3 SCENARIO DESCRIPTIONS

This chapter presents the seven exposure scenarios used in Phase III of the Savannah River Site (SRS) Dose Reconstruction Project, including the behavior of the four receptors comprising each scenario (28 receptors total). The behavior of each receptor, which was based on the scenario descriptions provided by CDC, was used to develop values for many of the parameters in the radiological assessment. Appendix E, Receptor Activities and Usage Rates, presents the derivation of point-estimate values for those parameters that depend on the receptors' behavior (e.g., times spent in various exposure locations). Appendix F, Parameter Values for Base Case Evaluation, presents model parameter values that are not clearly receptor-specific (e.g., food crop production rates).

The exposure scenarios considered for this report evolved over time. The six exposure scenarios that were originally proposed in 2002 by the Centers for Disease Control and Prevention (CDC) were modified and refined by the Savannah River Site Health Effects Subcommittee (SRSHES) and by preparers of this report. Ultimately seven scenarios were used in the analysis. Section 3.1 discusses the development of the scenarios. Section 3.2 discusses the seven scenarios used for the study. Section 3.3 discusses additional assumptions and specification for these scenarios. Section 3.4 provides an overview.

3.1 Scenarios Proposed by CDC and Considered by the SRSHES

CDC originally proposed the following six scenarios (1):

1. A rural family just downwind of the site boundary.
2. An urban/suburban family just downwind of the site boundary.
3. A delivery person.
4. An outdoors person (e.g., hunter, fisherman, camper, etc.).
5. A family living near the river.
6. A migrant worker family living mostly outdoors.

These scenarios describe hypothetical families that might have lived in the SRS vicinity. The activities, behaviors, and conditions ascribed to each scenario were meant to represent a range of activities that might have occurred in the area of the SRS, over the time period studied. The attributes postulated for these scenarios were intended to represent a broad range of lifestyles. Some of the attributes specified in the scenarios are expected to bound realistic attributes in a way that increases the dose estimates; that is, based on the scenario definitions alone, the dose estimates are generally expected to be conservative estimates of actual doses.

In January 2002, CDC presented proposed assumptions about these six scenarios at a meeting of the SRSHES in Charleston, South Carolina. The SRSHES formed a work group to consider the proposed scenarios. The SRSHES Work Group presented its comments and recommendations about the proposed scenarios at a September 2002 SRSHES meeting (1). Table 3-1 summarizes the CDC's proposed scenarios (as modified) and the SRSHES Work Group's comments and recommendations (1).

The SRS Dose Reconstruction Team discussed the proposed scenarios with CDC staff in early 2003 (2, 3). These discussions principally addressed overall decisions about the number of exposure scenarios to be considered, and where the hypothetical families comprising these exposure scenarios would live, work, attend church and school, obtain food, and recreate.

Table 3-1 CDC Proposed Scenarios and SRSHES Comments and Recommendations[1]

CDC Proposed Scenarios and Descriptions	Summary of SRSHES Work Group Comments and Recommendations
Rural	
▪ Use the closest downwind location where there could have been farms in 1955. ▪ Consider an adult and infants born in 1955 and 1964 (year of largest iodine release). ▪ Use default consumption values. ▪ Assume lots of time outdoors working in soil. ▪ Assume they drank milk from a backyard cow. ▪ Assume the crops were irrigated from Savannah River. ▪ Assumption of "working in soil" to include resuspension of soil contaminants in the breathing zone. ▪ In addition to two infants, consider the mother nursing at least one of the infants.	▪ Farm in rural Burke County, GA (Girard, GA, 3 miles W of the Savannah River, SW of SRS. Population about 200 in 1950s.) ▪ 1950s: 2 parents, 5 children. 1960s: 2 parents, 3 children. ▪ Schools: Girard Elementary, Waynesboro High School. ▪ Cash crops: peanuts, corn, cotton. Vegetables grown for family consumption. ▪ Religion: Methodist. ▪ In 1950s, 50% of meat & vegetables grown on farm. In 1960s, 25% grown on farm; most milk from one of two Girard dairies. Family had dairy cows. ▪ Family had dogs for pets and chickens. ▪ Some swimming, but minimal camping. No boating. ▪ Fishing from Briar Creek, 2 miles east of Girard. Hunting for deer, quail and dove. Limited trapping.
Urban/Suburban	
▪ Use closest downwind location where urban or suburban families could have lived in 1955. ▪ Consider an adult and infants born in 1955 and 1964 (year of largest iodine release). ▪ Use default consumption values. ▪ Assume the adult worked at the nearest industrial location downwind in 1955. ▪ Assume milk from the nearest dairy or rural neighbor. ▪ Assume the adult worked on-site at SRS in lieu of the "nearest industrial location." ▪ Assume the onsite work location was associated with higher radiological exposures -- e.g., SRS Canyons.	▪ Family lived in Augusta, GA near Broad and Greene Streets. ▪ 1950s: 2 parents, 2 children. 1960s: 2 parents, 3 children. ▪ Schools: Augusta neighborhood schools ▪ Father worked in the SRS F-Area Canyon Building from 1955 to 1992. The mother worked on site until well into her first pregnancy, but stayed home after birth of first child to raise the children. ▪ Attended local church in Augusta, GA. ▪ Food and milk were from local grocery stores in Augusta, GA. Milk was supplied to local stores from dairies in the Aiken and Augusta area. Include backyard cow. ▪ Include a family pet. ▪ Swimming & boating in Clark's Hill Lake. ▪ No hunting. Fished Clark's Hill Lake, 2 weekends/month.
Migrant	
▪ Use the closest downwind location. ▪ Consider an adult and infants born in 1955 and 1964 (year of largest iodine release). ▪ Use default consumption values ▪ Assume always outdoors contacting the soil. ▪ Assume that crops were irrigated by the Savannah River. ▪ Assume they obtained their food from the nearest local farm or grocery store.	▪ Scenario Location: TBD ▪ 1950s: 2 parents, 2 children. 1960s: 2 parents 3 children. ▪ Schools: TBD ▪ Work: TBD ▪ Religion: TBD ▪ Food Sources: TBD ▪ Swimming, Boating, Camping, Hunting, & Fishing: TBD.

[1] This is presented as a record of scenario development; the scenarios actually analyzed in Phase III are described in detail in Sections 3.2, 3.3, and 3.4.

Table 3-1 CDC Proposed Scenarios and SRSHES Comments and Recommendations[1]

CDC Proposed Scenarios and Descriptions	Summary of SRSHES Work Group Comments and Recommendations
Delivery	
▪ Same as Urban/Suburban Family. ▪ Use closest downwind location where urban or suburban families could have lived in 1955. ▪ Consider an adult and infants born in 1955 and 1964 (year of largest iodine release). ▪ Use default consumption values. ▪ Assume the adult worked at the nearest industrial location downwind in 1955. ▪ Assume they drank milk from the nearest dairy or rural neighbor. ▪ Assume that the person spent 8 hours per week on site.	▪ Family lived in Barnwell, SC. Father provided weekly beverage deliveries to SRS. ▪ 1950s: 2 parents, 2 children. 1960s: 2 parents, 3 children. ▪ Schools: Barnwell, SC school system. ▪ The delivery person worked at the Allendale Coca Cola Bottling Plant in Allendale, SC, and made routine deliveries to SRS, spending 8 hours/week on-site. No dosimetery. ▪ Consider backyard chickens and/or rabbits at home. ▪ Attended Mount Hope Baptist Church, Martin, SC. ▪ Food Sources: Barnwell, SC grocery stores, and Furses' Grocery Store, Martin, SC ▪ Swimming in Lower Three Runs Creek outside Martin, SC. Boating and camping at Little Hell Landing on Savannah River. ▪ Hunting at Lower Three Runs Creek area (known for poaching). Fishing at Lower Three Runs Creek, and Savannah River's Smith Lake. ▪ Family drank carbonated drinks, including beer.
Outdoor	
▪ Assume camping at the nearest downwind location making sense with the season (hunting, fishing, etc.) ▪ Assume that the person was always outdoors. ▪ Use default consumption values. ▪ Assume the person spent 8 hours per day on the Savannah River in the summer. ▪ Assume the person spent 8 hours per week on site hunting or fishing (in season). ▪ Assume the person obtained fish and meat (deer, game birds, turtles) from hunting and fishing onsite (some authorized, some not — a "poacher" assumption.)	▪ Family lived in Jackson, SC ▪ 1950s: 2 parents, 2 children. 1960s: 2 parents, 3 children. ▪ Schools: (1950) Jackson Elementary. (1986) Redcliff Elementary. Jackson High School. ▪ Worked as a hunter/trapper subcontractor to the primary SRS Contractor or the US Forest Service. Some potential exposure from trapping activities, streams, ponds, etc. ▪ Scenario includes the hypothetical poacher. ▪ Hunting dogs were family pets. ▪ Religion: First Baptist Church, Jackson, SC ▪ 50% of vegetables locally grown and irrigated from a surface creek. 75% of meat obtained from SRS. Fish from the Savannah River. Water from a well on home property. ▪ Boating in Savannah River from Jackson, SC, boat ramp. ▪ Took deer, hogs from work at SRS. Fished in Savannah River.
Near River	
▪ Use the nearest docking location downwind where people could have lived on houseboats in 1955. ▪ Consider an adult and infants born in 1955 and 1964 (year of largest iodine release). ▪ Use default consumption values. ▪ Assume always outdoors contacting the	▪ Scenario Location: Consider Martin-Millet area ▪ Family: TBD ▪ Schools: TBD ▪ Work: TBD ▪ Religion: TBD ▪ Food Sources: Shell fishing, shrimping, crabbing

