E-09	4.01E-02
1963	1.72E-02	2.22E-02	1.28E-07	5.73E-09	6.74E-09	3.94E-02
1964	3.16E-02	4.09E-02	2.36E-07	1.05E-08	1.24E-08	7.25E-02
1965	3.51E-03	4.54E-03	2.61E-08	1.17E-09	1.38E-09	8.05E-03
1966	3.11E-03	4.02E-03	2.31E-08	1.04E-09	1.22E-09	7.13E-03
1967	6.63E-03	8.58E-03	4.94E-08	2.21E-09	2.60E-09	1.52E-02
1968	1.48E-02	1.91E-02	1.10E-07	4.93E-09	5.80E-09	3.39E-02
1969	4.50E-03	5.82E-03	3.35E-08	1.50E-09	1.76E-09	1.03E-02
1970	4.24E-03	5.49E-03	3.16E-08	1.41E-09	1.66E-09	9.73E-03
1971	9.69E-04	1.25E-03	7.22E-09	3.23E-10	3.80E-10	2.22E-03
1972	2.30E-04	2.97E-04	1.71E-09	7.65E-11	9.00E-11	5.27E-04
1973	8.01E-05	1.04E-04	5.97E-10	2.67E-11	3.14E-11	1.84E-04
1974	7.45E-05	9.64E-05	5.55E-10	2.48E-11	2.92E-11	1.71E-04
1975	7.14E-06	9.24E-06	5.32E-11	2.38E-12	2.80E-12	1.64E-05
1976	2.04E-06	2.64E-06	1.52E-11	6.80E-13	8.00E-13	4.68E-06
1977	1.16E-04	1.50E-04	8.66E-10	3.88E-11	4.56E-11	2.67E-04
1978						
1979						
1980						
1981						
1982						
1983						
1984						
1985						
1986						
1987						
1988						
1989						
1990						
1991						
1992						
1993						
1994						
1995						
Totals	1.10E-01	1.43E-01	8.22E-07	3.68E-08	4.33E-08	2.53E-01
Percent	43.59%	56.41%	0.00%	0.00%	0.00%	

Table Sr-89. Population Liquid-Pathway Doses

	Aquatic Food	Water	Shore	Swimming	Boating	Total Liquid Pathway
	(per.-rem)	(per.-rem)	(per.-rem)	(per.-rem)	(per.-rem)	(per.-rem)
1954						
1955						
1956						
1957						
1958						
1959						
1960						
1961	3.14E-02	2.05E-01	1.82E-06	3.42E-08	1.14E-07	2.37E-01
1962	9.43E-02	6.17E-01	5.49E-06	1.03E-07	3.43E-07	7.12E-01
1963	9.27E-02	6.07E-01	5.39E-06	1.01E-07	3.37E-07	6.99E-01
1964	1.71E-01	1.12E+00	9.92E-06	1.86E-07	6.20E-07	1.29E+00
1965	1.89E-02	1.24E-01	1.10E-06	2.06E-08	6.88E-08	1.43E-01
1966	1.67E-02	1.10E-01	9.74E-07	1.83E-08	6.09E-08	1.26E-01
1967	3.58E-02	2.34E-01	2.08E-06	3.90E-08	1.30E-07	2.70E-01
1968	7.98E-02	5.22E-01	4.64E-06	8.70E-08	2.90E-07	6.02E-01
1969	2.43E-02	1.59E-01	1.41E-06	2.65E-08	8.82E-08	1.83E-01
1970	2.29E-02	1.50E-01	1.33E-06	2.50E-08	8.32E-08	1.73E-01
1971	5.23E-03	3.42E-02	3.04E-07	5.70E-09	1.90E-08	3.94E-02
1972	1.24E-03	8.10E-03	7.20E-08	1.35E-09	4.50E-09	9.34E-03
1973	4.32E-04	2.83E-03	2.51E-08	4.71E-10	1.57E-09	3.26E-03
1974	4.02E-04	2.63E-03	2.34E-08	4.38E-10	1.46E-09	3.03E-03
1975	3.85E-05	2.52E-04	2.24E-09	4.20E-11	1.40E-10	2.91E-04
1976	1.10E-05	7.20E-05	6.40E-10	1.20E-11	4.00E-11	8.30E-05
1977	6.27E-04	4.10E-03	3.65E-08	6.84E-10	2.28E-09	4.73E-03
1978						
1979						
1980						
1981						
1982						
1983						
1984						
1985						
1986						
1987						
1988						
1989						
1990						
1991						
1992						
1993						
1994						
1995						
Totals	5.95E-01	3.90E+00	3.46E-05	6.49E-07	2.16E-06	4.49E+00
Percent	13.25%	86.75%	0.00%	0.00%	0.00%	

Table Sr-89 Liquid. Sr-89 Liquid Releases and Maximally Exposed Individual Doses 1954 - 1995

Sr-89/90

(Including Unidentified Beta)

Half-Life

Sr-89/90 - 29.1 years

Total Curies Released (1954-1995)

Air - 4.70E+01

Streams - 1.52E+02

Basins (Decay Corrected) - 2.15E+02

Total Cumulative Risks (1954-1995)

MEI Air Pathway - 2.13E-06

MEI Liquid Pathway - 1.99E-06

Population Air - 6.46E-02

Population Liquid - 3.76E-02

Projected 30-year Risks Using Recent Annual Doses (average of years 1991-1995)

MEI Air Pathway - 4.15E-09

MEI Liquid Pathway - 2.06E-07

Population Air - 1.26E-04

Population Liquid - 3.90E-03

Critical Pathways

MEI Air Pathway - Vegetation Consumption = 91%, Inhalation = 6%

MEI Liquid Pathway - Water Consumption = 56%, Fish Consumption = 44%

Population Air Pathway - Vegetation Consumption = 74%, Inhalation = 23%

Population Liquid Pathway - Water Consumption = 86%, Aquatic Food = 14%

Discussion

Sr-89/90 are short- and medium-lived, very abundant fission products. Because Sr-90 has larger ingestion and inhalation dose factors than does Sr-89 (as well as most other common beta emitters), measured releases of Sr-89/90, and other unidentified beta emitters, are conservatively added with Sr-90 releases for dose and risk calculations (DOE, 1988). On a cumulative MEI and population risk basis, Sr-89/90 were the 6th most important liquid pathway radionuclides and the 7th and 8th most important air pathway radionuclides, respectively. The projected 30-year MEI liquid pathway risk is estimated to be 2.1E-07, which is the 3rd most important. The projected 30-year MEI air pathway risk is estimated to be 4.2E-09, which is the 8th most important. Estimated residual inventories ($>1.9\text{E}+06$ Ci) will cause Sr-89/90 to remain of importance, on a percentage-of-risk basis, in the near-to-distant (0-100 years) future. Refer to Carlton, 1994 for a more complete assessment of strontium at SRS.

Table Sr-89/90. Effluent Releases

	Sr-89,90 - Air	Sr-89,90 - Streams	Sr-89,90 - Basins	Sr-89,90 - Basins
	Curies	Curies	Curies	Decay Corrected (Ci)
1954		4.70E-02	7.31E-02	2.71E-02
1955	3.43E+01	2.75E-01	8.51E-01	3.23E-01
1956	8.49E+00	2.03E+00	1.02E+01	3.96E+00
1957	1.69E+00	1.12E+01	1.85E+02	7.38E+01
1958	3.36E-02	1.08E+00	1.52E+01	6.18E+00
1959	8.04E-01	2.67E+00	2.01E+01	8.42E+00
1960	1.37E-01	2.67E+01	5.28E+00	2.26E+00
1961	1.39E-01	7.47E+00	5.68E+00	2.49E+00
1962	3.46E-01	7.51E+00	5.61E+00	2.52E+00
1963	2.58E-01	1.19E+01	1.08E+01	4.97E+00
1964	1.01E-01	1.12E+01	4.87E+00	2.30E+00
1965	1.13E-01	8.60E+00	6.96E+00	3.37E+00
1966	3.41E-02	7.36E+00	4.58E+01	2.27E+01
1967	2.77E-02	1.86E+01	1.18E+02	5.99E+01
1968	3.81E-02	6.27E+00	3.98E+00	2.07E+00
1969	1.26E-01	4.22E+00	8.30E+00	4.42E+00
1970	6.25E-02	3.91E+00	8.02E+00	4.37E+00
1971	5.17E-02	3.75E+00	2.52E+00	1.41E+00
1972	1.35E-01	1.73E+00	1.02E+00	5.85E-01
1973	1.47E-02	1.96E+00	1.14E+00	6.67E-01
1974	1.14E-02	1.46E+00	3.31E-01	1.99E-01
1975	5.57E-03	1.25E+00	9.28E-01	5.71E-01
1976	5.38E-03	1.01E+00	6.75E-01	4.26E-01
1977	4.64E-03	7.57E-01	6.29E-01	4.07E-01
1978	3.90E-02	6.34E-01	2.46E+00	1.63E+00
1979	2.74E-03	1.27E+00	2.92E+00	1.98E+00
1980	4.57E-03	8.22E-01	2.93E-01	2.04E-01
1981	4.06E-03	7.07E-01	1.17E+00	8.34E-01
1982	3.36E-03	4.42E-01	8.18E-01	5.97E-01
1983	4.58E-03	3.50E-01	3.77E-01	2.82E-01
1984	4.02E-03	4.60E-01	5.35E-01	4.10E-01
1985	2.45E-03	3.02E-01	7.75E-01	6.08E-01
1986	1.89E-03	3.31E-01	3.06E-01	2.46E-01
1987	1.37E-03	3.96E-01	1.77E-01	1.46E-01
1988	3.22E-03	3.77E-01	3.66E-02	3.09E-02
1989	1.14E-03	2.67E-01	2.35E-02	2.03E-02
1990	8.00E-03	3.86E-01	4.21E-02	3.73E-02
1991	3.32E-03	5.86E-01	9.30E-04	8.44E-04
1992	2.03E-03	7.86E-01		
1993	2.27E-03	4.77E-01		
1994	2.11E-03	3.86E-01		
1995	5.52E-03	3.98E-01		
Totals	4.70E+01	1.52E+02	4.72E+02	2.15E+02

