4 ENVIRONMENTAL CONSEQUENCES

Potential environmental impacts associated with the resumption of L-Reactor operations arise both from normal operations and from potential accidents at the reactor (Section 4.1). The production of fuel and target assemblies by existing SRP facilities and the chemical extraction of products from irradiated assemblies will add incrementally to the potential effects of L-Reactor operations; these effects are described in Section 4.2. Section 4.2 also describes the effects from the transportation of material to and from the Savannah River Plant. Section 4.3 summarizes the dose commitments from L-Reactor and its support facilities; Section 4.4 describes the cumulative impacts from other SRP facilities and from major facilities near the Savannah River Plant. Environmental studies and monitoring programs for the proposed action are described in Section 4.5. Section 4.6 discusses the no-action alternative.

4.1 L-REACTOR OPERATION

This section characterizes the nonradiological and radiological effects of L-Reactor operation. Nonradiological effects include those that might result from an increased workforce, the withdrawal and discharge of cooling water, the discharge of liquid and atmospheric effluents, and the disposal of solid wastes. Radiological effects might include those that result from airborne and liquid releases, the disposal of low-level radioactive wastes, and the potential resuspension and transport of radiocesium in Steel Creek. Table 4-1 summarizes potential environmental impacts due to L-Reactor operations.

4.1.1 Nonradiological impacts

4.1.1.1 Land use and socioeconomics

Land use

The resumption of L-Reactor operations will not require the acquisition or the use of land off the SRP site; therefore, no direct land-use impacts are expected. Potential indirect land-use impacts in the region might be caused by the relocation of operational employees moving into the area. The small size of this operational labor force compared to the indigenous labor force of the region indicates that these indirect impacts will be inconsequential.

Four potentially significant historic sites in terms of the National Register of Historic Places criteria and one prehistoric site eligible for nomination to the National Register have been identified in the Steel Creek terrace and floodplain system. No direct impacts are expected to these sites because they were not adversely affected by high-water flow conditions during past L-Reactor operations (du Pont, 1982). A monitoring plan will be implemented to ensure the preservation of these resources.

Socioeconomics

Operational employment for L-Reactor, which began in 1981, is expected to peak at about 400 employees in mid-1983 and then decrease to 350 by mid-1984, or about 4.5 percent of the current workforce at the Savannah River Plant (du Pont, 1982).

At present, about one-half of the total operating workforce for L-Reactor has been hired and resides in the SRP area. The employees yet to be hired are assumed to relocate in the six-county area surrounding the Savannah River Plant in a pattern similar to that exhibited by present workers. Table 4-2 summarizes selected demographic characteristics of the projected relocating employees.

The total population associated with the projected relocating employees is not expected to affect the population growth trends of the six-county area. The relocating employees and their families are expected to account for less than 2 percent of the population growth of the area between 1980 and 1984. Similarly, the number of school-age children associated with the relocating employees is expected to be small in comparison to the increase in indigenous school children.

The number of relocating operational employees is not anticipated to have a major effect on housing except in areas where existing population growth might cause a shortage. The existing capabilities of other public services, such as police and fire protection, potable water systems, and wastewater treatment, will not be affected by the small demands caused by L-Reactor restart.

L-Reactor operations in fiscal year 1986 are expected to have total local expenditures on materials and services of approximately 3 million dollars, and a total payroll and overhead expenditure of about 21 million dollars. These expenditures are expected to result in the creation of about 50 regional job opportunities. In addition, these expected expenditures are anticipated to produce an additional direct and indirect income of another 3 million dollars. The total economic benefit to the SRP region during L-Reactor operation will amount to 400 direct and indirect job opportunities, about 25 million dollars in direct and indirect annual income and payroll, and 3 million dollars in direct annual expenditures on materials and services.

These contributions to the economy of the SRP area will, in part, pay for local and state government services directly through income, property, and license taxes and user fees, and indirectly through sales taxes on goods and services. These economic benefits to government jurisdictions should offset the increased services that might be required by the small number of potential relocating operational employees.

4.1.1.2 Surface-water usage

The L-Reactor will use a once-through cooling-water system similar to that used during its previous operations. The L-Reactor cooling-water system withdraws water from the Savannah River. This withdrawal of 11 cubic meters per second of river water for cooling purposes might affect the aquatic ecology of the river from (1) the impingement of aquatic organisms (primarily fish) on the intake screens and (2) the entrainment in the cooling water of aquatic organisms (predominantly fish eggs and larvae) smaller than the screen mesh in the intake systems. The proposed operation of L-Reactor will withdraw about 7 percent of the 7-day, 10-year low flow of the Savannah River, or about 4 percent of the average flow of the river.

During studies conducted on the Savannah River and at the Savannah River Plant from March 1977 to February 1978, an average of about 11 fish were impinged per day (McFarlane et al., 1978a; du Pont, 1982). The species most commonly impinged were channel catfish, warmouth, threadfin shad, and yellow perch (McFarlane et al., 1978b). In general, more fish were impinged during periods of higher river water flow and cooler water temperatures. With the resumption of L-Reactor operations, the pumpage of cooling water, based on the 1977-1978 study, might result in the impingement of about 5 more fish per day.