Table 3-1 CDC Proposed Scenarios and SRSHES Comments and Recommendations[1]

CDC Proposed Scenarios and Descriptions	Summary of SRSHES Work Group Comments and Recommendations
Savannah River. ▪ Assume they obtained their food from the nearest local farm or grocery store. ▪ Validate with the Citizens Advisory Board that the boat scenario is plausible; if so, define a location. ▪ If not plausible, replace with a new scenario: a site construction worker living in a trailer.	▪ Swimming, Boating, Camping, Hunting, & Fishing: TBD.

Source: (1).

3.2 Exposure Scenarios and Locations

As discussed in Chapter 6, releases to the air from any SRS source were modeled as being transported in each of sixteen sectors defined by the sixteen major compass directions. In any sector, at a given distance from a source, concentrations were modeled as being the same along all points of an arc defined by the radial distance from the source. This is shown in Figure 3-1. It shows the relative radionuclide concentration from a unit source at a distance of ten miles from the source.

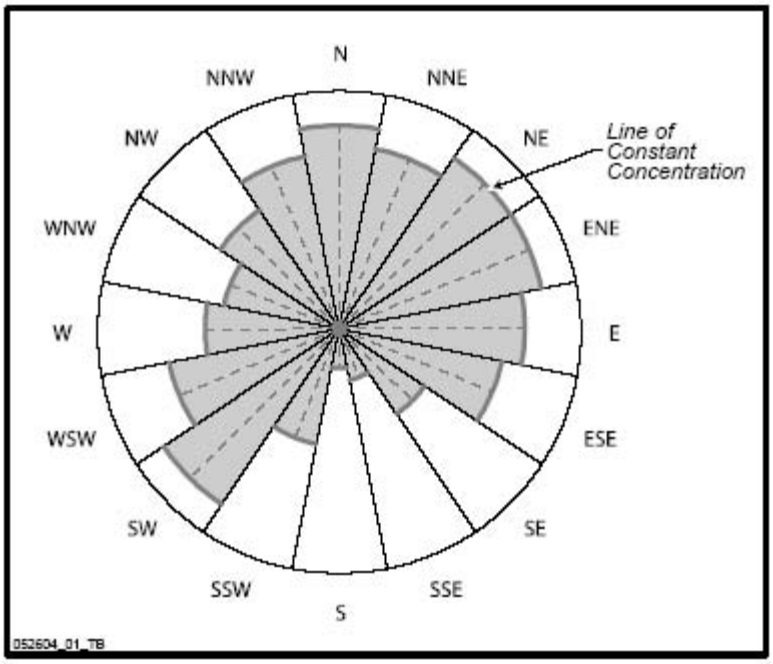

Figure 3-1 Example of Modeled Radionuclide Concentration at Ten Miles from a Unit SRS Source

The meaning of this modeling simplification is that at a given distance (radius) from a source, the same concentration will be determined for any angle within a given sector. Thus, two hypothetical exposure locations that are fairly close together will generally not differ significantly in modeled concentrations unless they happen to lie in different sectors.

3.2.1 Exposure Scenarios and Locations Considered for Phase III

In addition to the six exposure scenarios originally proposed by CDC, a seventh was added. When the scenario locations were plotted on a map of the area surrounding the SRS, it was noted that approximately 90° out of 360° -- generally toward the northeast – was without an exposure scenario. Therefore a seventh – identified as Rural Family #2 – was added with concurrence from CDC and the SRSHES.

In each scenario, exposure locations were identified to represent where family members lived, worked, attended school, engaged in recreational activities, where their food was grown, and other activities. For all seven scenarios, exposures to radionuclides were modeled at ten locations for radionuclides released to the air and two locations for radionuclides released to water.

The exposure locations assumed for the seven exposure scenarios are shown in Figure 3-2. Table 3-2 summarizes the exposure locations for contamination released into the air, while Table 3-3 summarizes the exposure locations for contamination released to surface water. The Lower Three Runs Creek exposure location is in the vicinity of Martin, South Carolina. The downstream Savannah River exposure location is representative of multiple possible locations downstream from the site.

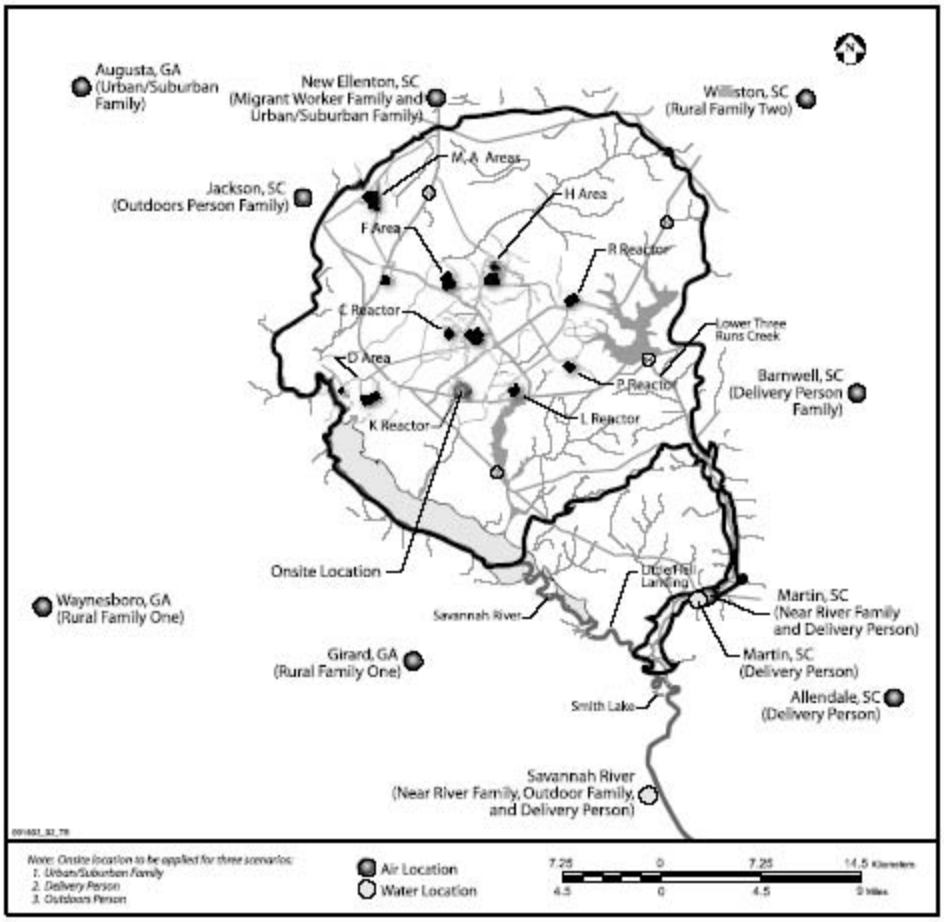

Figure 3-2 Exposure Locations for Exposure Scenarios

Table 3-2 Summary of Exposure Locations for SRS Releases to Air

Exposure Scenario	Activity*	Exposure Location									
		Girard, GA	Waynesboro, GA	Martin, SC	Augusta, GA	Williston, SC	SRS Onsite Location	Barnwell, SC	Allendale, SC	Jackson, SC	New Ellenton, SC
Rural Family One	All except high school†	X									
	High school		X								
Rural Family Two	All activities					X					
Urban/Suburban Family	All except employment				X						
	Employment						X				
Migrant Worker Family	All activities										X
Delivery Person Family	All except those below:							X			
	Employment								X		
	Employment						X				
	Church, grocery (partial), swimming, boating, hunting, fishing			X							
Outdoors Person Family	All except employment									X	
	Employment						X				
Near River Family	All activities			X							

* Activities included school, work, recreation, church, production of foodstuffs, and indoor and outdoor activities around the home.