Table Sr-89/90. MEI Air-Pathway Doses

	Plume	Ground	Inhalation	Vegetation	Milk	Meat	Total Air Pathway
	(mrem)	(mrem)	(mrem)	(mrem)	(mrem)	(mrem)	(mrem)
1954							
1955			1.24E-01	1.96E+00	4.12E-02	8.92E-03	2.13E+00
1956			3.06E-02	4.84E-01	1.02E-02	2.21E-03	5.27E-01
1957			6.09E-03	9.64E-02	2.03E-03	4.40E-04	1.05E-01
1958			1.21E-04	1.92E-03	4.03E-05	8.74E-06	2.09E-03
1959			2.89E-03	4.58E-02	9.65E-04	2.09E-04	4.99E-02
1960			4.92E-04	7.79E-03	1.64E-04	3.55E-05	8.48E-03
1961			5.01E-04	7.93E-03	1.67E-04	3.62E-05	8.64E-03
1962			1.25E-03	1.97E-02	4.15E-04	9.00E-05	2.15E-02
1963			9.30E-04	1.47E-02	3.10E-04	6.72E-05	1.60E-02
1964			3.64E-04	5.76E-03	1.21E-04	2.63E-05	6.27E-03
1965			4.06E-04	6.44E-03	1.35E-04	2.94E-05	7.01E-03
1966			1.23E-04	1.94E-03	4.09E-05	8.87E-06	2.12E-03
1967			9.97E-05	1.58E-03	3.32E-05	7.20E-06	1.72E-03
1968			1.37E-04	2.17E-03	4.57E-05	9.91E-06	2.36E-03
1969			4.55E-04	7.20E-03	1.52E-04	3.29E-05	7.84E-03
1970			2.25E-04	3.56E-03	7.50E-05	1.63E-05	3.88E-03
1971			1.86E-04	2.95E-03	6.20E-05	1.34E-05	3.21E-03
1972			4.86E-04	7.70E-03	1.62E-04	3.51E-05	8.38E-03
1973			5.28E-05	8.36E-04	1.76E-05	3.81E-06	9.10E-04
1974			4.10E-05	6.49E-04	1.37E-05	2.96E-06	7.07E-04
1975			2.00E-05	3.17E-04	6.68E-06	1.45E-06	3.45E-04
1976			1.94E-05	3.07E-04	6.45E-06	1.40E-06	3.34E-04
1977			1.67E-05	2.64E-04	5.56E-06	1.21E-06	2.88E-04
1978			1.41E-04	2.23E-03	4.68E-05	1.01E-05	2.42E-03
1979			9.86E-06	1.56E-04	3.29E-06	7.12E-07	1.70E-04
1980			1.65E-05	2.60E-04	5.48E-06	1.19E-06	2.84E-04
1981			1.46E-05	2.31E-04	4.87E-06	1.06E-06	2.52E-04
1982			1.21E-05	1.92E-04	4.03E-06	8.74E-07	2.09E-04
1983			1.65E-05	2.61E-04	5.50E-06	1.19E-06	2.84E-04
1984			1.45E-05	2.29E-04	4.83E-06	1.05E-06	2.50E-04
1985			8.82E-06	1.40E-04	2.94E-06	6.37E-07	1.52E-04
1986			6.80E-06	1.08E-04	2.27E-06	4.91E-07	1.17E-04
1987			4.92E-06	7.79E-05	1.64E-06	3.55E-07	8.48E-05
1988			1.16E-05	1.84E-04	3.86E-06	8.37E-07	2.00E-04
1989			4.10E-06	6.49E-05	1.37E-06	2.96E-07	7.07E-05
1990			2.88E-05	4.56E-04	9.60E-06	2.08E-06	4.96E-04
1991			1.20E-05	1.89E-04	3.99E-06	8.64E-07	2.06E-04
1992			7.31E-06	1.16E-04	2.44E-06	5.28E-07	1.26E-04
1993			8.17E-06	1.29E-04	2.72E-06	5.90E-07	1.41E-04
1994			7.60E-06	1.20E-04	2.53E-06	5.49E-07	1.31E-04
1995			1.99E-05	3.15E-04	6.62E-06	1.44E-06	3.43E-04
Totals			1.69E-01	2.68E+00	5.65E-02	1.22E-02	2.92E+00
Percent			5.80%	91.85%	1.93%	0.42%	

Table Sr-89/90. Population Air-Pathway Doses

	Plume	Ground	Inhalation	Vegetation	Milk	Meat	Total Air Pathway
	(per.-rem)	(per.-rem)	(per.-rem)	(per.-rem)	(per.-rem)	(per.-rem)	(per.-rem)
1954							
1955			1.48E+01	4.81E+01	1.51E+00	1.99E-01	6.45E+01
1956			3.65E+00	1.19E+01	3.73E-01	4.92E-02	1.60E+01
1957			7.27E-01	2.37E+00	7.44E-02	9.81E-03	3.18E+00
1958			1.44E-02	4.70E-02	1.48E-03	1.95E-04	6.32E-02
1959			3.46E-01	1.13E+00	3.54E-02	4.66E-03	1.51E+00
1960			5.88E-02	1.91E-01	6.01E-03	7.93E-04	2.57E-01
1961			5.99E-02	1.95E-01	6.12E-03	8.07E-04	2.62E-01
1962			1.49E-01	4.84E-01	1.52E-02	2.01E-03	6.50E-01
1963			1.11E-01	3.62E-01	1.14E-02	1.50E-03	4.86E-01
1964			4.34E-02	1.41E-01	4.44E-03	5.86E-04	1.90E-01
1965			4.85E-02	1.58E-01	4.97E-03	6.55E-04	2.12E-01
1966			1.47E-02	4.77E-02	1.50E-03	1.98E-04	6.41E-02
1967			1.19E-02	3.88E-02	1.22E-03	1.61E-04	5.21E-02
1968			1.64E-02	5.33E-02	1.68E-03	2.21E-04	7.16E-02
1969			5.44E-02	1.77E-01	5.56E-03	7.33E-04	2.38E-01
1970			2.69E-02	8.75E-02	2.75E-03	3.63E-04	1.18E-01
1971			2.22E-02	7.24E-02	2.27E-03	3.00E-04	9.72E-02
1972			5.81E-02	1.89E-01	5.94E-03	7.83E-04	2.54E-01
1973			6.30E-03	2.05E-02	6.45E-04	8.50E-05	2.76E-02
1974			4.90E-03	1.59E-02	5.01E-04	6.61E-05	2.14E-02
1975			2.39E-03	7.79E-03	2.45E-04	3.23E-05	1.05E-02
1976			2.31E-03	7.53E-03	2.37E-04	3.12E-05	1.01E-02
1977			1.99E-03	6.49E-03	2.04E-04	2.69E-05	8.71E-03
1978			1.68E-02	5.47E-02	1.72E-03	2.26E-04	7.34E-02
1979			1.18E-03	3.83E-03	1.20E-04	1.59E-05	5.15E-03
1980			1.97E-03	6.40E-03	2.01E-04	2.65E-05	8.59E-03
1981			1.75E-03	5.68E-03	1.79E-04	2.35E-05	7.63E-03
1982			1.44E-03	4.70E-03	1.48E-04	1.95E-05	6.32E-03
1983			1.97E-03	6.41E-03	2.02E-04	2.66E-05	8.61E-03
1984			1.73E-03	5.63E-03	1.77E-04	2.33E-05	7.56E-03
1985			1.05E-03	3.43E-03	1.08E-04	1.42E-05	4.60E-03
1986			8.12E-04	2.64E-03	8.31E-05	1.10E-05	3.55E-03
1987			5.88E-04	1.91E-03	6.01E-05	7.93E-06	2.57E-03
1988			1.38E-03	4.51E-03	1.42E-04	1.87E-05	6.05E-03
1989			4.90E-04	1.59E-03	5.01E-05	6.61E-06	2.14E-03
1990			3.44E-03	1.12E-02	3.52E-04	4.64E-05	1.50E-02
1991			1.43E-03	4.65E-03	1.46E-04	1.93E-05	6.25E-03
1992			8.73E-04	2.84E-03	8.93E-05	1.18E-05	3.82E-03
1993			9.76E-04	3.18E-03	9.99E-05	1.32E-05	4.27E-03
1994			9.07E-04	2.95E-03	9.28E-05	1.22E-05	3.97E-03
1995			2.37E-03	7.73E-03	2.43E-04	3.20E-05	1.04E-02
Totals			2.02E+01	6.59E+01	2.07E+00	2.73E-01	8.84E+01
Percent			22.87%	74.48%	2.34%	0.31%	

Table Sr-89/90. MEI Liquid-Pathway Doses

	Fish	Water	Shore	Swimming	Boating	Total Liquid Pathway
	(mrem)	(mrem)	(mrem)	(mrem)	(mrem)	(mrem)
1954	3.71E-04	4.70E-04				8.41E-04
1955	2.17E-03	2.75E-03				4.92E-03
1956	1.61E-02	2.03E-02				3.64E-02
1957	8.85E-02	1.12E-01				2.01E-01
1958	8.56E-03	1.08E-02				1.94E-02
1959	2.11E-02	2.67E-02				4.77E-02
1960	2.11E-01	2.67E-01				4.78E-01
1961	5.90E-02	7.47E-02				1.34E-01
1962	5.94E-02	7.51E-02				1.34E-01
1963	9.40E-02	1.19E-01				2.13E-01
1964	8.82E-02	1.12E-01				2.00E-01
1965	6.79E-02	8.60E-02				1.54E-01
1966	5.81E-02	7.36E-02				1.32E-01
1967	1.47E-01	1.86E-01				3.33E-01
1968	4.95E-02	6.27E-02				1.12E-01
1969	3.33E-02	4.22E-02				7.54E-02
1970	3.09E-02	3.91E-02				7.00E-02
1971	2.96E-02	3.75E-02				6.71E-02
1972	1.36E-02	1.73E-02				3.09E-02
1973	1.55E-02	1.96E-02				3.50E-02
1974	1.15E-02	1.46E-02				2.61E-02
1975	9.89E-03	1.25E-02				2.24E-02
1976	7.97E-03	1.01E-02				1.80E-02
1977	5.98E-03	7.57E-03				1.35E-02
1978	5.01E-03	6.34E-03				1.14E-02
1979	9.99E-03	1.27E-02				2.26E-02
1980	6.49E-03	8.22E-03				1.47E-02
1981	5.59E-03	7.07E-03				1.27E-02
1982	3.49E-03	4.42E-03				7.91E-03
1983	2.76E-03	3.50E-03				6.26E-03
1984	3.63E-03	4.60E-03				8.23E-03
1985	2.39E-03	3.02E-03				5.41E-03
1986	2.61E-03	3.31E-03				5.92E-03
1987	3.13E-03	3.96E-03				7.09E-03
1988	2.98E-03	3.77E-03				6.74E-03
1989	2.11E-03	2.67E-03				4.78E-03
1990	3.05E-03	3.86E-03				6.90E-03
1991	4.63E-03	5.86E-03				1.05E-02
1992	6.21E-03	7.86E-03				1.41E-02
1993	3.77E-03	4.77E-03				8.54E-03
1994	3.05E-03	3.86E-03				6.91E-03
1995	3.14E-03	3.98E-03				7.12E-03
Totals	1.20E+00	1.52E+00				2.73E+00
Percent	44.13%	55.87%				

Table Sr-89/90. Population Liquid-Pathway Doses

	Aquatic Food	Water	Shore	Swimming	Boating	Total Liquid Pathway
	(per.-rem)	(per.-rem)	(per.-rem)	(per.-rem)	(per.-rem)	(per.-rem)
1954	2.27E-03	1.36E-02				1.59E-02
1955	1.33E-02	7.98E-02				9.31E-02
1956	9.84E-02	5.90E-01				6.88E-01
1957	5.42E-01	3.25E+00				3.79E+00
1958	5.24E-02	3.14E-01				3.66E-01
1959	1.29E-01	7.73E-01				9.02E-01
1960	1.29E+00	7.74E+00				9.04E+00
1961	3.62E-01	2.17E+00				2.53E+00
1962	3.64E-01	2.18E+00				2.54E+00
1963	5.76E-01	3.45E+00				4.03E+00
1964	5.40E-01	3.24E+00				3.78E+00
1965	4.16E-01	2.49E+00				2.91E+00
1966	3.56E-01	2.13E+00				2.49E+00
1967	8.99E-01	5.39E+00				6.29E+00
1968	3.03E-01	1.82E+00				2.12E+00
1969	2.04E-01	1.22E+00				1.43E+00
1970	1.89E-01	1.13E+00				1.32E+00
1971	1.82E-01	1.09E+00				1.27E+00
1972	8.36E-02	5.01E-01				5.84E-01
1973	9.47E-02	5.67E-01				6.62E-01
1974	7.05E-02	4.22E-01				4.93E-01
1975	6.06E-02	3.63E-01				4.24E-01
1976	4.88E-02	2.92E-01				3.41E-01
1977	3.66E-02	2.19E-01				2.56E-01
1978	3.07E-02	1.84E-01				2.15E-01
1979	6.12E-02	3.67E-01				4.28E-01
1980	3.98E-02	2.38E-01				2.78E-01
1981	3.42E-02	2.05E-01				2.39E-01
1982	2.14E-02	1.28E-01				1.50E-01
1983	1.69E-02	1.01E-01				1.18E-01
1984	2.23E-02	1.33E-01				1.56E-01
1985	1.46E-02	8.76E-02				1.02E-01
1986	1.60E-02	9.60E-02				1.12E-01
1987	1.92E-02	1.15E-01				1.34E-01
1988	1.82E-02	1.09E-01				1.27E-01
1989	1.29E-02	7.75E-02				9.04E-02
1990	1.87E-02	1.12E-01				1.30E-01
1991	2.84E-02	1.70E-01				1.98E-01
1992	3.80E-02	2.28E-01				2.66E-01
1993	2.31E-02	1.38E-01				1.61E-01
1994	1.87E-02	1.12E-01				1.31E-01
1995	1.93E-02	1.15E-01				1.35E-01
Totals	7.37E+00	4.42E+01				5.15E+01
Percent	14.30%	85.70%				