The most commonly entrained fish eggs were those of the American shad, which comprised about 96 percent of all fish eggs collected during the spring of 1977 (McFarlane et al., 1978a). Based on the volume of cooling water withdrawn during the 1977 spawning season and on the estimated density of shad eggs in the river (McFarlane et al., 1978b), an increase in the pumping of cooling water for L-Reactor could result in the entrainment of 3.2 million additional eggs, or less than 5 percent of those passing the Savannah River Plant. If similar spawning conditions were to occur at lower flows, ranging from 127 to 166 cubic meters per second (7-day, 10-year low flow), between 9.8 and 16.2 million eggs would be lost, or 13 to 22 percent of the shad eggs passing the Savannah River Plant would be entrained. L-Reactor cooling-water withdrawal could result in a projected maximum loss of adult shad of about 60 kilograms. In 1979, the commercial landing of shad from the Savannah River amounted to about 57,600 kilograms (du Pont, 1982).

The Savannah River floodplain serves as a spawning area; significant numbers of larvae from the floodplain enter the river. During April and May of 1977, an estimated 75 million fish larvae were transported to the river along a 6.6-kilometer reach adjacent to the Savannah River Plant. The most commonly entrained fish larvae during the 1977 study were blueback herring, Dorosoma sp., and other unidentified clupeids. Under conditions similar to those of the 1977 survey, an increase in cooling-water withdrawal for L-Reactor could result in 9 million larvae entrained or about 4 percent of the estimated 216 million larvae in the river near the SRP pumphouses (McFarlane et al., 1978a).

4.1.1.3 Liquid effluents

The L-Reactor cooling-water system will discharge thermal effluent to the Savannah River via the Steel Creek system. In addition, the L-Reactor area will discharge wastewater to Steel Creek. This section describes the potential effects of these discharges.

Thermal discharge to Steel Creek and Steel Creek delta

The cooling-water effluent from L-Reactor will be discharged directly into Steel Creek at temperatures about 79°C and at a flow rate of about 11 cubic meters per second. Modeling of L-Reactor thermal discharges (Figure 4-1) indicates that the cooling-water effluent will enter the swamp at temperatures between 40°C (spring) and 44°C (summer). The following table compares typical spring effluent temperatures at several locations in Steel Creek to summer temperatures that could occur under the most severe 5-day meteorological conditions observed from 1976 to 1980 (August 6-10, 1980):

Location	Typical spring temperature (°C)	Most severe 5-day summer temperature (°C)
L-Reactor outfall[a]	70	79
Road A-14	54	67
Road A	51	56
Road A-17	44	48
Swamp at delta	40	44
Mouth of creek at Savannah River	29	32

a. L-Reactor outfall temperatures depend on reactor power, cooling-water flow rate, and ambient cooling-water makeup temperature.

When L-Reactor is operating, Steel Creek above the swamp will be subjected to temperatures above 40°C or at least 20°C above ambient creek temperatures. Most biota found in Steel Creek will not survive temperatures above 40°C.

Wetland impacts. The Savannah River Plant contains approximately 31,400 acres of bottomland wetlands and about 7800 acres of swamp adjacent to the Savannah River. Approximately 2800 acres of the Savannah River swamp have not been impacted by thermal discharges from operating reactors. The resumption of L-Reactor operations potentially will affect about 1000 acres of wetlands, or about 3 percent of the SRP wetlands habitat; these wetlands were impacted during L-Reactor operation before 1968. Of this 1000 acres, approximately 420 acres of swamp and 580 acres of the Steel Creek corridor will receive adverse impacts. No critical habitats of endangered or threatened species, as designated by the U.S. Fish and Wildlife Service, occur on the Savannah River Plant.

The Steel Creek corridor has been undergoing a post-thermal recovery since L-Reactor was placed on standby in February 1968. When L-Reactor is restarted, its cooling-water discharge (about 11 cubic meters per second) is expected to have similar effects to those that occurred from 1954 to 1958 and from 1963 to 1968. Aquatic macrophytes and woody plants will be lost. Only procaryotic organisms such as thermophilic bacteria are expected to inhabit waters with temperatures greater than 40°C. Species that inhabit cooler backwater pools or other suitable substrates might experience a reduction in productivity.

Emergent wetland flora and submergent hydrophytes, which have revegetated the Steel Creek delta since 1968, will be eliminated and their substrates will revert to mudflats after resumption of operations. Some herbaceous flora will become established on exposed floodplain sediments and elevated stumps and logs of fallen trees. Almost all the scrub-shrub and willow-dominated communities also are anticipated to be eliminated. Because the water temperature at the confluence of Steel Creek and the Savannah River is estimated to be typical of southeastern warm-water streams, no significant impact to riverine vegetation is expected.