† For all receptors, excluding the children of Rural Family One, the same exposure location was used for their high school as for their residence. Children of all scenarios attended grade school at the same exposure location that was used for their residence.

Table 3-3 Summary of Exposure Locations for SRS Releases to Surface Water

Scenario	Activities / Pathways	Downstream Savannah River	Lower Three Runs Creek	No Exposure to Water Affected By Liquid Releases*
Rural Family One	All activities†			X
Rural Family Two	All activities†			X
Urban/Suburban Family	All activities†			X
Migrant Worker Family	All activities†			X
Delivery Person Family	Fishing, swimming, shoreline		X	
	Fishing, shoreline, boating	X		
Outdoors Person Family	Fishing, shoreline, boating	X‡		X§
	Swimming			
Near River Family	All activities†	X		

*Exposure occurred in water not affected by releases from the SRS to water.
†"All activities" included fishing, boating, swimming, and shoreline.
‡Shoreline exposures were only received at work by the Adult Male and the children when they each reached age 18. Recreational shoreline activities by all family members were in unaffected water.
§For the entire family while recreating on the Savannah River.

The scenarios and exposure locations are:

- Rural Family One. This family lived on a farm near Girard, Georgia. The Girard exposure location was where the family hunted, fished, and grew or produced much of their food. Although the adults always stayed near the farm, the children attended high school in Waynesboro, Georgia.

- Rural Family Two. This family lived on a farm near Williston, South Carolina. The Williston exposure location was where the family hunted, fished, and grew or produced much of their food. All family members lived at the Williston exposure location for all 39 years, including grade and high school for the children.

- Urban/Suburban Family. This family lived near the intersection of East Boundary and East Telfair Street in Augusta, Georgia. The Augusta exposure location was assumed for most family activities including swimming, boating, and fishing. It was the exposure location where much of the family's food was grown or produced, including half of their milk. The other half of their milk came from cows located in New Ellenton, South Carolina. The father worked onsite at SRS. The children also worked onsite at SRS when they grew up. A representative location on the SRS site, near the K-Reactor, was assumed as a work exposure location.

- Migrant Worker Family. This family lived in New Ellenton, South Carolina, for half of any year. The New Ellenton exposure location was assumed for all exposures and activities (home, schools, church, work, recreation, and the source for locally grown vegetables, milk, and meat).

- Delivery Person Family. This family lived in Barnwell, South Carolina, and attended church in Martin, South Carolina. Some of the food eaten by this family was obtained from Barnwell and some from Martin. The father worked in Allendale, South Carolina, and onsite at SRS. (So did the children when they grew up.) A representative location on the SRS site, near the K-Reactor, was assumed as a work exposure location. The father hunted deer and wild fowl near Martin. The family engaged in recreation on the shore of Lower Three Runs Creek (at Martin) and on the shore of the Savannah River below its confluence with Lower Three Runs Creek. [2] The family boated on, and ate fish from, the Savannah River at this same exposure location. The family also ate fish that were caught in Lower Three Runs Creek.

- Outdoors Person Family. This family lived in Jackson, South Carolina, where the family also attended church and the children went to grade and high school. Much of the food eaten by the family was grown in Jackson. The father worked and hunted on the SRS site (as did the children when they grew up). The same location on the SRS site, near the K-Reactor, was assumed for the work exposure location and the hunting exposure location. The father boated on the Savannah River while working and with his family for recreation.[3] The family swam and spent time along the shoreline at the Jackson Boat Ramp, which is upstream of the SRS discharge to the Savannah River. All family members ate fish that were caught in the Savannah River below its confluence with Lower Three Runs Creek.

- Near River Family. This family lived in Martin, South Carolina.[4] The Martin exposure location was assumed for all activities (home, schools, church, work, recreation, source of milk, and the source of locally grown vegetables). In addition, the family boated in, and ate fish from, the Savannah River below its confluence with Lower Three Runs Creek.

Discussion of assumptions about exposure scenarios and locations. The following discussion provides additional information about the selection of exposure scenarios and the locations:

- Two rural farming families – Rural Family One and Rural Family Two -- were assumed rather than one. Rural Family Two was added to the area near Williston, South Carolina. CDC staff had suggested adding an exposure scenario to the northeast of SRS to assure that possible radiation exposures in that direction would be considered (3). It was decided that this exposure scenario would be a rural family similar to the farming family located near Girard, Georgia (Rural Family One).

- New Ellenton, South Carolina, was chosen as the exposure location for the Migrant Worker Family. Although a migrant worker scenario had been proposed by CDC, the location where the scenario would be sited was undetermined. (The SRSHES Work Group did not recommend a location (1).) The Migrant Worker Scenario was located in New Ellenton to assure that exposures from radionuclides released to the north from SRS would be considered, and because migrant farm families were probably present in the New Ellenton area during much of the period of interest (2). In addition, the New Ellenton area was chosen as the location of a dairy patronized by the Urban/Suburban Family (2).

- The Urban/Suburban Family was assumed to fish, swim, and boat at the Augusta exposure location. The SRSHES Scenarios Work Group had proposed using Clark's Hill Lake (now called the Strom

[2] Exposures from air immersion and deposition that were received while conducting water-related activities were modeled assuming the Martin exposure location.
[3] All boating occurred below the confluence of the Savannah River with Lower Three Runs Creek.
[4] Note that Martin, South Carolina, is not directly on the river.

Thurmond Reservoir) for these activities (1). The Augusta location was chosen as an alternative, in order to help limit the number of exposure locations that had to be modeled. Because both Clark's Hill Lake and Augusta are well above any point of surface water discharge from SRS, at neither location would receptors have experienced radiological exposures from radionuclides released by SRS to surface water. The only exposures would have been from radionuclides that had been released into the air. But Augusta is closer to SRS than Clark's Hill Lake, and both locations are northeast of SRS. For this reason, Augusta was a more conservative choice than Clark's Hill Lake.

- Any person exposed on the SRS site was assumed not to have been a radiological worker whose radiation exposures would have been routinely measured. This person would have had access to the site but not to areas controlled for purposes of radiation protection. Two candidate locations were identified: (1) near K-Reactor, and (2) the F- and H-Areas. Although hunting was probably more likely near K-Reactor, more people were employed in the F- and H-Areas. The K-Reactor vicinity was chosen to represent the exposure location for all onsite receptors, whether working or hunting.

- For all scenarios, all hypothetical family members stayed in the SRS area over the entire 39-year period. Children born and raised in the area always remained at home except for participating in specified activities such as school and recreation. After finishing high school, the children lived in their home communities. Each child adopted the same occupation and recreational activities as the adult male in their family from age 18 on.

- All radiation exposures associated with the Savannah River (boating, swimming, shoreline, fishing) were assumed to occur at a location below the confluence of the Savannah River with Lower Three Runs Creek. Below the confluence, the Savannah River contained radionuclides that were discharged into the river through the Savannah River Swamp as well as radionuclides that were discharged into the river from Lower Three Runs Creek. The flow rate was not significantly larger than further upstream. For purposes of calculating air exposures while recreating on the Savannah River (e.g., immersion and inhalation doses), the Martin location was assumed as representative. Martin, Smith Lake, and Little Hell Landing are all within a few miles of one another.

3.2.2 Additional Refinements to Proposed Exposure Scenarios

In addition to the overall decisions described above, several refinements were made to the specifics of the exposure scenarios proposed by the CDC and addressed by the SRSHES:

Consumption of locally acquired milk. It was assumed for all scenarios that family members drank milk from cows located in the SRS vicinity, meaning that all milk contained radionuclides that had been released into the air from SRS. This assumption met the intent of the SRSHES Work Group's suggestion that the urban/suburban and rural families should drink milk from family cows (1).

Consumption of poultry. It was assumed that much of the poultry eaten by all members of all scenarios was produced in the SRS vicinity. This assumption largely met the intent of the SRSHES Work Group's suggestion to include family chickens in some scenarios (1).