Table Sr-89/90 Air. Sr-89/90 Atmospheric Releases and Maximally Exposed Individual Doses 1954 - 1995

Table Sr-89/90 Liquid. Sr-89/90 Liquid Releases and Maximally Exposed Individual Doses 1954 - 1995

Tc-99

Half-Life

Tc-99 - 2.13E+05 years

Total Curies Released (1954-1995)

Air - 0.0

Streams - 8.80E-03

Basins (Decay Corrected) - 0.0

Total Cumulative Risks (1954-1995)

MEI Air Pathway - 0.0

MEI Liquid Pathway - 8.99E-13

Population Air - 0.0

Population Liquid - 2.44E-08

Projected 30-year Risks Using Recent Annual Doses (average of years 1991-1995)

MEI Air Pathway - 0.0

MEI Liquid Pathway - 5.40E-12

Population Air - 0.0

Population Liquid - 1.46E-07

Critical Pathways

MEI Air Pathway - N/A

MEI Liquid Pathway - Water Consumption = 71%, Fish Consumption = 29%

Population Air Pathway - N/A

Population Liquid Pathway - Water Consumption = 76%, Aquatic Food = 24%

Discussion

Tc-99 is a very long-lived fission product that, because of its low beta energy (0.292 MeV) and low specific activity, is difficult to measure in effluents and has not been routinely measured in environmental samples. Only during 1994 have liquid releases of Tc-99 been quantified, based on measured concentrations in samples of groundwater outcropping from the F-Area and H-Area seepage basins and the SWDF (Arnett, 1995). Cumulative releases of, and doses from, Tc-99 were estimated by Carlton (1993b) to be of negligible risk. However, because of its very long half-life and estimated long-term residual inventory ($>6.5\text{E}+04$ Ci), Tc-99 may become of importance, on a percentage-of-risk basis, in the distant (>100 years) future. Refer to Carlton, 1993b for a more complete assessment of technetium at SRS.

Table Tc-99. Effluent Releases

	Tc-99 - Air	Tc-99 - Streams	Tc-99 - Basins	Tc-99 - Basins
	Curies	Curies	Curies	Decay Corrected (Ci)
1954				
1955				
1956				
1957				
1958				
1959				
1960				
1961				
1962				
1963				
1964				
1965				
1966				
1967				
1968				
1969				
1970				
1971				
1972				
1973				
1974				
1975				
1976				
1977				
1978				
1979				
1980				
1981				
1982				
1983				
1984				
1985				
1986				
1987				
1988				
1989				
1990				
1991				
1992				
1993				
1994		8.80E-03		
1995				
Totals		8.80E-03		

Table Tc-99. MEI Liquid-Pathway Doses

	Fish (mrem)	Water (mrem)	Shore (mrem)	Swimming (mrem)	Boating (mrem)	Total Liquid Pathway (mrem)
1954						
1955						
1956						
1957						
1958						
1959						
1960						
1961						
1962						
1963						
1964						
1965						
1966						
1967						
1968						
1969						
1970						
1971						
1972						
1973						
1974						
1975						
1976						
1977						
1978						
1979						
1980						
1981						
1982						
1983						
1984						
1985						
1986						
1987						
1988						
1989						
1990						
1991						
1992						
1993						
1994	3.52E-07	8.80E-07	3.08E-11	5.90E-15	6.95E-15	1.23E-06
1995						
Totals	3.52E-07	8.80E-07	3.08E-11	5.90E-15	6.95E-15	1.23E-06
Percent	28.57%	71.43%	0.00%	0.00%	0.00%	

Table Tc-99. Population Liquid-Pathway Doses

	Aquatic Food	Water	Shore	Swimming	Boating	Total Liquid Pathway
	(per.-rem)	(per.-rem)	(per.-rem)	(per.-rem)	(per.-rem)	(per.-rem)
1954						
1955						
1956						
1957						
1958						
1959						
1960						
1961						
1962						
1963						
1964						
1965						
1966						
1967						
1968						
1969						
1970						
1971						
1972						
1973						
1974						
1975						
1976						
1977						
1978						
1979						
1980						
1981						
1982						
1983						
1984						
1985						
1986						
1987						
1988						
1989						
1990						
1991						
1992						
1993						
1994	7.90E-06	2.55E-05	1.32E-09	1.06E-13	3.61E-13	3.34E-05
1995						
Totals	7.90E-06	2.55E-05	1.32E-09	1.06E-13	3.61E-13	3.34E-05
Percent	23.64%	76.35%	0.00%	0.00%	0.00%	

Table Tc-99 Liquid. Tc-99 Liquid Release and Maximally Exposed Individual Doses 1954 - 1995

Th-232

Half-Life

Th-232 - 1.40E+10 years

Total Curies Released (1954-1995)

Air - 0.0

Streams - 0.0

Basins (Decay Corrected) - 1.67E-01

Total Cumulative Risks (1954-1995)

MEI Air Pathway - 0.0

MEI Liquid Pathway - 0.0

Population Air - 0.0

Population Liquid - 0.0

Projected 30-year Risks Using Recent Annual Doses (average of years 1991-1995)

MEI Air Pathway - 0.0

MEI Liquid Pathway - 0.0

Population Air - 0.0

Population Liquid - 0.0

Critical Pathways

MEI Air Pathway - N/A

MEI Liquid Pathway - N/A

Population Air Pathway - N/A

Population Liquid Pathway - N/A

Discussion

Th-232 is a very long-lived activation product that was not released to the atmosphere or site streams. Therefore, offsite doses and risks have not been calculated. Past releases to site seepage basins were small and were measured to have occurred only in 1968. The estimated long term residual inventory of Th-232 also is small ($<8.0\text{E}+00$ Ci). However, because of its very long half-life and very large inhalation and ingestion dose factors (DOE, 1988), Th-232 may become of importance, on a percentage-of-risk basis, in the distant (>100 years) future.

Table Th-232. Effluent Releases

	Th-232	Th-232	Th-232	Th-232-Basin
	Air (Curies)	Streams (Curies)	Basins (Curies)	Decay Corrected (Ci)
1954				
1955				
1956				
1957				
1958				
1959				
1960				
1961				
1962				
1963				
1964				
1965				
1966				
1967				
1968			1.67E-01	1.67E-01
1969				
1970				
1971				
1972				
1973				
1974				
1975				
1976				
1977				
1978				
1979				
1980				
1981				
1982				
1983				
1984				
1985				
1986				
1987				
1988				
1989				
1990				
1991				
1992				
1993				
1994				
1995				
Totals			1.67E-01	1.67E-01

U-235/238

Half-Life

U-235 - 7.04E+08 years U-238 - 4.47E+09 years

Total Curies Released (1954-1995)

Air - 9.61E-01

Streams - 2.47E+01

Basins (Decay Corrected) - 1.68E+01

Total Cumulative Risks (1954-1995)

MEI Air Pathway - 3.36E-07

MEI Liquid Pathway - 3.78E-07

Population Air - 3.52E-02

Population Liquid - 1.14E-02

Projected 30-year Risks Using Recent Annual Doses (average of years 1991-1995)

MEI Air Pathway - 2.10E-08

MEI Liquid Pathway - 5.04E-10

Population Air - 2.14E-03

Population Liquid - 1.52E-05

Critical Pathways

MEI Air Pathway - Inhalation = 69%, Vegetation Consumption = 21%

MEI Liquid Pathway - Water Consumption = 91%, Fish Consumption = 5%

Population Air Pathway - Inhalation = 80%, Ground = 15%

Population Liquid Pathway - Water Consumption = 88%, Shore = 7%

Discussion

U-235/238 are long-lived alpha-emitting radionuclides with large ingestion and inhalation dose factors (DOE, 1988b). On a cumulative MEI and population risk basis, U-235/238 were the 11th and 9th most important air pathway radionuclides, respectively and the 10th and 11th most important liquid pathway radionuclides, respectively. The projected 30-year MEI air pathway risk from U-235/238 is estimated at 2.1E-08, which is the 5th most important. The projected 30-year MEI liquid pathway risk is estimated at 5.0E-10, which is the 6th most important. Estimated long-term residual inventories (>7.0E+01 Ci) may cause U-235/238 to remain of importance, on a percentage-of-risk basis, in the future.

Refer to Evans, 1992 for a more complete assessment of uranium at SRS.

Table U-235/238. Effluent Releases

	U-235,238		U-235,238		U-235,238		U-235,238-Basin	
	Air (Curies)	Streams	(Curies)	Basins	(Curies)	Decay Corrected (Ci)		
1954								
1955	3.06E-01	7.00E-02		1.66E-01		1.66E-01		
1956	1.19E-01	5.20E-01		7.20E-01		7.20E-01		
1957	2.25E-03	1.05E-01		7.78E-01		7.78E-01		
1958	1.60E-03	3.60E-02		5.12E-01		5.12E-01		
1959	7.15E-03	3.90E-02		6.96E-01		6.96E-01		
1960	2.00E-02	1.10E-01		8.36E-01		8.36E-01		
1961	1.02E-01	1.10E-01		3.66E-01		3.66E-01		
1962	8.86E-03	5.30E-01		6.58E-01		6.58E-01		
1963	3.15E-02	1.95E+00		7.05E-01		7.05E-01		
1964	5.55E-02	4.96E-01		1.83E+00		1.83E+00		
1965	5.18E-02	9.00E-01		6.60E-01		6.60E-01		
1966	2.06E-02	4.44E+00		5.13E-01		5.13E-01		
1967	1.92E-02	6.42E+00		1.91E-01		1.91E-01		
1968	2.67E-02	4.21E+00		5.60E-01		5.60E-01		
1969	6.87E-02	1.26E+00		1.11E+00		1.11E+00		
1970	1.66E-02	6.82E-01		1.41E+00		1.41E+00		
1971	5.17E-03	3.48E-01		2.40E-01		2.40E-01		
1972	7.73E-03	3.90E-01		2.30E-01		2.30E-01		
1973	5.11E-03	2.19E-01		1.79E-01		1.79E-01		
1974	8.67E-03	3.49E-01		1.06E-01		1.06E-01		
1975	4.73E-03	4.41E-01		1.36E-01		1.36E-01		
1976	4.97E-03	3.63E-01		2.62E-01		2.62E-01		
1977	1.57E-03	8.44E-02		1.18E-01		1.18E-01		
1978	3.06E-03	5.59E-02		1.82E-01		1.82E-01		
1979	2.44E-03	6.40E-02		1.77E-01		1.77E-01		
1980	4.01E-03	1.90E-01		2.90E-01		2.90E-01		
1981	6.07E-03	1.71E-01		7.28E-01		7.28E-01		
1982	9.15E-03	4.21E-02		3.61E-01		3.61E-01		
1983	4.47E-03	1.73E-02		4.81E-01		4.81E-01		
1984	2.19E-03	9.70E-03		1.72E-01		1.72E-01		
1985	2.54E-03	1.35E-03		1.69E-01		1.69E-01		
1986	1.57E-03	4.39E-02		1.16E+00		1.16E+00		
1987	8.52E-03	5.49E-03		5.19E-02		5.19E-02		
1988	1.47E-03	5.49E-03		2.21E-02		2.21E-02		
1989	5.05E-03	4.25E-04						
1990	5.22E-03	1.41E-03						
1991	2.68E-03	3.24E-03						
1992	1.58E-03	1.90E-03						
1993	1.92E-03	1.14E-05						
1994	2.23E-03	1.00E-05						
1995	1.57E-03	3.29E-04						
Totals	9.61E-01	2.47E+01		1.68E+01		1.68E+01		