Hunting and trapping. It was assumed for several scenarios that the adult male spent time outdoors while hunting and trapping. Radiation exposures received through consumption of game animals was modeled for the two rural families, the Delivery Person Family, and the Outdoors Person Family by assuming that meat from game animals could be represented as either a form of beef or poultry (see Section 3.2.2).

Consumption of crustaceans. All radiation exposures from eating aquatic animals were assumed to come from eating fish. The SRSHES Work Group had suggested that shell fishing, shrimping, and crabbing should be considered as food sources for the Near River Family scenario (1). However, the potential for the crustaceans cited by the SRSHES to be present at the scenario locations was considered very remote. The habitat for the crustaceans cited is located a significant distance downriver in brackish water, far enough away from SRS so that the levels of radiation in the crustaceans would be quite small.

Irrigation. Irrigation with water contaminated with radionuclides from SRS was not modeled as an exposure pathway. Although the proposed CDC scenario had envisioned that the rural family and migrant families would irrigate crops with water taken from the Savannah River (1), it was determined that such a pathway would be unrealistic for the SRS area.

Houseboating. The Near River Family was assumed to live in Martin, South Carolina, an exposure location that was consistent with the recommendations of the SRSHES Work Group (1). CDC had proposed that the family living near the river should live on a houseboat (1). Yet there was no evidence that persons lived on houseboats in the SRS area.

Family Composition. Each exposure scenario consists of two adults and two children. The SRSHES Work Group had suggested that five children be assumed for the rural family and three for the delivery person family (1). Modeling additional children would not provide significantly different information from that already obtained from the two children already studied. Each scenario proposed by CDC included two children who were born during years that SRS released large quantities of radionuclides into the air (1).

Religion. It was assumed that all family members attended religious services for a few hours each week. This assumption was consistent with the SRSHES Work Group's suggestions (1). For most scenarios, it was assumed that the place of worship was near the family residence. The scope of the study did not support making distinctions between the specific locations of the structures within a small geographical area.

Pets. Pets were not modeled as a separate exposure pathway. The SRSHES Work Group suggested that persons living in the SRS vicinity would probably have had pets such as hunting dogs (1). These pets may have brought radionuclides into a house from dust or dirt caught in their fur. However, the Phase III radiological assessment made no distinction between radionuclide concentrations indoors or outdoors, in the air. Given that a generally accepted model for exposure to radionuclides from contaminated pets is not available, that many modeling assumptions were conservative, and that doses from this pathway were not expected to be large, dose estimates for this pathway were not included in this Phase of the dose reconstruction.

Nursing mothers. The rural family scenario as proposed by CDC called for a mother nursing at least one of the children (1). Separate exposures through this pathway were not modeled because a standard approach to simulate this pathway was not readily available. However, the Phase III radiological assessment did consider the consumption of contaminated foodstuffs by infants, including contaminated cow's milk, which should have simulated these exposures.

***In Utero* Exposures**. It was assumed that the Adult Female for the Urban/Suburban Family scenario always worked at home. The SRSHES Work Group had suggested that the mother of the urban/suburban family be assumed to work onsite until well into her pregnancy (1). It was recognized that the Work Group's proposed assumption was directed at assessing *in utero* exposure to an unborn child. However,

neither the modeling approach used nor the dose and risk coefficients that were used as principal components of the analysis address such exposures.[5]

3.3 Additional Assumptions About Scenarios

To perform the Phase III radiological assessments, it was necessary to add several additional assumptions to those provided by the CDC and the SRSHES to address specific features of the exposure scenarios. These assumptions are addressed in detail in Appendix E and summarized here:

3.3.1 Composition of Exposure Scenario Families

It was assumed that each of the seven hypothetical families had the same composition:

- A male who was an adult (over age 18) in 1954.
- A female who was an adult (over age 18) in 1954.
- A male child born in 1955.
- A male child born in 1964.

This family composition was chosen to model infant exposures during 1955 and 1964, when releases of radionuclides to the environment were relatively large. Male children were modeled because males receive slightly larger radiation exposures for some pathways than females (e.g., males eat more than females) and therefore provide more conservative estimates of doses and risks. It was desirable to make both children the same sex in order to allow direct comparison of the effect of being born at different times.

Figure 3-4 presents the age and gender of each receptor for each year of exposure. A 39-year period was modeled starting at the beginning of 1954 and finishing at the end of 1992. Information about the age and gender of each member of the scenario families was used to determine the ingestion rates of certain foods (Section 3.2.2), the times spent performing different activities (Section 3.2.3), and breathing rates. In addition, information about each individual's age and gender was used to convert exposure levels to lifetime radiation dose and cancer risk as discussed in Chapter 10 and Appendix D.

As the children grew from infants to adults, assumptions about parameter values were made that were appropriate for their age. Each child was assumed to grow from a male infant (his first year), to a preschooler (three years from age 2-4), to a grade-school aged child (seven years from age 5-11), to a teenager (six years from age 12-17) years), to an adult age (all remaining years from age 18 on). After each child reached age 18, parameter values appropriate for an adult were maintained for the rest of the study period. The Child Born in 1955 became an adult in 1973; the Child Born in 1964 became an adult in 1982.

3.3.2 Food Products

To address radiation exposures through consumption of food and animal products, quantities of each food product eaten by each receptor were estimated as well as the fraction of each food product that had been contaminated with radionuclides released by SRS. (See Appendix E for details.)

[5]The dose and risk coefficients that were used are up-to-date coefficients issued by the Environmental Protection Agency in their 1992 update to Federal Guidance Report 13, Cancer Risk Coefficients for Environmental Exposure to Radionuclides (4).

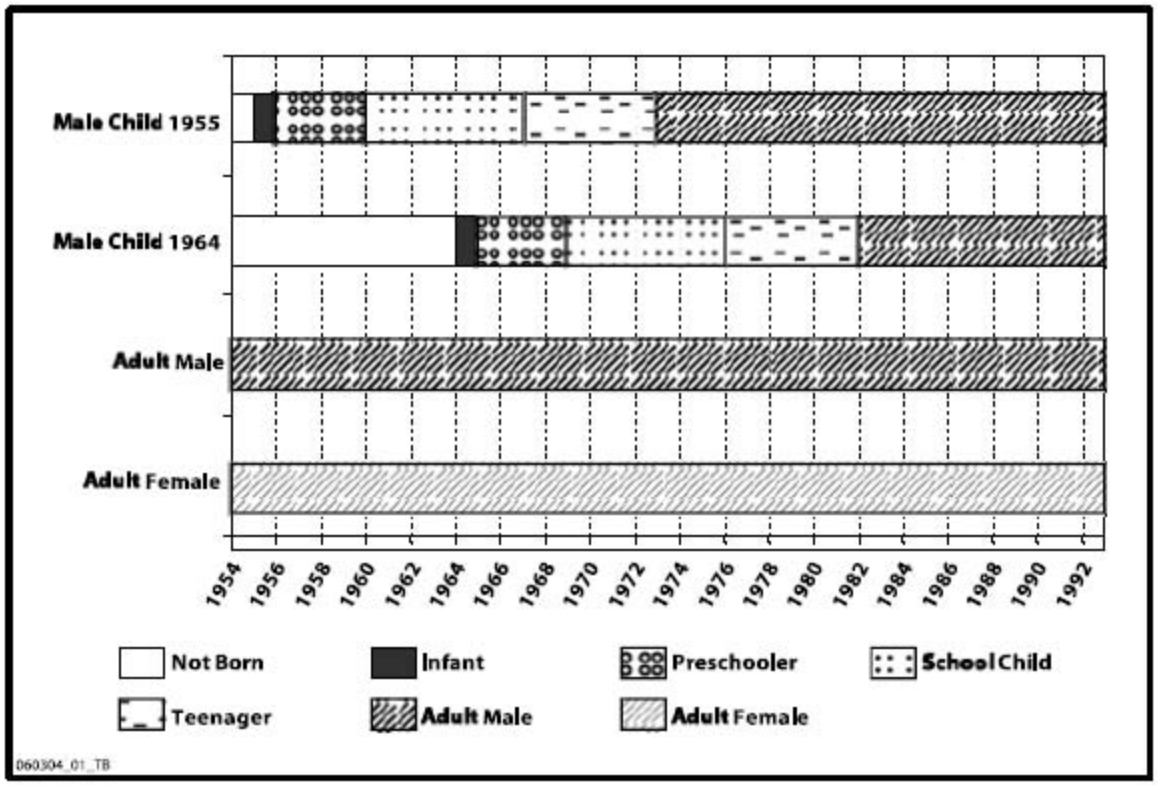

Figure 3-4 Age and Gender Categories of Modeled Receptors by Year

Assumptions were made for each family member about the consumption rates of the food products listed below. The primary data source for these assumptions was EPA's Exposure Factors Handbook (5):

- Leafy vegetables
- Root vegetables
- Fruit
- Grain
- Beef.
- Poultry
- Milk
- Eggs
- Fish

The quantity of each food product consumed annually depended on the age and gender of the receptor. Adults living in the SRS vicinity at the start of SRS operations in 1954 ate a constant annual quantity of each food product over the 39 years of the study. Adult females generally ate less food than did the adult males. The children ate different quantities of each food product depending on their age. When each child reached age 18, they thereafter ate each food product in annual quantities appropriate for an adult male.

Assumptions about food product contamination depended on the food product and scenario. If the food product was grown or produced locally (e.g., from local farms or dairies), then it was assumed that all was contaminated. If the food product was from a local store, then it was assumed that some (generally half) was obtained locally (and therefore contaminated) and the remainder was obtained from sources external to the SRS vicinity.

For beef, poultry, fruit, and vegetables, a time-dependent, locally-produced fraction was assumed for Rural Families One and Two consistent with the SRSHES Work Group recommendations for meat and vegetables (see Table 3-1). The fraction that was eaten that originated from the farm was reduced after the end of 1959. For other scenarios it was assumed that half of the beef, poultry, fruit, and vegetables from stores were produced locally.

Radiation exposure from eating game animals taken near the SRS site was modeled by assuming that meat from all game animals could be represented as forms of beef (e.g., venison) or poultry (e.g. wild fowl). Members of Rural Family One and Two, the Delivery Person Family, and the Outdoors Person Family were assumed to eat game animal meat. The total quantities of beef and poultry that these members ate were the same as that eaten by comparable members of the other three scenarios. However, larger fractions of this meat were assumed to be locally produced for these four scenarios compared to the other three scenarios.

3.3.3 Times Spent Per Activity

Each member of each scenario was assigned a home area, a work area for the Adult Male (and for the children after they became adults), food procurement areas, and areas for activities including church, school, work, hunting, fishing, swimming, and boating. Times spent in each area not derived from the suggestions of the SRSHES Work Group (1) were mainly determined using EPA's Exposure Factors Handbook (5) and an SRS report on land and water use characteristics in the vicinity of the Savannah River (6). Times spent performing each activity were used in assessing radiation exposures through several exposure pathways (e.g., the radiation dose received at an exposure location from immersion in a plume of contaminated air depended on the time spent at that exposure location). Assessments of radiation exposure from contaminated soil depended on the time spent either indoors or outdoors.

Home. The time spent at home depended on assumptions for each member of each scenario about work, church, school, and recreation. The times spent by each family member either indoors or outdoors were assumed based on data from EPA's Exposure Factors Handbook (5). Different times indoors and outdoors were assumed based on whether the family member was an adult male, an adult female, or a child within a particular age group.

Food Procurement. It was generally assumed that food for family members was obtained locally to their residences. As noted above, some food was obtained from stores and some was locally grown. However, half the milk for the Urban/Suburban Family scenario was obtained from an exposure location away from their residence, and half of all food products (other than fish) for the Delivery Person Family scenario was obtained from an exposure location away from their residence. For these situations, the difference in external or inhalation exposures that may have occurred during the limited time spent in these locations obtaining food was not assessed. However, the assessment did consider the location where the food was grown.

Church. All members of each scenario spent 104 hours per year (52 weeks/year x 2 hours/week) at church. All church hours were assumed to be part of the time all receptors spent indoors.

School. Children and teenagers attending school each spent 1,260 hours per year in school. Of these 1,260 hours, 900 hours were spent indoors and 360 hours were spent outdoors (5 hours indoors/day, 2 hours outdoors/day x 180 days/year). It was assumed that no food was obtained or was grown in the school locations.

Hunting/Fishing. For most scenarios, it was assumed that when the Adult Male was hunting (Rural Families One and Two, and Delivery Person Family), the amount of time spent hunting was included in

the residential outside hours. The Outdoors Person hunted as part of work, and all hunting hours were spent outside.

Swimming, Shoreline, and Boating. Most members of most scenarios were assumed to swim for 21 hours each year and spend 85 hours each year along a river or creek shoreline based on data from the SRS report on land and water use characteristics in the vicinity of the Savannah River (6). But members of the Near River Family spent 91 hours per year swimming (an hour per day during the summer for each member) as well as 365 hours per year along the Savannah River shoreline. These assumptions were based on the statement by the SRSHES Work Group to "assume they were always in contact with the Savannah River" (1). All hours were spent outdoors. The Adult Male of the Outdoors Person Family annually spent 260 additional hours on the Savannah River shoreline as part of work.

Consistent with the recommendations of the SRSHES Work Group (1), members of Rural Families One and Two and the Migrant Family did not go boating. Members of the Urban/Suburban, Delivery Person, and Outdoors Person Families boated in the Savannah River for 96 hours per year based on data from the SRS report (6). Members of the Near River Family boated in the Savannah River vicinity for 192 hours per year – i.e., twice the value in the SRS report (6). These assumptions were based on the statement by the SRSHES Work Group to "assume they were always in contact with the Savannah River" (1).

3.4 Overview of Final Exposure Scenarios

The seven scenarios and the assumed home locations for each of the hypothetical families making up these scenarios are described in detail in the following sections:

Section 3.3.1: Rural Family One in Girard, Georgia.

Section 3.3.2: Rural Family Two in Williston, South Carolina.

Section 3.3.3: Urban/Suburban Family in Augusta, Georgia.

Section 3.3.4: Migrant Worker Family in New Ellenton, South Carolina.

Section 3.3.5: Delivery Person Family in Barnwell, South Carolina.

Section 3.3.6: Outdoors Person Family in Jackson, South Carolina.

Section 3.3.7: Near River Family in Martin, South Carolina.

3.4.1 Rural Family One

This hypothetical family lived in Girard, Georgia. All family members spent much of their work, home activities, and recreation time outdoors. The Adult Male was a farmer, and the Adult Female worked at home. The family hunted, fished, and swam in the Girard area and in the nearby area of Briar Creek. The family did no boating. The children stayed at home until they reached school age; then they attended grade schools in Girard and high school in Waynesboro, Georgia. When not attending school, the children remained in the Girard area. When the children grew to adulthood, they became farmers and fished, hunted, and engaged in recreational activities in the Girard area. All family members remained permanently in the Girard area. Figure 3-5 shows the exposure locations of Rural Family One.

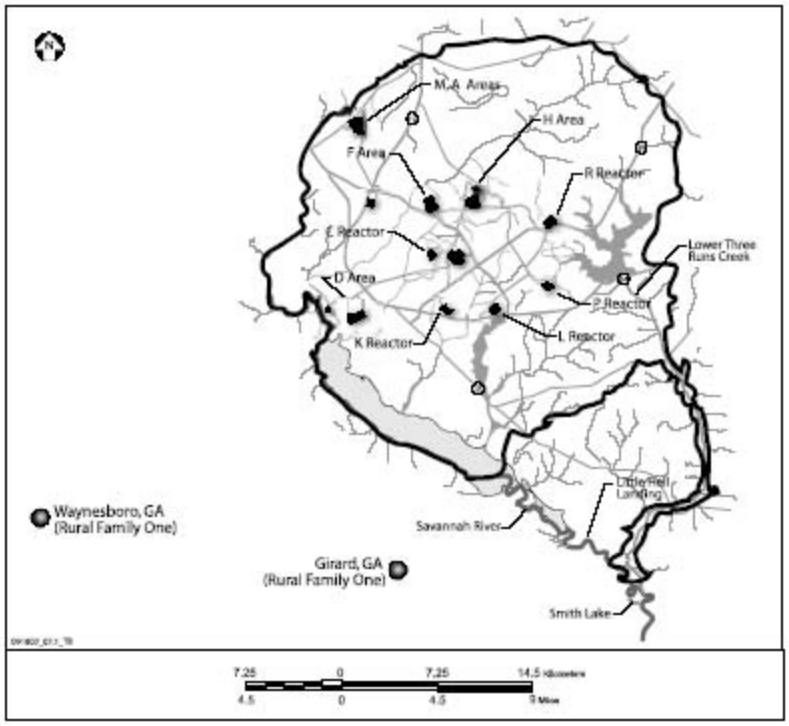

Figure 3-5 Exposure Locations of Rural Family One

All the family's milk and eggs came from cows and hens located in Girard. The fish eaten by the family was caught in Briar Creek or other nearby locations. Because Briar Creek is not located hydrologically downstream from SRS, none of the fish consumed by the family was affected by SRS release of radionuclides to surface water. During the 1950s, half of the beef, poultry, leafy and root vegetables, and fruit eaten by the family was grown or produced on the family farm. The remainder came from other sources such as stores in Girard. Half of this remaining food was locally grown or produced. Beginning in 1960, only 25% of their beef, poultry, vegetables, and fruit was grown or produced on the family farm. The remaining 75% came from sources such as stores. Half of this remaining food was grown or produced in Girard, and half came from sources outside the SRS. It was assumed that all of the locally-grown grain eaten by the family was corn.[6] Drinking water and water used to irrigate the food grown and eaten by the family came from local ground water or surface water sources that were assumed to be unaffected by SRS releases.