Table U-235/238. MEI Air-Pathway Doses

	Plume (mrem)	Ground (mrem)	Inhalation (mrem)	Vegetation (mrem)	Milk (mrem)	Meat (mrem)	Total Air Pathway (mrem)
1954							
1955		1.47E-02	1.01E-01	3.06E-02	3.98E-04	7.34E-05	1.47E-01
1956		5.71E-03	3.93E-02	1.19E-02	1.55E-04	2.86E-05	5.71E-02
1957		1.08E-04	7.43E-04	2.25E-04	2.93E-06	5.40E-07	1.08E-03
1958		7.68E-05	5.28E-04	1.60E-04	2.08E-06	3.84E-07	7.67E-04
1959		3.43E-04	2.36E-03	7.15E-04	9.30E-06	1.72E-06	3.43E-03
1960		9.60E-04	6.60E-03	2.00E-03	2.60E-05	4.80E-06	9.59E-03
1961		4.90E-03	3.37E-02	1.02E-02	1.33E-04	2.45E-05	4.89E-02
1962		4.25E-04	2.92E-03	8.86E-04	1.15E-05	2.13E-06	4.25E-03
1963		1.51E-03	1.04E-02	3.15E-03	4.10E-05	7.56E-06	1.51E-02
1964		2.66E-03	1.83E-02	5.55E-03	7.22E-05	1.33E-05	2.66E-02
1965		2.49E-03	1.71E-02	5.18E-03	6.73E-05	1.24E-05	2.48E-02
1966		9.89E-04	6.80E-03	2.06E-03	2.68E-05	4.94E-06	9.88E-03
1967		9.22E-04	6.34E-03	1.92E-03	2.50E-05	4.61E-06	9.21E-03
1968		1.28E-03	8.81E-03	2.67E-03	3.47E-05	6.41E-06	1.28E-02
1969		3.30E-03	2.27E-02	6.87E-03	8.93E-05	1.65E-05	3.29E-02
1970		7.97E-04	5.48E-03	1.66E-03	2.16E-05	3.98E-06	7.96E-03
1971		2.48E-04	1.71E-03	5.17E-04	6.72E-06	1.24E-06	2.48E-03
1972		3.71E-04	2.55E-03	7.73E-04	1.00E-05	1.86E-06	3.71E-03
1973		2.45E-04	1.69E-03	5.11E-04	6.64E-06	1.23E-06	2.45E-03
1974		4.16E-04	2.86E-03	8.67E-04	1.13E-05	2.08E-06	4.16E-03
1975		2.27E-04	1.56E-03	4.73E-04	6.15E-06	1.14E-06	2.27E-03
1976		2.39E-04	1.64E-03	4.97E-04	6.46E-06	1.19E-06	2.38E-03
1977		7.54E-05	5.18E-04	1.57E-04	2.04E-06	3.77E-07	7.53E-04
1978		1.47E-04	1.01E-03	3.06E-04	3.98E-06	7.34E-07	1.47E-03
1979		1.17E-04	8.05E-04	2.44E-04	3.17E-06	5.86E-07	1.17E-03
1980		1.92E-04	1.32E-03	4.01E-04	5.21E-06	9.62E-07	1.92E-03
1981		2.91E-04	2.00E-03	6.07E-04	7.89E-06	1.46E-06	2.91E-03
1982		4.39E-04	3.02E-03	9.15E-04	1.19E-05	2.20E-06	4.39E-03
1983		2.15E-04	1.48E-03	4.47E-04	5.81E-06	1.07E-06	2.14E-03
1984		1.05E-04	7.23E-04	2.19E-04	2.85E-06	5.26E-07	1.05E-03
1985		1.22E-04	8.38E-04	2.54E-04	3.30E-06	6.10E-07	1.22E-03
1986		7.54E-05	5.18E-04	1.57E-04	2.04E-06	3.77E-07	7.53E-04
1987		4.09E-04	2.81E-03	8.52E-04	1.11E-05	2.04E-06	4.09E-03
1988		7.06E-05	4.85E-04	1.47E-04	1.91E-06	3.53E-07	7.05E-04
1989		2.42E-04	1.67E-03	5.05E-04	6.57E-06	1.21E-06	2.42E-03
1990		2.51E-04	1.72E-03	5.22E-04	6.79E-06	1.25E-06	2.50E-03
1991		1.29E-04	8.84E-04	2.68E-04	3.48E-06	6.43E-07	1.29E-03
1992		7.58E-05	5.21E-04	1.58E-04	2.05E-06	3.79E-07	7.58E-04
1993		9.22E-05	6.34E-04	1.92E-04	2.50E-06	4.61E-07	9.21E-04
1994		1.07E-04	7.36E-04	2.23E-04	2.90E-06	5.35E-07	1.07E-03
1995		7.52E-05	5.17E-04	1.57E-04	2.04E-06	3.76E-07	7.51E-04
Totals		4.61E-02	3.17E-01	9.61E-02	1.25E-03	2.31E-04	4.61E-01
Percent		10.01%	68.82%	20.85%	0.27%	0.05%	

Table U-235/238. Population Air-Pathway Doses

	Plume	Ground	Inhalation	Vegetation	Milk	Meat	Total Air Pathway
	(per.-rem)	(per.-rem)	(per.-rem)	(per.-rem)	(per.-rem)	(per.-rem)	(per.-rem)
1954							
1955		2.36E+00	1.22E+01	7.34E-01	1.41E-02	1.62E-03	1.53E+01
1956		9.16E-01	4.76E+00	2.86E-01	5.47E-03	6.31E-04	5.97E+00
1957		1.73E-02	9.00E-02	5.40E-03	1.04E-04	1.19E-05	1.13E-01
1958		1.23E-02	6.40E-02	3.84E-03	7.36E-05	8.48E-06	8.02E-02
1959		5.51E-02	2.86E-01	1.72E-02	3.29E-04	3.79E-05	3.59E-01
1960		1.54E-01	8.00E-01	4.80E-02	9.20E-04	1.06E-04	1.00E+00
1961		7.85E-01	4.08E+00	2.45E-01	4.69E-03	5.41E-04	5.12E+00
1962		6.82E-02	3.54E-01	2.13E-02	4.08E-04	4.70E-05	4.44E-01
1963		2.43E-01	1.26E+00	7.56E-02	1.45E-03	1.67E-04	1.58E+00
1964		4.27E-01	2.22E+00	1.33E-01	2.55E-03	2.94E-04	2.78E+00
1965		3.99E-01	2.07E+00	1.24E-01	2.38E-03	2.75E-04	2.60E+00
1966		1.59E-01	8.24E-01	4.94E-02	9.48E-04	1.09E-04	1.03E+00
1967		1.48E-01	7.68E-01	4.61E-02	8.83E-04	1.02E-04	9.63E-01
1968		2.06E-01	1.07E+00	6.41E-02	1.23E-03	1.42E-04	1.34E+00
1969		5.29E-01	2.75E+00	1.65E-01	3.16E-03	3.64E-04	3.45E+00
1970		1.28E-01	6.64E-01	3.98E-02	7.64E-04	8.80E-05	8.33E-01
1971		3.98E-02	2.07E-01	1.24E-02	2.38E-04	2.74E-05	2.59E-01
1972		5.95E-02	3.09E-01	1.86E-02	3.56E-04	4.10E-05	3.88E-01
1973		3.93E-02	2.04E-01	1.23E-02	2.35E-04	2.71E-05	2.56E-01
1974		6.68E-02	3.47E-01	2.08E-02	3.99E-04	4.60E-05	4.35E-01
1975		3.64E-02	1.89E-01	1.14E-02	2.18E-04	2.51E-05	2.37E-01
1976		3.83E-02	1.99E-01	1.19E-02	2.29E-04	2.63E-05	2.49E-01
1977		1.21E-02	6.28E-02	3.77E-03	7.22E-05	8.32E-06	7.87E-02
1978		2.36E-02	1.22E-01	7.34E-03	1.41E-04	1.62E-05	1.53E-01
1979		1.88E-02	9.76E-02	5.86E-03	1.12E-04	1.29E-05	1.22E-01
1980		3.09E-02	1.60E-01	9.62E-03	1.84E-04	2.13E-05	2.01E-01
1981		4.67E-02	2.43E-01	1.46E-02	2.79E-04	3.22E-05	3.04E-01
1982		7.05E-02	3.66E-01	2.20E-02	4.21E-04	4.85E-05	4.59E-01
1983		3.44E-02	1.79E-01	1.07E-02	2.06E-04	2.37E-05	2.24E-01
1984		1.69E-02	8.76E-02	5.26E-03	1.01E-04	1.16E-05	1.10E-01
1985		1.96E-02	1.02E-01	6.10E-03	1.17E-04	1.35E-05	1.27E-01
1986		1.21E-02	6.28E-02	3.77E-03	7.22E-05	8.32E-06	7.87E-02
1987		6.56E-02	3.41E-01	2.04E-02	3.92E-04	4.52E-05	4.27E-01
1988		1.13E-02	5.88E-02	3.53E-03	6.76E-05	7.79E-06	7.37E-02
1989		3.89E-02	2.02E-01	1.21E-02	2.32E-04	2.68E-05	2.53E-01
1990		4.02E-02	2.09E-01	1.25E-02	2.40E-04	2.77E-05	2.62E-01
1991		2.06E-02	1.07E-01	6.43E-03	1.23E-04	1.42E-05	1.34E-01
1992		1.22E-02	6.32E-02	3.79E-03	7.27E-05	8.37E-06	7.92E-02
1993		1.48E-02	7.68E-02	4.61E-03	8.83E-05	1.02E-05	9.63E-02
1994		1.72E-02	8.92E-02	5.35E-03	1.03E-04	1.18E-05	1.12E-01
1995		1.21E-02	6.27E-02	3.76E-03	7.21E-05	8.31E-06	6.65E-02
Totals		7.39E+00	3.84E+01	2.31E+00	4.42E-02	5.09E-03	4.82E+01
Percent		15.33%	79.78%	4.79%	0.09%	0.01%	