[6] This assumption was made for all receptors and scenarios. As discussed in Appendix E, individuals in the SRS vicinity would have consumed grain products such as breads, pasta, or flours; however, most of these grain products were likely grown or produced out of the SRS vicinity and therefore were not contaminated by SRS operations. But it is plausible to assume that individuals in the SRS vicinity consume locally grown corn. Such consumption could occur for those persons living in a suburban as well as a rural environment. Although corn may have been consumed as a vegetable, uptake of radionuclides by corn is appropriately modeled as grain uptake.

3.4.2 Rural Family Two

Rural Family Two was a hypothetical family substantially similar to Rural Family One, except that the family lived and spent all their time in Williston, South Carolina. Figure 3-6 shows the exposure location of Rural Family Two.

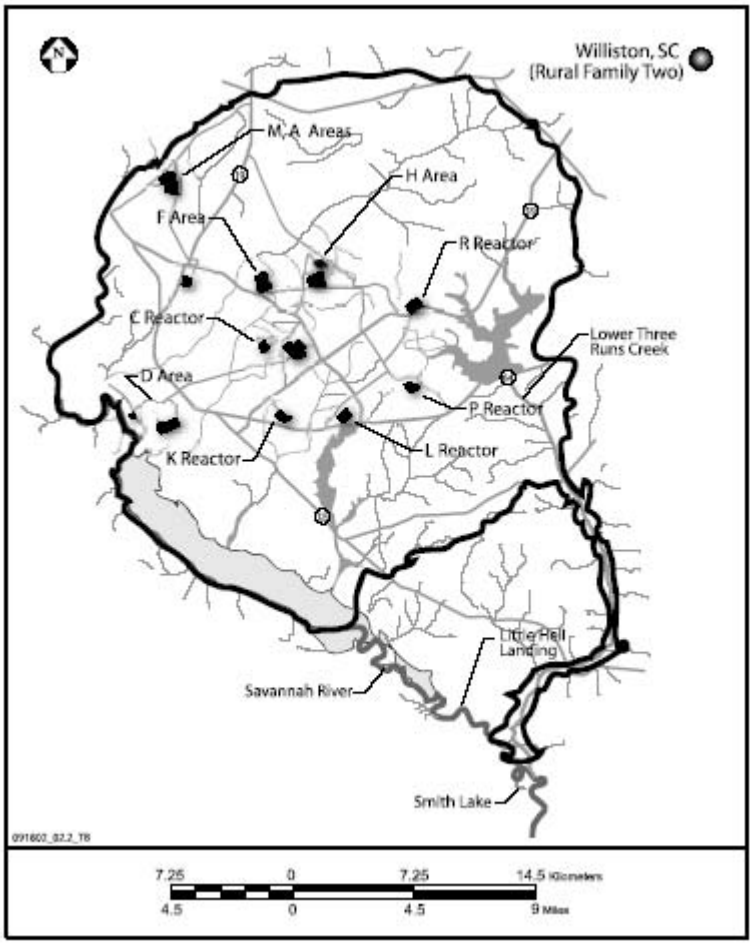

Figure 3-6 Exposure Location of Rural Family Two

All family members spent much of their work, home activities, and recreation time outdoors. The adult male was a farmer, and the adult female worked at home. The family hunted, fished, and swam in the Williston area. Like Rural Family One, this family did no boating. The children stayed at home until they reached school age, and then they attended schools in Williston. When not attending school, the children remained in the Williston area. When the children grew to adulthood, they became farmers. The family always lived, engaged in recreational activities, and worked in and around the Williston area.

All of the family's milk and eggs came from cows and hens located in Williston (on the family farm or nearby). All of the fish eaten by the family was caught in streams or ponds in or near Williston. Because these streams and ponds are not hydrologically downstream from SRS, none of the fish eaten by the family was affected by SRS releases of radioactive material to surface water.

During the 1950s, half of the beef, poultry, leafy and root vegetables, and fruit eaten by the family was grown or produced on the family farm. The remaining half came from other sources such as stores in Williston. Half of this remaining food (i.e., food not grown or raised on the family farm) was grown or produced in Williston and the other half came from outside the SRS area. Beginning in 1960, only 25% of their beef, poultry, vegetables, and fruit was grown or produced on the family farm. The remaining 75% was obtained from other sources such as stores in Williston. Half of this remaining food was locally-grown or produced, and half came from outside the SRS area.

All locally-grown grain eaten by the family was corn. Drinking water and water used to irrigate any food grown and eaten by the family came from ground- or surface-water sources assumed to be unaffected by SRS releases

3.4.3 Urban/Suburban Family

This hypothetical family lived in Augusta, Georgia, and all family members were present there for most activities including school and church. The Adult Male worked onsite at SRS for the duration of the study period (39 years). The children worked onsite at SRS beginning in 1973 for the Child Born in 1955 and 1982 for the Child Born in 1964. All family members swam, boated, and fished in the Savannah River flowing through the Augusta area, a location well upstream of any point of radionuclude discharge to surface water from SRS. Figure 3-7 shows the exposure locations of the Urban/Suburban Family.

Half the family's milk came from cows in the Augusta area and half from cows in the New Ellenton area. All eggs came from hens located in the Augusta area. Half of their beef, poultry, leafy vegetables, root vegetables, and fruit was grown or produced in the Augusta area, and half came from unaffected non-local sources. All locally-grown grain eaten by the family was corn. Fish came from sources unaffected by liquid releases from SRS (e.g., from the nearby Savannah River). Drinking water and water used to irrigate any food grown and eaten by the family came from ground- or surface-water sources assumed to be unaffected by SRS releases

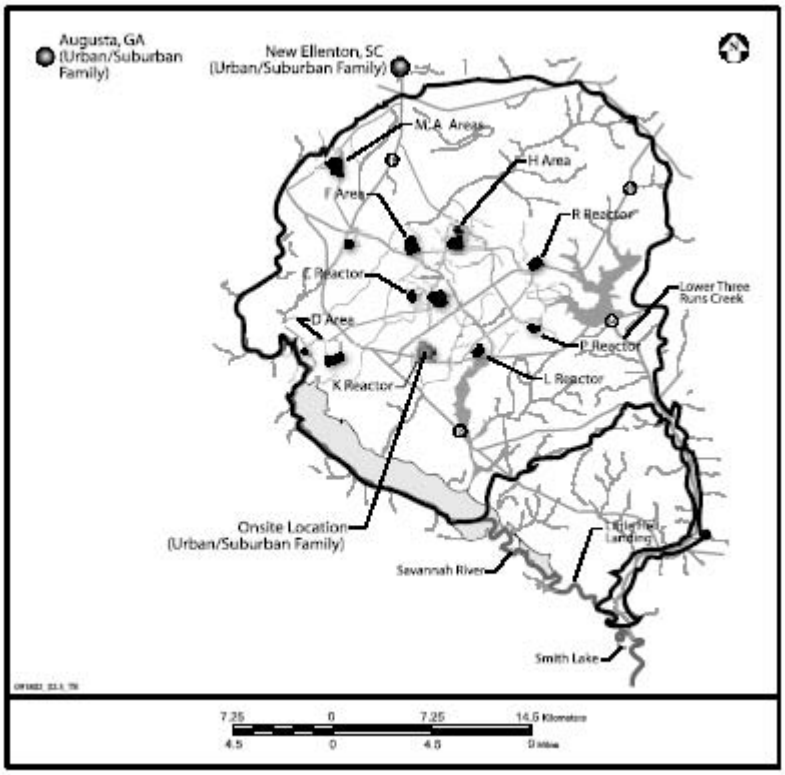

Figure 3-7 Exposure Locations of Urban/Suburban Family

3.4.4 Migrant Worker Family

All family members spent much of their work, home activities, and recreation time outdoors in New Ellenton, S.C. Figure 3-8 shows the exposure location of the Migrant Worker Family. Because the Adult Male and Adult Female worked as migrant farm workers, the family lived in New Ellenton for only half of any year. While living in New Ellenton, the family participated in hunting, trapping, and other outdoor activities. The family did no boating but did participate in other water sports such as fishing and swimming in local pools, ponds, and creeks. The children stayed at home until they reached school age and attended schools in New Ellenton. When the children grew to adulthood, they became migrant farmers spending half the year in New Ellenton and half the year away from the SRS vicinity.

During the six months of each year that the family lived in New Ellenton, all of their milk and eggs were produced or collected in or near New Ellenton. Half of the family's beef, poultry, leafy vegetables, root vegetables, and fruit was grown or produced in the New Ellenton area and half came from sources outside the SRS vicinity. All of their corn was grown in the New Ellenton area. Because ponds and creeks in the vicinity of New Ellenton are not hydrologically downstream from SRS, none of the fish eaten by the family was affected by SRS liquid releases. Drinking water and water used to irrigate foods eaten by the family came from ground water or surface water sources unaffected by SRS liquid releases.

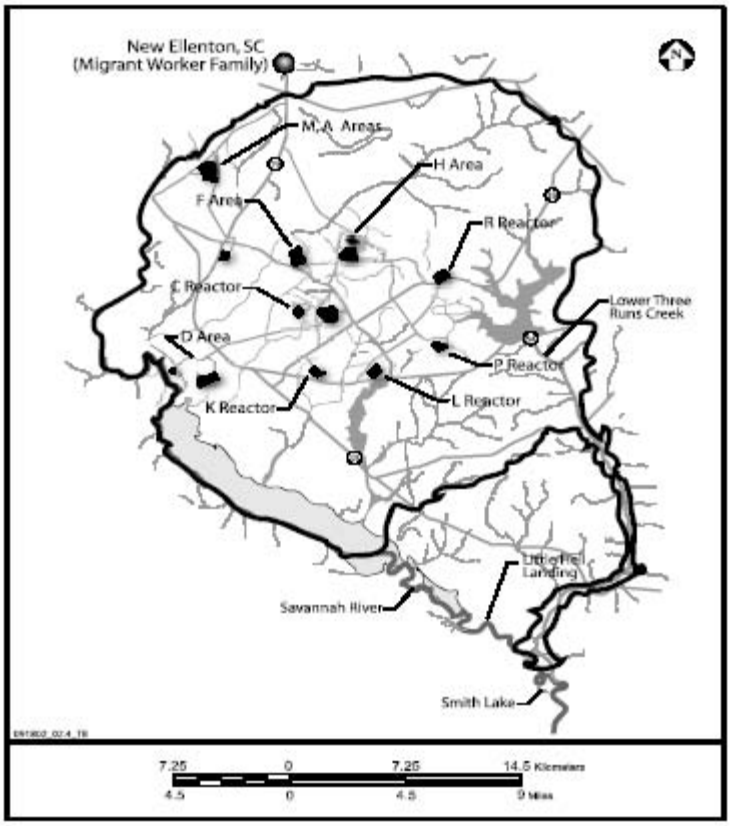

Figure 3-8 Exposure Location of Migrant Worker Family

3.4.5 Delivery Person Family

This hypothetical family lived in Barnwell, South Carolina, where the children attended grade and high school. Because the Adult Male worked as a delivery driver for a bottling plant located in Allendale, South Carolina, he spent portions of his time in Allendale and portions onsite at SRS, where he made periodic deliveries. (When the children reached 18, they lived in Barnwell and became delivery drivers like the Adult Male.) All family members attended religious services in Martin, South Carolina, for two hours each week. All family members swam, fished, and spent time along the shoreline at Lower Three Runs Creek near Martin. The adult male hunted for deer and fowl in the Martin vicinity. Figure 3-9 shows the exposure locations of the Delivery Person Family.

The family boated on the Savannah River using the boat ramp at Little Hell Landing, which is upstream of the confluence of the Savannah River with Lower Three Runs Creek. The family then moved the boat to the Smith Lake area for fishing and activities along the Savannah River shoreline. Smith Lake is located just below the confluence of the Savannah River with Lower Three Runs Creek. The family did not swim in the Savannah River.

Half of the family's milk and eggs came from cows and hens in the Barnwell area and half came from cows and hens in the Martin area. In addition, half the family's beef and poultry came from Barnwell and half from Martin. Half of the beef and poultry from Barnwell was actually produced in the Barnwell area, and half was acquired from sources away from the SRS area. Of the beef and poultry from Martin, 25% consisted of meat from hunting deer and wild fowl. That is, 25% of the beef from Martin consisted of locally-hunted venison while 25% of the poultry from Martin consisted of locally-hunted wild fowl. Of the remaining 75% of the beef and poultry from Martin, half was produced in the Martin area and half was acquired (e.g., by stores) from sources well away from the SRS.[7]

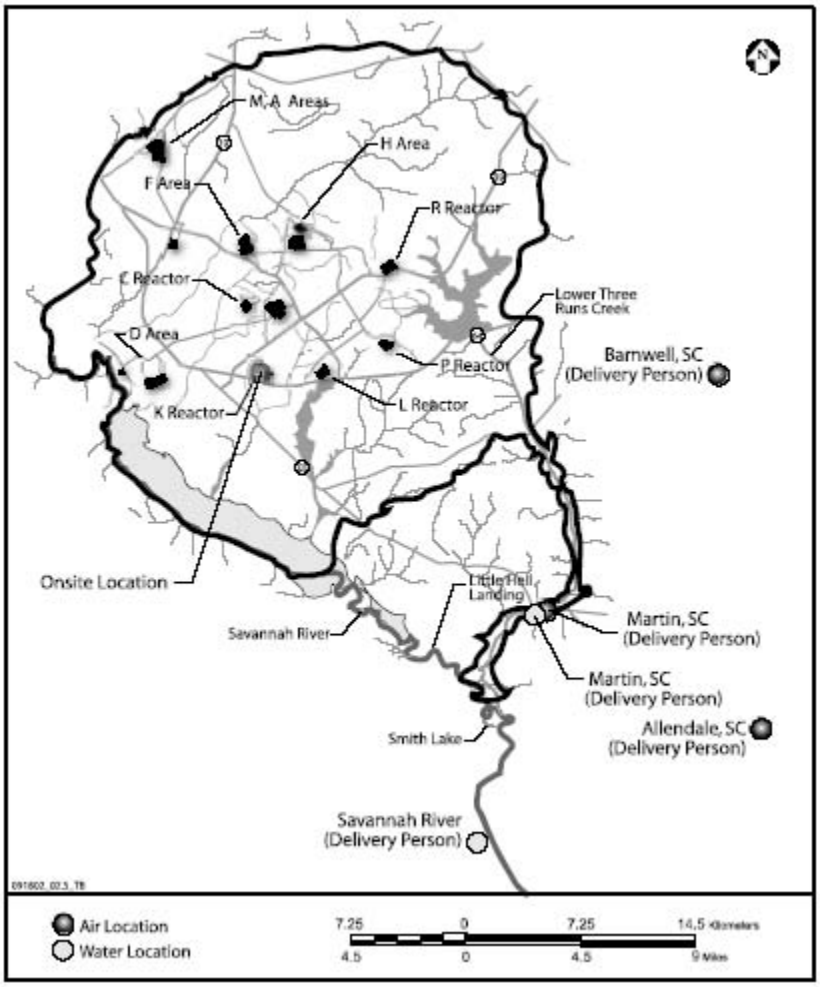

Figure 3-9 Exposure Locations of Delivery Person Family

Half the leafy vegetables, root vegetables, and fruit came from Barnwell, and half came from Martin. Half of the produce obtained in the Barnwell area was grown in areas away from the SRS vicinity and half of the produce obtained in the Martin area was grown in areas away from the SRS vicinity. Half of the corn eaten by the family was grown in Barnwell and half in Martin.

Half of the fish eaten by the family was caught in Lower Three Runs Creek at Martin and half was caught in the Savannah River.