Table U-235/238. MEI Liquid-Pathway Doses

	Fish	Water	Shore	Swimming	Boating	Total Liquid Pathway
	(mrem)	(mrem)	(mrem)	(mrem)	(mrem)	(mrem)
1954						
1955	7.00E-05	1.33E-03	6.79E-05	1.33E-08	1.54E-08	1.47E-03
1956	5.20E-04	9.88E-03	5.04E-04	9.88E-08	1.14E-07	1.09E-02
1957	1.05E-04	2.00E-03	1.02E-04	2.00E-08	2.31E-08	2.20E-03
1958	3.60E-05	6.84E-04	3.49E-05	6.84E-09	7.92E-09	7.55E-04
1959	3.90E-05	7.41E-04	3.78E-05	7.41E-09	8.58E-09	8.18E-04
1960	1.10E-04	2.09E-03	1.07E-04	2.09E-08	2.42E-08	2.31E-03
1961	1.10E-04	2.09E-03	1.07E-04	2.09E-08	2.42E-08	2.31E-03
1962	5.30E-04	1.01E-02	5.14E-04	1.01E-07	1.17E-07	1.11E-02
1963	1.95E-03	3.71E-02	1.89E-03	3.71E-07	4.29E-07	4.09E-02
1964	4.96E-04	9.42E-03	4.81E-04	9.42E-08	1.09E-07	1.04E-02
1965	9.00E-04	1.71E-02	8.73E-04	1.71E-07	1.98E-07	1.89E-02
1966	4.44E-03	8.44E-02	4.31E-03	8.44E-07	9.77E-07	9.31E-02
1967	6.42E-03	1.22E-01	6.23E-03	1.22E-06	1.41E-06	1.35E-01
1968	4.21E-03	8.00E-02	4.08E-03	8.00E-07	9.26E-07	8.83E-02
1969	1.26E-03	2.39E-02	1.22E-03	2.39E-07	2.77E-07	2.64E-02
1970	6.82E-04	1.30E-02	6.62E-04	1.30E-07	1.50E-07	1.43E-02
1971	3.48E-04	6.61E-03	3.38E-04	6.61E-08	7.66E-08	7.30E-03
1972	3.90E-04	7.41E-03	3.78E-04	7.41E-08	8.58E-08	8.18E-03
1973	2.19E-04	4.16E-03	2.12E-04	4.16E-08	4.82E-08	4.59E-03
1974	3.49E-04	6.63E-03	3.39E-04	6.63E-08	7.68E-08	7.32E-03
1975	4.41E-04	8.38E-03	4.28E-04	8.38E-08	9.70E-08	9.25E-03
1976	3.63E-04	6.90E-03	3.52E-04	6.90E-08	7.99E-08	7.61E-03
1977	8.44E-05	1.60E-03	8.19E-05	1.60E-08	1.86E-08	1.77E-03
1978	5.59E-05	1.06E-03	5.42E-05	1.06E-08	1.23E-08	1.17E-03
1979	6.40E-05	1.22E-03	6.21E-05	1.22E-08	1.41E-08	1.34E-03
1980	1.90E-04	3.61E-03	1.84E-04	3.61E-08	4.18E-08	3.98E-03
1981	1.71E-04	3.25E-03	1.66E-04	3.25E-08	3.76E-08	3.59E-03
1982	4.21E-05	8.00E-04	4.08E-05	8.00E-09	9.26E-09	8.83E-04
1983	1.73E-05	3.29E-04	1.68E-05	3.29E-09	3.81E-09	3.63E-04
1984	9.70E-06	1.84E-04	9.41E-06	1.84E-09	2.13E-09	2.03E-04
1985	1.35E-06	2.57E-05	1.31E-06	2.57E-10	2.97E-10	2.83E-05
1986	4.39E-05	8.34E-04	4.26E-05	8.34E-09	9.66E-09	9.21E-04
1987	5.49E-06	1.04E-04	5.33E-06	1.04E-09	1.21E-09	1.15E-04
1988	5.49E-06	1.04E-04	5.33E-06	1.04E-09	1.21E-09	1.15E-04
1989	4.25E-07	8.08E-06	4.12E-07	8.08E-11	9.35E-11	8.91E-06
1990	1.41E-06	2.68E-05	1.37E-06	2.68E-10	3.10E-10	2.96E-05
1991	3.24E-06	6.16E-05	3.14E-06	6.16E-10	7.13E-10	6.79E-05
1992	1.90E-06	3.61E-05	1.84E-06	3.61E-10	4.18E-10	3.98E-05
1993	1.14E-08	2.17E-07	1.11E-08	2.17E-12	2.51E-12	2.39E-07
1994	1.00E-08	1.90E-07	9.70E-09	1.90E-12	2.20E-12	2.10E-07
1995	3.29E-07	6.25E-06	3.19E-07	6.25E-11	7.23E-11	6.90E-06
Totals	2.47E-02	4.69E-01	2.39E-02	4.69E-06	5.43E-06	5.18E-01
Percent	4.77%	90.60%	4.63%	0.00%	0.00%	

Table U-235/238. Population Liquid-Pathway Doses

	Aquatic Food	Water	Shore	Swimming	Boating	Total Liquid Pathway
	(per.-rem)	(per.-rem)	(per.-rem)	(per.-rem)	(per.-rem)	(per.-rem)
1954						
1955	2.35E-03	3.92E-02	2.80E-03	2.38E-07	8.40E-07	4.43E-02
1956	1.74E-02	2.91E-01	2.08E-02	1.77E-06	6.24E-06	3.29E-01
1957	3.52E-03	5.88E-02	4.20E-03	3.57E-07	1.26E-06	6.65E-02
1958	1.21E-03	2.02E-02	1.44E-03	1.22E-07	4.32E-07	2.28E-02
1959	1.31E-03	2.18E-02	1.56E-03	1.33E-07	4.68E-07	2.47E-02
1960	3.69E-03	6.16E-02	4.40E-03	3.74E-07	1.32E-06	6.97E-02
1961	3.69E-03	6.16E-02	4.40E-03	3.74E-07	1.32E-06	6.97E-02
1962	1.78E-02	2.97E-01	2.12E-02	1.80E-06	6.36E-06	3.36E-01
1963	6.53E-02	1.09E+00	7.80E-02	6.63E-06	2.34E-05	1.24E+00
1964	1.66E-02	2.78E-01	1.98E-02	1.69E-06	5.95E-06	3.14E-01
1965	3.02E-02	5.04E-01	3.60E-02	3.06E-06	1.08E-05	5.70E-01
1966	1.49E-01	2.49E+00	1.78E-01	1.51E-05	5.33E-05	2.81E+00
1967	2.15E-01	3.60E+00	2.57E-01	2.18E-05	7.70E-05	4.07E+00
1968	1.41E-01	2.36E+00	1.68E-01	1.43E-05	5.05E-05	2.67E+00
1969	4.22E-02	7.06E-01	5.04E-02	4.28E-06	1.51E-05	7.98E-01
1970	2.28E-02	3.82E-01	2.73E-02	2.32E-06	8.18E-06	4.32E-01
1971	1.17E-02	1.95E-01	1.39E-02	1.18E-06	4.18E-06	2.20E-01
1972	1.31E-02	2.18E-01	1.56E-02	1.33E-06	4.68E-06	2.47E-01
1973	7.34E-03	1.23E-01	8.76E-03	7.45E-07	2.63E-06	1.39E-01
1974	1.17E-02	1.95E-01	1.40E-02	1.19E-06	4.19E-06	2.21E-01
1975	1.48E-02	2.47E-01	1.76E-02	1.50E-06	5.29E-06	2.79E-01
1976	1.22E-02	2.03E-01	1.45E-02	1.23E-06	4.36E-06	2.30E-01
1977	2.83E-03	4.73E-02	3.38E-03	2.87E-07	1.01E-06	5.35E-02
1978	1.87E-03	3.13E-02	2.24E-03	1.90E-07	6.71E-07	3.54E-02
1979	2.14E-03	3.58E-02	2.56E-03	2.18E-07	7.68E-07	4.05E-02
1980	6.37E-03	1.06E-01	7.60E-03	6.46E-07	2.28E-06	1.20E-01
1981	5.73E-03	9.58E-02	6.84E-03	5.81E-07	2.05E-06	1.08E-01
1982	1.41E-03	2.36E-02	1.68E-03	1.43E-07	5.05E-07	2.67E-02
1983	5.80E-04	9.69E-03	6.92E-04	5.88E-08	2.08E-07	1.10E-02
1984	3.25E-04	5.43E-03	3.88E-04	3.30E-08	1.16E-07	6.15E-03
1985	4.52E-05	7.56E-04	5.40E-05	4.59E-09	1.62E-08	8.55E-04
1986	1.47E-03	2.46E-02	1.76E-03	1.49E-07	5.27E-07	2.78E-02
1987	1.84E-04	3.07E-03	2.20E-04	1.87E-08	6.59E-08	3.48E-03
1988	1.84E-04	3.07E-03	2.20E-04	1.87E-08	6.59E-08	3.48E-03
1989	1.42E-05	2.38E-04	1.70E-05	1.45E-09	5.10E-09	2.69E-04
1990	4.72E-05	7.90E-04	5.64E-05	4.79E-09	1.69E-08	8.93E-04
1991	1.09E-04	1.81E-03	1.30E-04	1.10E-08	3.89E-08	2.05E-03
1992	6.37E-05	1.06E-03	7.60E-05	6.46E-09	2.28E-08	1.20E-03
1993	3.82E-07	6.38E-06	4.56E-07	3.88E-11	1.37E-10	7.22E-06
1994	3.35E-07	5.60E-06	4.00E-07	3.40E-11	1.20E-10	6.34E-06
1995	1.10E-05	1.84E-04	1.32E-05	1.12E-09	3.95E-09	2.08E-04
Totals	8.27E-01	1.38E+01	9.87E-01	8.39E-05	2.96E-04	1.56E+01
Percent	5.29%	88.40%	6.31%	0.00%	0.00%	

Table U-235/238 Air. U-235/238 Atmospheric Releases and Maximally Exposed Individual Doses 1954 - 1995

Table U-235/238 Liquid. U-235/238 Liquid Releases and Maximally Exposed Individual Doses 1954 - 1995

Xe-131m

Half-Life

Xe-131m - 11.9 days

Total Curies Released (1954-1995)

Air - 1.03E+04

Streams - 0.0

Basins (Decay Corrected) - 0.0

Total Cumulative Risks (1954-1995)

MEI Air Pathway - 2.90E-10

MEI Liquid Pathway - 0.0

Population Air - 8.19E-06

Population Liquid - 0.0

Projected 30-year Risks Using Recent Annual Doses (average of years 1991-1995)

MEI Air Pathway - 0.0

MEI Liquid Pathway - 0.0

Population Air - 0.0

Population Liquid - 0.0

Critical Pathways

MEI Air Pathway - Plume = 100%

MEI Liquid Pathway - N/A

Population Air Pathway - Plume = 100%

Population Liquid Pathway - N/A

Discussion

Xe-131m is a short-lived, gaseous fission product. On a cumulative risk basis, Xe-131m accounted for much less than 1% of the total cumulative MEI and population air pathway risks and was the 26th most important airborne radionuclide. Because all SRS reactors are now shut down, projected releases of, and risks from, Xe-131m are expected to remain nil. Refer to Carlton, 1995 for a more complete assessment of noble gases, including Xe-131m, at SRS.