[7] Combining the venison and wild fowl obtained from hunting with other beef and poultry obtained in Martin, it was assumed that 62.5% of all beef (including venison) obtained from Martin potentially contained radionuclides from the SRS, as did 62.5% of all poultry (including wild fowl) eaten by the family.

3.4.6 Outdoors Person Family

This hypothetical family lived in Jackson, South Carolina, and all family members were present there for most activities including school and religious services. When the children grew to adulthood, they continued to live in Jackson. Family members were not present in Jackson during employment activities for the Adult Male nor during employment activities for the children after they each reached age 18. The Adult Male worked onsite at SRS as a hunter, as did the children when they grew up. During the time the Adult Male spent onsite at SRS annually, he took game animals in the form of deer and birds, and caught fish from the Savannah River. His job required him to spend 260 hours per year along on the Savannah River shoreline as well as 260 hours per the year boating on the Savannah River. Figure 3-10 shows the exposure locations of the Outdoors Person Family.

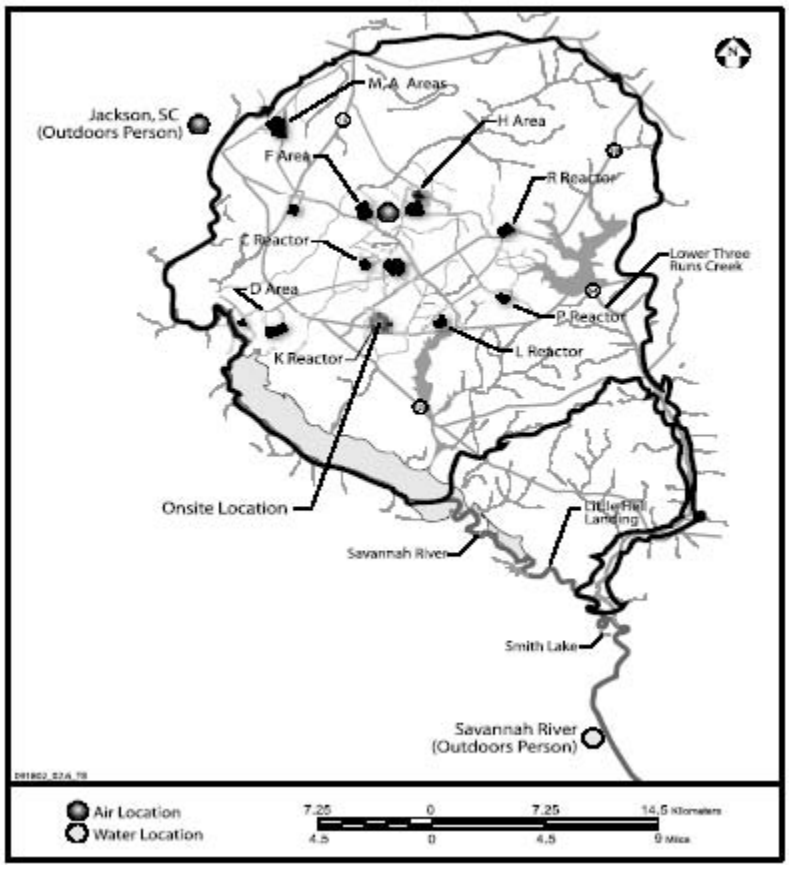

Figure 3-10 Exposure Locations of Outdoors Person Family

All family members (including the Adult Male) engaged in recreational swimming in the Savannah River and spent time along the Savannah River shoreline near the Jackson boat ramp (upstream of sources of SRS radionuclide release to the Savannah River). All family members boated in the Savannah River downstream of SRS.[8]

All milk and eggs came from cows and hens located in Jackson. Half the leafy and root vegetables and fruit were grown in Jackson, and half came from sources away from the SRA area. All of the family corn was grown in Jackson.

Three-quarters of the family's beef and poultry consisted of venison and wild fowl that was hunted by the Adult Male on the SRS site. Their remaining beef and poultry came from other sources such as stores. Of

[8] After putting the boat in the water at the Jackson boat ramp, the family moved the boat to an area downstream of the confluence of the Savannah River with Lower Three Runs Creek. Therefore, the Adult Male received radiation exposures while recreationally boating as well as while working at the SRS.

this, half was produced in Jackson and half came from sources away from the SRS area. All fish taken from the Savannah River contained radionuclides from SRS operations.

3.4.7 Near River Family

This hypothetical family lived in Martin, SC. All members spent much of their work, home activities, and recreation time outdoors. The family lived, worked, and went to school and church in Martin, and participated in outdoor activities such as hunting, fishing, and boating. Figure 3-11 shows the exposure location of the Near River Family.

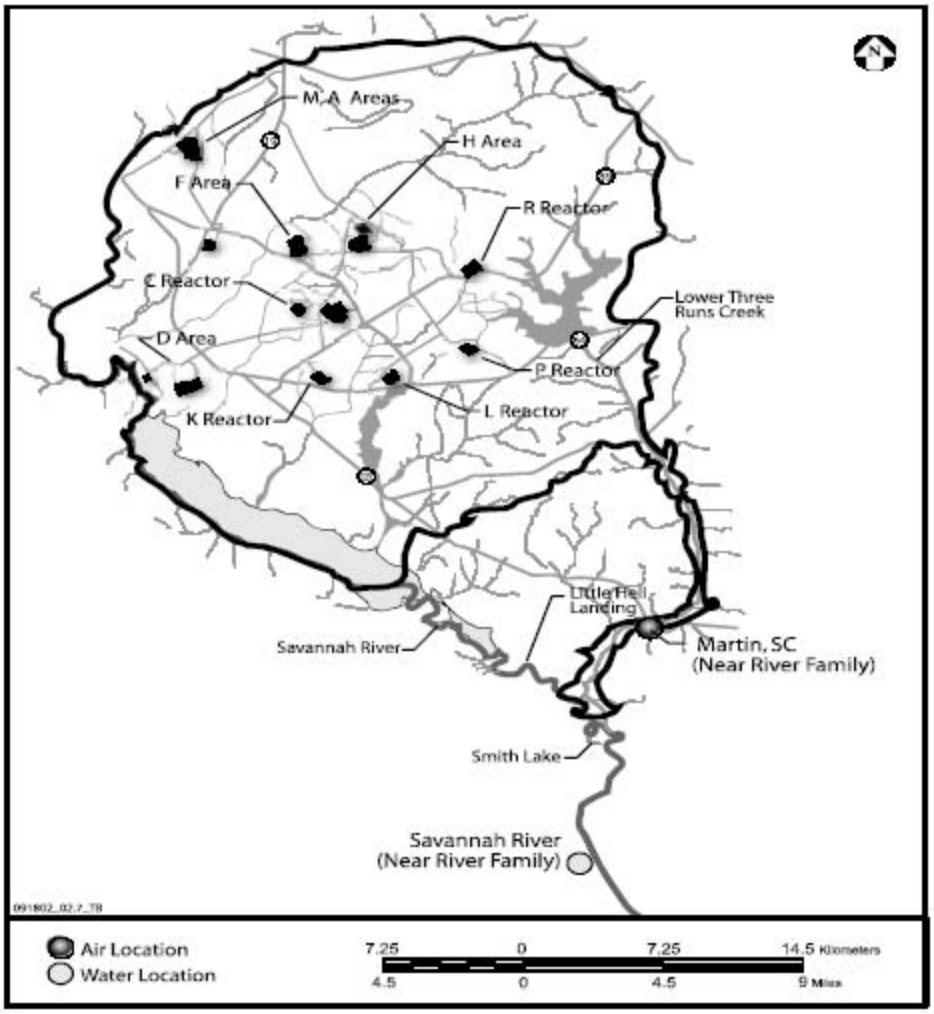

Figure 3-11 Exposure Locations for Near River Family

This family spent twice as much time boating (in the Savannah River) as did other families. Each family member spent an average of an hour per day of each year on the Savannah River shoreline, and an average of an hour a day swimming during the summer in the Savannah River. When the children grew up, they continued to live in Martin. The family's milk and eggs all came from cows and hens located in Martin. Half of the family's beef, poultry, leafy vegetables, root vegetables, and fruit was grown or produced in Martin and half came from sources outside the SRS vicinity. All of the corn eaten by the

family was grown in Martin. All of the fish eaten by the family was caught in the Savannah River below its confluence with Lower Three Runs Creek. Drinking water and any irrigation used to produce the food eaten by the family came from sources assumed to be unaffected by SRS releases.

3.5 References

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