Table Xe-131m. Effluent Releases and Air-Pathway MEI and Population Doses

	Xe-131m	Max. Exp. Ind. Dose	Population Dose
	Air (Curies)	(mrem)	(person-rem)
1954			
1955			
1956			
1957			
1958			
1959			
1960	6.90E+02	2.69E-05	7.59E-04
1961	5.00E+02	1.95E-05	5.50E-04
1962	2.90E+02	1.13E-05	3.19E-04
1963	1.40E+02	5.46E-06	1.54E-04
1964	1.70E+02	6.63E-06	1.87E-04
1965	6.10E+02	2.38E-05	6.71E-04
1966	2.60E+02	1.01E-05	2.86E-04
1967	1.89E+03	7.37E-05	2.08E-03
1968	9.30E+02	3.63E-05	1.02E-03
1969	8.50E+02	3.32E-05	9.35E-04
1970	1.00E+03	3.90E-05	1.10E-03
1971	1.09E+03	4.25E-05	1.20E-03
1972	2.92E+02	1.14E-05	3.21E-04
1973	5.11E+02	1.99E-05	5.62E-04
1974	1.35E+02	5.27E-06	1.49E-04
1975	5.80E+00	2.26E-07	6.38E-06
1976	6.31E+02	2.46E-05	6.94E-04
1977	1.21E+01	4.72E-07	1.33E-05
1978	7.08E+01	2.76E-06	7.79E-05
1979	9.11E+00	3.55E-07	1.00E-05
1980	1.93E-01	7.53E-09	2.12E-07
1981	6.42E+00	2.50E-07	7.06E-06
1982	5.86E+01	2.29E-06	6.45E-05
1983	1.96E+01	7.64E-07	2.16E-05
1984	1.84E+01	7.18E-07	2.02E-05
1985	5.00E+00	1.95E-07	5.50E-06
1986	3.00E-01	1.17E-08	3.30E-07
1987			
1988			
1989			
1990			
1991			
1992			
1993			
1994			
1995			
Totals	1.02E+04	3.98E-04	1.12E-02

Table Xe-131m Air. Xe-131m Atmospheric Releases and Maximally Exposed Individual Doses 1954 - 1995

Xe-133

Half-Life

Xe-133 - 5.25 days

Total Curies Released (1954-1995)

Air - 4.71E+05

Streams - 0.0

Basins (Decay Corrected) - 0.0

Total Cumulative Risks (1954-1995)

MEI Air Pathway - 1.62E-08

MEI Liquid Pathway - 0.0

Population Air - 1.51E-03

Population Liquid - 0.0

Projected 30-year Risks Using Recent Annual Doses (average of years 1991-1995)

MEI Air Pathway - 0.0

MEI Liquid Pathway - 0.0

Population Air - 0.0

Population Liquid - 0.0

Critical Pathways

MEI Air Pathway - Plume = 100%

MEI Liquid Pathway - N/A

Population Air Pathway - Plume = 100%

Population Liquid Pathway - N/A

Discussion

Xe-133 is a short-lived, gaseous fission product. On a cumulative risk basis, Xe-133 accounted for much less than 1% of the total cumulative MEI and population air pathway risks and was the 18th and 16th most important airborne radionuclide, respectively. Because all SRS reactors are now shut down, projected releases of, and risks from, Xe-133 are expected to remain nil. Refer to Carlton, 1995 for a more complete assessment of noble gases, including Xe-133, at SRS.

Table Xe-133. Effluent Releases and Air-Pathway MEI and Population Doses

	Xe-133	Max. Exp. Ind. Dose	Population Dose
	Air (Curies)	(mrem)	(person-rem)
1954	6.00E+01	2.82E-06	2.64E-04
1955	2.00E+02	9.40E-06	8.80E-04
1956	4.00E+02	1.88E-05	1.76E-03
1957	1.00E+02	4.70E-06	4.40E-04
1958	2.60E+03	1.22E-04	1.14E-02
1959	5.00E+03	2.35E-04	2.20E-02
1960	7.41E+03	3.48E-04	3.26E-02
1961	4.02E+03	1.89E-04	1.77E-02
1962	2.60E+03	1.22E-04	1.14E-02
1963	8.40E+03	3.95E-04	3.70E-02
1964	2.00E+03	9.40E-05	8.80E-03
1965	4.22E+03	1.98E-04	1.86E-02
1966	4.43E+04	2.08E-03	1.95E-01
1967	1.48E+05	6.96E-03	6.51E-01
1968	4.92E+04	2.31E-03	2.16E-01
1969	2.20E+04	1.03E-03	9.68E-02
1970	1.80E+04	8.46E-04	7.92E-02
1971	2.52E+04	1.18E-03	1.11E-01
1972	3.91E+04	1.84E-03	1.72E-01
1973	2.24E+04	1.05E-03	9.86E-02
1974	5.51E+03	2.59E-04	2.42E-02
1975	1.07E+03	5.03E-05	4.71E-03
1976	2.48E+03	1.17E-04	1.09E-02
1977	2.30E+03	1.08E-04	1.01E-02
1978	2.19E+03	1.03E-04	9.64E-03
1979	5.34E+03	2.51E-04	2.35E-02
1980	7.76E+03	3.65E-04	3.41E-02
1981	3.93E+03	1.85E-04	1.73E-02
1982	4.25E+03	2.00E-04	1.87E-02
1983	3.40E+03	1.60E-04	1.50E-02
1984	3.69E+03	1.73E-04	1.62E-02
1985	4.63E+03	2.18E-04	2.04E-02
1986	1.06E+04	4.98E-04	4.66E-02
1987	5.32E+03	2.50E-04	2.34E-02
1988	3.49E+03	1.64E-04	1.54E-02
1989			
1990			
1991			
1992			
1993			
1994			
1995			
Totals	4.71E+05	2.21E-02	2.07E+00

Table Xe-133 Air. Xe-133 Atmospheric Releases and Maximally Exposed Individual Doses 1954 - 1995

Xe-135

Half-Life

Xe-135 - 9.1 hours

Total Curies Released (1954-1995)

Air - 1.60E+05

Streams - 0.0

Basins (Decay Corrected) - 0.0

Total Cumulative Risks (1954-1995)

MEI Air Pathway - 3.51E-08

MEI Liquid Pathway - 0.0

Population Air - 2.69E-03

Population Liquid - 0.0

Projected 30-year Risks Using Recent Annual Doses (average of years 1991-1995)

MEI Air Pathway - 1.15E-13

MEI Liquid Pathway - 0.0

Population Air - 8.78E-09

Population Liquid - 0.0

Critical Pathways

MEI Air Pathway - Plume = 100%

MEI Liquid Pathway - N/A

Population Air Pathway - Plume = 100%

Population Liquid Pathway - N/A

Discussion

Xe-135 is a short-lived, gaseous fission product. On a cumulative risk basis, Xe-135 accounted for much less than 1% of the total cumulative MEI and population air pathway risks and was the 15th most important airborne radionuclide. Because all SRS reactors are now shut down, projected releases of, and risks from, Xe-135 are expected to remain nil. Refer to Carlton, 1995 for a more complete assessment of noble gases, including Xe-135, at SRS.

Table Xe-135. Effluent Releases and Air-Pathway MEI and Population Doses

	Xe-135	Max. Exp. Ind. Dose	Population Dose
	Air (Curies)	(mrem)	(person-rem)
1954	8.00E+01	2.40E-05	1.84E-03
1955	3.00E+02	9.00E-05	6.90E-03
1956	5.00E+02	1.50E-04	1.15E-02
1957	1.00E+02	3.00E-05	2.30E-03
1958	4.00E+03	1.20E-03	9.20E-02
1959	6.50E+03	1.95E-03	1.50E-01
1960	9.60E+03	2.88E-03	2.21E-01
1961	4.70E+03	1.41E-03	1.08E-01
1962	3.40E+03	1.02E-03	7.82E-02
1963	1.20E+04	3.60E-03	2.76E-01
1964	8.00E+02	2.40E-04	1.84E-02
1965	1.80E+03	5.40E-04	4.14E-02
1966	2.10E+03	6.30E-04	4.83E-02
1967	2.96E+04	8.88E-03	6.81E-01
1968	1.24E+04	3.72E-03	2.85E-01
1969	5.40E+03	1.62E-03	1.24E-01
1970	2.60E+03	7.80E-04	5.98E-02
1971	4.71E+03	1.41E-03	1.08E-01
1972	1.18E+04	3.54E-03	2.71E-01
1973	9.38E+03	2.81E-03	2.16E-01
1974	2.18E+03	6.54E-04	5.01E-02
1975	7.27E+02	2.18E-04	1.67E-02
1976	7.33E+02	2.20E-04	1.69E-02
1977	1.54E+03	4.62E-04	3.54E-02
1978	1.69E+03	5.07E-04	3.89E-02
1979	4.46E+03	1.34E-03	1.03E-01
1980	6.37E+03	1.91E-03	1.47E-01
1981	2.53E+03	7.59E-04	5.82E-02
1982	2.42E+03	7.26E-04	5.57E-02
1983	2.36E+03	7.08E-04	5.43E-02
1984	2.48E+03	7.44E-04	5.70E-02
1985	1.80E+03	5.40E-04	4.14E-02
1986	2.60E+03	7.80E-04	5.98E-02
1987	3.48E+03	1.04E-03	8.00E-02
1988	2.98E+03	8.94E-04	6.85E-02
1989			
1990			
1991			
1992			
1993	3.19E-02	9.57E-09	7.34E-07
1994	2.17E-02	6.51E-09	4.99E-07
1995	3.36E-02	1.01E-08	7.73E-07
Totals	1.60E+05	4.80E-02	3.68E+00

Table Xe-135 Air. Xe-135 Atmospheric Releases and Maximally Exposed Individual Doses 1954 - 1995

Y-91

Half-Life

Y-91 - 58.5 days

Total Curies Released (1954-1995)

Air - 0.0

Streams - $1.17\text{E}+02$

Basins (Decay Corrected) - $<1.00\text{E}-12$

Total Cumulative Risks (1954-1995)

MEI Air Pathway - 0.0

MEI Liquid Pathway - $9.56\text{E}-08$

Population Air - 0.0

Population Liquid - $9.90\text{E}-03$

Projected 30-year Risks Using Recent Annual Doses (average of years 1991-1995)

MEI Air Pathway - 0.0

MEI Liquid Pathway - 0.0

Population Air - 0.0

Population Liquid - 0.0

Critical Pathways

MEI Air Pathway - N/A

MEI Liquid Pathway - Water Consumption = 61%, Fish Consumption = 39%

Population Air Pathway - N/A

Population Liquid Pathway - Aquatic Food = 84%, Water Consumption = 16%

Discussion

Y-91 is a short-lived fission product that has not been measured in discharges to site streams since 1978. On a cumulative MEI and population risk basis, Y-91 was the 17th and 12th most important liquid pathway radionuclide, respectively. Future releases of Y-91 are expected to remain nil.

Table Y-91. Effluent Releases

	Y-91 - Air Curies	Y-91 - Streams Curies	Y-91 - Basins Curies	Y-91 - Basins Decay Corrected (Ci)
1954				
1955				
1956				
1957				
1958				
1959				
1960				
1961				
1962				
1963				
1964				
1965		2.77E+01		
1966		1.73E+01		
1967		1.86E+01		
1968		3.09E+01		
1969		9.69E+00		
1970		9.78E+00		
1971		2.29E+00		
1972		2.10E-01	1.30E-01	<1.00E-12
1973		1.27E-01	9.70E-02	<1.00E-12
1974		1.28E-01	1.74E-01	<1.00E-12
1975		1.40E-02	3.00E-03	<1.00E-12
1976		7.50E-02	5.10E-02	<1.00E-12
1977		8.15E-02	1.95E-02	<1.00E-12
1978		3.71E-03	1.84E-02	<1.00E-12
1979			8.20E-03	<1.00E-12
1980			8.25E-04	<1.00E-12
1981			6.66E-04	<1.00E-12
1982			8.34E-03	<1.00E-12
1983			2.38E-05	<1.00E-12
1984			5.28E-03	<1.00E-12
1985			2.26E-03	<1.00E-12
1986				
1987				
1988				
1989			1.54E-05	<1.00E-12
1990				
1991				
1992				
1993				
1994				
1995				
Totals		1.17E+02	5.19E-01	<1.00E-12

Table Y-91. MEI Liquid-Pathway Doses

	Fish	Water	Shore	Swimming	Boating	Total Liquid Pathway
	(mrem)	(mrem)	(mrem)	(mrem)	(mrem)	(mrem)
1954						
1955						
1956						
1957						
1958						
1959						
1960						
1961						
1962						
1963						
1964						
1965	1.22E-02	1.88E-02	3.05E-06	1.19E-07	1.41E-07	3.10E-02
1966	7.61E-03	1.18E-02	1.90E-06	7.44E-08	8.82E-08	1.94E-02
1967	8.18E-03	1.26E-02	2.05E-06	8.00E-08	9.49E-08	2.08E-02
1968	1.36E-02	2.10E-02	3.40E-06	1.33E-07	1.58E-07	3.46E-02
1969	4.26E-03	6.59E-03	1.07E-06	4.17E-08	4.94E-08	1.09E-02
1970	4.30E-03	6.65E-03	1.08E-06	4.21E-08	4.99E-08	1.10E-02
1971	1.01E-03	1.56E-03	2.52E-07	9.85E-09	1.17E-08	2.57E-03
1972	9.24E-05	1.43E-04	2.31E-08	9.03E-10	1.07E-09	2.35E-04
1973	5.59E-05	8.64E-05	1.40E-08	5.46E-10	6.48E-10	1.42E-04
1974	5.63E-05	8.70E-05	1.41E-08	5.50E-10	6.53E-10	1.43E-04
1975	6.16E-06	9.52E-06	1.54E-09	6.02E-11	7.14E-11	1.57E-05
1976	3.30E-05	5.10E-05	8.25E-09	3.23E-10	3.83E-10	8.40E-05
1977	3.59E-05	5.54E-05	8.97E-09	3.50E-10	4.16E-10	9.13E-05
1978	1.63E-06	2.52E-06	4.08E-10	1.60E-11	1.89E-11	4.16E-06
1979						
1980						
1981						
1982						
1983						
1984						
1985						
1986						
1987						
1988						
1989						
1990						
1991						
1992						
1993						
1994						
1995						
Totals	5.14E-02	7.95E-02	1.29E-05	5.03E-07	5.96E-07	1.31E-01
Percent	39.28%	60.71%	0.01%	0.00%	0.00%	

Table Y-91. Population Liquid-Pathway Doses

	Aquatic Food	Water	Shore	Swimming	Boating	Total Liquid Pathway
	(per.-rem)	(per.-rem)	(per.-rem)	(per.-rem)	(per.-rem)	(per.-rem)
1954						
1955						
1956						
1957						
1958						
1959						
1960						
1961						
1962						
1963						
1964						
1965	2.69E+00	5.26E-01	1.25E-04	2.16E-06	7.48E-06	3.21E+00
1966	1.68E+00	3.29E-01	7.79E-05	1.35E-06	4.67E-06	2.01E+00
1967	1.80E+00	3.53E-01	8.37E-05	1.45E-06	5.02E-06	2.16E+00
1968	3.00E+00	5.87E-01	1.39E-04	2.41E-06	8.34E-06	3.58E+00
1969	9.40E-01	1.84E-01	4.36E-05	7.56E-07	2.62E-06	1.12E+00
1970	9.49E-01	1.86E-01	4.40E-05	7.63E-07	2.64E-06	1.13E+00
1971	2.22E-01	4.35E-02	1.03E-05	1.79E-07	6.18E-07	2.66E-01
1972	2.04E-02	3.99E-03	9.45E-07	1.64E-08	5.67E-08	2.44E-02
1973	1.23E-02	2.41E-03	5.72E-07	9.91E-09	3.43E-08	1.47E-02
1974	1.24E-02	2.43E-03	5.76E-07	9.98E-09	3.46E-08	1.48E-02
1975	1.36E-03	2.66E-04	6.30E-08	1.09E-09	3.78E-09	1.62E-03
1976	7.28E-03	1.43E-03	3.38E-07	5.85E-09	2.03E-08	8.70E-03
1977	7.91E-03	1.55E-03	3.67E-07	6.36E-09	2.20E-08	9.45E-03
1978	3.60E-04	7.05E-05	1.67E-08	2.89E-10	1.00E-09	4.30E-04
1979						
1980						
1981						
1982						
1983						
1984						
1985						
1986						
1987						
1988						
1989						
1990						
1991						
1992						
1993						
1994						
1995						
Totals	1.13E+01	2.22E+00	5.26E-04	9.12E-06	3.16E-05	1.36E+01
Percent	83.62%	16.38%	0.00%	0.00%	0.00%	

Zn-65

Half-Life

Zn-65 - 243.8 days

Total Curies Released (1954-1995)

Air - 0.0

Streams - 1.42E+02

Basins (Decay Corrected) - 1.39E-05

Total Cumulative Risks (1954-1995)

MEI Air Pathway - 0.0

MEI Liquid Pathway - 5.94E-06

Population Air - 0.0

Population Liquid - 8.98E-01

Projected 30-year Risks Using Recent Annual Doses (average of years 1991-1995)

MEI Air Pathway - 0.0

MEI Liquid Pathway - 0.0

Population Air - 0.0

Population Liquid - 0.0

Critical Pathways

MEI Air Pathway - N/A

MEI Liquid Pathway - Fish Consumption = 97%, Water Consumption = 2%

Population Air Pathway - N/A

Population Liquid Pathway - Aquatic Food = 99.6%, Water Consumption = 0.4%

Discussion

Zn-65 is a short-lived activation product that has not been measured in site airborne effluents and has not been measured in liquid effluents to site streams since 1975. However, on a cumulative MEI and population risk basis, Zn-65 was the 4th and 1st most important liquid pathway radionuclide, respectively. The cumulative population risk was estimated to be 9.0E-01, which is 51% of the site total.

The fish consumption and aquatic food pathways are the most critical for Zn-65 due to its large bioaccumulation factor in freshwater fish (2,000) and saltwater invertebrates (50,000) (NRC, 1977a). Future releases of Zn-65 are expected to remain nil. Refer to Carlton, 1996 for a more complete assessment of Zn-65 at SRS.

Table Zn-65. Effluent Releases

	Zn-65 to Air	Zn-65 to Streams	Zn-65 to Basins	Zn-65 to Basins
	Curies	Curies	Curies	Decay Corrected (Ci)
1954				
1955				
1956				
1957				
1958				
1959				
1960		4.29E+00		
1961		2.06E+01		
1962		3.19E+01		
1963		3.34E+01		
1964		1.99E+01	4.00E-02	4.43E-16
1965		8.94E+00	3.34E-01	1.04E-14
1966		7.52E+00	1.00E-02	8.80E-16
1967		7.32E+00	1.20E-01	2.98E-14
1968		4.51E+00	3.82E+00	2.67E-12
1969		1.54E+00	5.60E-01	1.10E-12
1970		5.10E-01		
1971		1.75E+00	3.00E-02	4.71E-13
1972				
1973				
1974		1.37E-01	7.60E-01	2.67E-10
1975		2.00E-03	5.67E-01	5.62E-10
1976			4.38E-01	1.22E-09
1977			5.31E-01	4.18E-09
1978			5.38E-02	1.20E-09
1979			8.00E-02	5.01E-09
1980			1.40E-01	2.47E-08
1981			7.44E-02	3.71E-08
1982			9.18E-02	1.29E-07
1983			9.45E-02	3.74E-07
1984			1.00E-02	1.12E-07
1985			3.00E-03	9.45E-08
1986			5.19E-02	4.61E-06
1987			2.08E-02	5.21E-06
1988			4.71E-03	3.32E-06
1989				
1990				
1991				
1992				
1993				
1994				
1995				
Totals		1.42E+02	7.83E+00	1.39E-05

Table Zn-65. MEI Liquid Pathway Doses

	Fish	Water	Shore	Swimming	Boating	Total Liquid Pathway
	(mrem)	(mrem)	(mrem)	(mrem)	(mrem)	(mrem)
1954						
1955						
1956						
1957						
1958						
1959						
1960	2.40E-01	4.72E-03	3.22E-04	3.05E-06	3.60E-06	2.45E-01
1961	1.15E+00	2.27E-02	1.55E-03	1.46E-05	1.73E-05	1.18E+00
1962	1.79E+00	3.51E-02	2.39E-03	2.26E-05	2.68E-05	1.82E+00
1963	1.87E+00	3.67E-02	2.51E-03	2.37E-05	2.81E-05	1.91E+00
1964	1.11E+00	2.19E-02	1.49E-03	1.41E-05	1.67E-05	1.14E+00
1965	5.01E-01	9.83E-03	6.71E-04	6.35E-06	7.51E-06	5.11E-01
1966	4.21E-01	8.27E-03	5.64E-04	5.34E-06	6.32E-06	4.30E-01
1967	4.10E-01	8.05E-03	5.49E-04	5.20E-06	6.15E-06	4.19E-01
1968	2.53E-01	4.96E-03	3.38E-04	3.20E-06	3.79E-06	2.58E-01
1969	8.62E-02	1.69E-03	1.16E-04	1.09E-06	1.29E-06	8.81E-02
1970	2.86E-02	5.61E-04	3.83E-05	3.62E-07	4.28E-07	2.92E-02
1971	9.80E-02	1.93E-03	1.31E-04	1.24E-06	1.47E-06	1.00E-01
1972						
1973						
1974	7.67E-03	1.51E-04	1.03E-05	9.73E-08	1.15E-07	7.83E-03
1975	1.12E-04	2.20E-06	1.50E-07	1.42E-09	1.68E-09	1.14E-04
1976						
1977						
1978						
1979						
1980						
1981						
1982						
1983						
1984						
1985						
1986						
1987						
1988						
1989						
1990						
1991						
1992						
1993						
1994						
1995						
Totals	7.97E+00	1.57E-01	1.07E-02	1.01E-04	1.20E-04	8.14E+00
Percent	97.94%	1.92%	0.13%	0.00%	0.00%	

Table Zn-65. Population Liquid Pathway Doses

	Aquatic Food	Water	Shore	Swimming	Boating	Total Liquid Pathway
	(per.-rem)	(per.-rem)	(per.-rem)	(per.-rem)	(per.-rem)	(per.-rem)
1954						
1955						
1956						
1957						
1958						
1959						
1960	3.69E+01	1.33E-01	1.33E-02	5.58E-05	1.89E-04	3.71E+01
1961	1.77E+02	6.39E-01	6.39E-02	2.68E-04	9.06E-04	1.78E+02
1962	2.75E+02	9.89E-01	9.89E-02	4.15E-04	1.40E-03	2.76E+02
1963	2.88E+02	1.04E+00	1.04E-01	4.34E-04	1.47E-03	2.89E+02
1964	1.71E+02	6.17E-01	6.17E-02	2.59E-04	8.76E-04	1.72E+02
1965	7.70E+01	2.77E-01	2.77E-02	1.16E-04	3.93E-04	7.73E+01
1966	6.47E+01	2.33E-01	2.33E-02	9.78E-05	3.31E-04	6.50E+01
1967	6.30E+01	2.27E-01	2.27E-02	9.52E-05	3.22E-04	6.33E+01
1968	3.88E+01	1.40E-01	1.40E-02	5.86E-05	1.98E-04	3.90E+01
1969	1.33E+01	4.77E-02	4.77E-03	2.00E-05	6.78E-05	1.33E+01
1970	4.39E+00	1.58E-02	1.58E-03	6.63E-06	2.24E-05	4.41E+00
1971	1.51E+01	5.43E-02	5.43E-03	2.28E-05	7.70E-05	1.51E+01
1972						
1973						
1974	1.18E+00	4.25E-03	4.25E-04	1.78E-06	6.03E-06	1.18E+00
1975	1.72E-02	6.20E-05	6.20E-06	2.60E-08	8.80E-08	1.73E-02
1976						
1977						
1978						
1979						
1980						
1981						
1982						
1983						
1984						
1985						
1986						
1987						
1988						
1989						
1990						
1991						
1992						
1993						
1994						
1995						
Totals	1.23E+03	4.41E+00	4.41E-01	1.85E-03	6.26E-03	1.23E+03
Percent	99.60%	0.36%	0.04%	0.00%	0.00%	

Table Zn-65 Liquid. Zn-65 Liquid Releases and Maximally Exposed Individual Doses 1954 -1995

Zr-95

Half-Life

Zr-95 - 64.02 days

Total Curies Released (1954-1995)

Air - 3.12E+00

Streams - 0.0

Basins (Decay Corrected) - <1.00E-12

Total Cumulative Risks (1954-1995)

MEI Air Pathway - 8.43E-09

MEI Liquid Pathway - 0.0

Population Air - 4.82E-04

Population Liquid - 0.0

Projected 30-year Risks Using Recent Annual Doses (average of years 1991-1995)

MEI Air Pathway - 7.31E-13

MEI Liquid Pathway - 0.0

Population Air - 6.28E-09

Population Liquid - 0.0

Critical Pathways

MEI Air Pathway - Ground = 76%, Vegetation Consumption = 18%

MEI Liquid Pathway - N/A

Population Air Pathway - Ground = 85%, Vegetation Consumption = 10%

Population Liquid Pathway - N/A

Discussion

Zr-95 is a short-lived, but abundant, fission product. Because Zr-95 has a larger air pathway dose factor than Nb-95, measured airborne releases of Zr-Nb-95 are conservatively added with Zr-95 releases for dose and risk calculations. On a cumulative MEI and population risk basis, Zr-95 was the 22nd and 21st most important air pathway radionuclide. Future releases of Zr-95 are expected to remain essentially nil.

Table Zr-95. Effluent Releases

	Zr-95/Nb-95 - Air	Zr-95 - Streams	Zr-95 - Basins	Zr-95 - Basins
	Curies	Curies	Curies	Decay Corrected (Ci)
1954				
1955				
1956				
1957				
1958				
1959				
1960	2.12E-01			
1961	2.99E-01			
1962	1.74E-01			
1963	1.50E-01			
1964	2.23E-01			
1965	2.16E-01			
1966	2.06E-01			
1967	2.10E-01			
1968	3.11E-01			
1969	2.85E-01			
1970	2.74E-01			
1971	1.35E-01		4.27E+00	<1.00E-12
1972	1.51E-01		7.05E+00	<1.00E-12
1973	6.93E-02		1.14E+01	<1.00E-12
1974	3.34E-02		4.12E+00	<1.00E-12
1975	1.35E-02		9.72E-01	<1.00E-12
1976	1.43E-02		5.70E+00	<1.00E-12
1977	1.44E-02		2.20E+00	<1.00E-12
1978	7.33E-03		2.07E+00	<1.00E-12
1979	1.32E-02		2.38E+00	<1.00E-12
1980	1.35E-02		3.09E+00	<1.00E-12
1981	1.71E-02		5.64E+00	<1.00E-12
1982	1.44E-02		6.32E+00	<1.00E-12
1983	1.12E-02		3.78E+00	<1.00E-12
1984	1.38E-02		7.02E+00	<1.00E-12
1985	2.92E-02		1.03E+01	<1.00E-12
1986	4.38E-03		8.46E-01	<1.00E-12
1987	1.67E-03		1.33E-01	<1.00E-12
1988	7.60E-04		1.86E-02	<1.00E-12
1989	5.80E-05			
1990				
1991				
1992				
1993				
1994				
1995	4.51E-05			
Totals	3.12E+00		7.73E+01	<1.00E-12

Table Zr-95: MEI Air-Pathway Doses

	Plume (mrem)	Ground (mrem)	Inhalation (mrem)	Vegetation (mrem)	Milk (mrem)	Meat (mrem)	Total Air Pathway (mrem)
1954							
1955							
1956							
1957							
1958							
1959							
1960		5.94E-04	1.10E-05	1.44E-04	1.65E-08	3.60E-05	7.85E-04
1961		8.37E-04	1.55E-05	2.03E-04	2.33E-08	5.08E-05	1.11E-03
1962		4.87E-04	9.05E-06	1.18E-04	1.36E-08	2.96E-05	6.44E-04
1963		4.20E-04	7.80E-06	1.02E-04	1.17E-08	2.55E-05	5.55E-04
1964		6.24E-04	1.16E-05	1.52E-04	1.74E-08	3.79E-05	8.26E-04
1965		6.05E-04	1.12E-05	1.47E-04	1.68E-08	3.67E-05	8.00E-04
1966		5.77E-04	1.07E-05	1.40E-04	1.61E-08	3.50E-05	7.63E-04
1967		5.88E-04	1.09E-05	1.43E-04	1.64E-08	3.57E-05	7.77E-04
1968		8.71E-04	1.62E-05	2.11E-04	2.43E-08	5.29E-05	1.15E-03
1969		7.98E-04	1.48E-05	1.94E-04	2.22E-08	4.85E-05	1.06E-03
1970		7.67E-04	1.42E-05	1.86E-04	2.14E-08	4.66E-05	1.01E-03
1971		3.78E-04	7.02E-06	9.18E-05	1.05E-08	2.30E-05	5.00E-04
1972		4.23E-04	7.85E-06	1.03E-04	1.18E-08	2.57E-05	5.59E-04
1973		1.94E-04	3.60E-06	4.71E-05	5.41E-09	1.18E-05	2.57E-04
1974		9.35E-05	1.74E-06	2.27E-05	2.61E-09	5.68E-06	1.24E-04
1975		3.78E-05	7.02E-07	9.18E-06	1.05E-09	2.30E-06	5.00E-05
1976		4.00E-05	7.44E-07	9.72E-06	1.12E-09	2.43E-06	5.29E-05
1977		4.03E-05	7.49E-07	9.79E-06	1.12E-09	2.45E-06	5.33E-05
1978		2.05E-05	3.81E-07	4.98E-06	5.72E-10	1.25E-06	2.71E-05
1979		3.70E-05	6.86E-07	8.98E-06	1.03E-09	2.24E-06	4.89E-05
1980		3.78E-05	7.02E-07	9.18E-06	1.05E-09	2.30E-06	5.00E-05
1981		4.79E-05	8.89E-07	1.16E-05	1.33E-09	2.91E-06	6.33E-05
1982		4.03E-05	7.49E-07	9.79E-06	1.12E-09	2.45E-06	5.33E-05
1983		3.14E-05	5.82E-07	7.62E-06	8.74E-10	1.90E-06	4.15E-05
1984		3.86E-05	7.18E-07	9.38E-06	1.08E-09	2.35E-06	5.11E-05
1985		8.18E-05	1.52E-06	1.99E-05	2.28E-09	4.96E-06	1.08E-04
1986		1.23E-05	2.28E-07	2.98E-06	3.42E-10	7.45E-07	1.62E-05
1987		4.68E-06	8.68E-08	1.14E-06	1.30E-10	2.84E-07	6.18E-06
1988		2.13E-06	3.95E-08	5.17E-07	5.93E-11	1.29E-07	2.81E-06
1989		1.62E-07	3.02E-09	3.94E-08	4.52E-12	9.86E-09	2.15E-07
1990							
1991							
1992							
1993							
1994							
1995		1.26E-07	2.35E-09	3.07E-08	3.52E-12	7.67E-09	1.67E-07
Totals		8.73E-03	1.62E-04	2.12E-03	2.43E-07	5.30E-04	1.15E-02
Percent		75.63%	1.40%	18.37%	0.00%	4.59%	

Table Zr-95. Population Air-Pathway Doses

	Plume	Ground	Inhalation	Vegetation	Milk	Meat	Total Air Pathway
	(per.-rem)	(per.-rem)	(per.-rem)	(per.-rem)	(per.-rem)	(per.-rem)	(per.-rem)
1954							
1955							
1956							
1957							
1958							
1959							
1960		3.82E-02	1.34E-03	4.66E-03	5.72E-07	7.42E-04	4.49E-02
1961		5.38E-02	1.88E-03	6.58E-03	8.07E-07	1.05E-03	6.33E-02
1962		3.13E-02	1.10E-03	3.83E-03	4.70E-07	6.09E-04	3.69E-02
1963		2.70E-02	9.45E-04	3.30E-03	4.05E-07	5.25E-04	3.18E-02
1964		4.01E-02	1.40E-03	4.91E-03	6.02E-07	7.81E-04	4.72E-02
1965		3.89E-02	1.36E-03	4.75E-03	5.83E-07	7.56E-04	4.57E-02
1966		3.71E-02	1.30E-03	4.53E-03	5.56E-07	7.21E-04	4.36E-02
1967		3.78E-02	1.32E-03	4.62E-03	5.67E-07	7.35E-04	4.45E-02
1968		5.60E-02	1.96E-03	6.84E-03	8.40E-07	1.09E-03	6.59E-02
1969		5.13E-02	1.80E-03	6.27E-03	7.70E-07	9.98E-04	6.04E-02
1970		4.93E-02	1.73E-03	6.03E-03	7.40E-07	9.59E-04	5.80E-02
1971		2.43E-02	8.51E-04	2.97E-03	3.65E-07	4.73E-04	2.86E-02
1972		2.72E-02	9.51E-04	3.32E-03	4.08E-07	5.29E-04	3.20E-02
1973		1.25E-02	4.37E-04	1.52E-03	1.87E-07	2.43E-04	1.47E-02
1974		6.01E-03	2.10E-04	7.35E-04	9.02E-08	1.17E-04	7.07E-03
1975		2.43E-03	8.51E-05	2.97E-04	3.65E-08	4.73E-05	2.86E-03
1976		2.57E-03	9.01E-05	3.15E-04	3.86E-08	5.01E-05	3.03E-03
1977		2.59E-03	9.07E-05	3.17E-04	3.89E-08	5.04E-05	3.05E-03
1978		1.32E-03	4.62E-05	1.61E-04	1.98E-08	2.57E-05	1.55E-03
1979		2.38E-03	8.32E-05	2.90E-04	3.56E-08	4.62E-05	2.80E-03
1980		2.43E-03	8.51E-05	2.97E-04	3.65E-08	4.73E-05	2.86E-03
1981		3.08E-03	1.08E-04	3.76E-04	4.62E-08	5.99E-05	3.62E-03
1982		2.59E-03	9.07E-05	3.17E-04	3.89E-08	5.04E-05	3.05E-03
1983		2.02E-03	7.06E-05	2.46E-04	3.02E-08	3.92E-05	2.37E-03
1984		2.48E-03	8.69E-05	3.04E-04	3.73E-08	4.83E-05	2.92E-03
1985		5.26E-03	1.84E-04	6.42E-04	7.88E-08	1.02E-04	6.18E-03
1986		7.88E-04	2.76E-05	9.64E-05	1.18E-08	1.53E-05	9.28E-04
1987		3.01E-04	1.05E-05	3.67E-05	4.51E-09	5.85E-06	3.54E-04
1988		1.37E-04	4.79E-06	1.67E-05	2.05E-09	2.66E-06	1.61E-04
1989		1.04E-05	3.65E-07	1.28E-06	1.57E-10	2.03E-07	1.23E-05
1990							
1991							
1992							
1993							
1994							
1995			2.84E-07	9.92E-07	1.22E-10	1.58E-07	1.43E-06
Totals		5.61E-01	1.96E-02	6.86E-02	8.42E-06	1.09E-02	6.60E-01
Percent		84.98%	2.97%	10.39%	0.00%	1.65%	

Table Zr-Nb-95 Air. Zr-Nb-95 Atmospheric Releases and Maximally Exposed Individual Doses 1954 - 1995

Appendix B

Review of Critical Radionuclides at SRS

Airborne Pathway Critical Radionuclides:

Pages B-1 through B-8

Liquid Pathway Critical Radionuclides:

Pages B-9 through B-16

1954 - 1960

1961 - 1965

1966 - 1970

1971 - 1975

1976 - 1980

1981 - 1985

1986 - 1990

1991 - 1995

1954 - 1960

1961 - 1965

1966 - 1970

1971 - 1975

1976 - 1980

1981 - 1985

1986 - 1990

1991 - 1995

Appendix C

Review of Critical Pathways at SRS

Critical Airborne Pathways :

Pages C-1 through C-8

Critical Liquid Pathways:

Pages C-9 through C-16

1954 - 1960

1961 - 1965

1966 - 1970

1971 - 1975

1976 - 1980

1981 - 1985

1986 - 1990

1991 - 1995

1954 - 1960

1961 - 1965

1966 - 1970

1971 - 1975

1976 - 1980

1981 - 1985

1986 - 1990

1991 - 1995