Flooding and siltation associated with the thermal discharge is expected to modify aquatic habitat in the Steel Creek floodplain and delta. The delta is expected to expand into the swamp at a rate of about 3 acres per year. Wetland habitat is expected to be eliminated or modified at a rate of about 7 to 10 acres per year due to thermal discharge and its associated flooding, siltation (Smith et al., 1981), and fluctuating water levels.

Except for backwater pools or other cool-water refuges, the high water temperatures from the outfall to the delta will make this section of Steel Creek uninhabitable for amphibian eggs and larvae. Adult life forms might survive along the stream margins, or relocate to adjacent habitats.

Reptiles are more dependent on aquatic habitat for food (i.e., insects, fish, amphibians) and shelter than for reproduction. The elevated water temperature and the elimination of prey organisms will eliminate the habitats of semiaquatic snakes and turtles upstream from the delta, and will cause a marked decrease in species richness. Portions of the delta might provide marginal habitat for water snakes and turtles following L-Reactor restart.

The endangered American alligator inhabits all parts of Steel Creek from the L-Reactor outfall to the cypress-tupelo forest adjacent to the Steel Creek delta; it also uses areas lateral to Steel Creek, including Carolina bays, backwater lagoons, and beaver ponds. The number of alligators inhabiting the Steel Creek ecosystem is not known precisely, but about 25 individuals have been observed. The release of cooling water from L-Reactor will eliminate alligator habitat in Steel Creek from the reactor outfall to the Savannah River, except for backwater pools or other cool-water refuges, by increasing the water temperature above physiologically tolerable limits, eliminating its principal food sources, and possibly inundating its nests and shallow-water wintering habitats (Smith et al., 1981, 1982).

Adult alligators should be able to avoid heated areas and emigrate to nearby habitats. During winter, alligators might seek the warmer effluent waters until temperatures again rise above acceptable limits in late spring and summer. Juveniles also are expected to avoid thermal effluents, but these smaller alligators could have more difficulty relocating to suitable habitats and would be exposed to greater predation. A startup in late spring and summer could destroy both nests and eggs. Winter startup could be fatal to torpid individuals that overwinter along the shallow banks. The proposed resumption of L-Reactor operations in October is considered to occur within an optimal time period because it would not conflict with the alligators' nesting season.

Waterfowl and wading birds will be affected by the thermal discharge more than the other avifauna of the Steel Creek ecosystem. The use of Steel Creek above the delta by waterfowl is uncommon, but the delta and other areas above the Savannah River support hundreds of overwintering ducks, including mallard, wood duck, black duck, blue-winged and green-winged teal, and hooded merganser. Wading birds such as the heron, egret, and wood stork also will lose feeding and breeding habitat along Steel Creek and might move to similar habitats (Smith et al., 1981, 1982).

Semiaquatic mammals that will be affected by the thermal effluent include the beaver, river otter, mink, and muskrat. Adults should not experience mortality due to increased flow and temperature, but flooding during the breeding season could adversely affect the young. Except for the muskrat, these species are common throughout the Savannah River Plant.

A wetlands assessment is presented in Appendix B.

Aquatic impacts. The reintroduction of cooling-water effluent to Steel Creek will eliminate most of the biota of the main channel from the L-Reactor outfall downstream to the delta. Populations of thermotolerant and thermophilic algae, such as blue-greens, would be expected to increase (Gibbons and Sharitz, 1974). These organisms thrive in areas where species more sensitive to elevated temperatures cannot compete. Based on information from the thermal streams (Four Mile Creek and Pen Branch), few higher organisms will survive in the main stream channel of Steel Creek. As the effluent moves away from the L-Reactor outfall, the temperature will decline and more organisms will occur, beginning with the most thermally tolerant (du Pont, 1982).

During thermal discharge, Steel Creek will not be suitable for fish of recreational or commercial importance; fish presently in Steel Creek will be eliminated. In addition, the warmer waters of Steel Creek might prevent access to the floodplain swamp by fish from the river. Temperature tolerance data indicate that most, if not all, spawning activity could be eliminated by the thermal effluent; however, other similar spawning habitat is available in nonthermally affected areas on the Savannah River Plant and along the Savannah River. The most common fish remaining in the Steel Creek area probably will be the mosquitofish, although a few centrarchids might occur in backwater areas and tributary streams such as Meyers Branch (Cherry et al., 1976; Falke and Smith, 1974; Ferens and Murphy, 1974; McFarlane, 1976; McFarlane et al., 1978a).

Thermal discharge to the Savannah River

Thermal discharges to the Savannah River come from Beaver Dam Creek, Four Mile Creek, and Pen Branch via the mouth of Steel Creek in the Savannah River swamp. L-Reactor will contribute to an increase in the thermal discharge from Steel Creek and to an increase in the size of the thermal plume in the Savannah River. The following sections describe the thermal plume from the Steel Creek discharge, estimate the overall thermal impact on the Savannah River in relation to the thermal effluent criteria of the South Carolina National Pollutant Discharge Elimination System (NPDES; SCDHEC, 1981), and describe potential ecological effects.

Thermal plume. Since 1968, with K-Reactor discharging to Pen Branch, the temperature of the water released from the mouth of Steel Creek typically has been less than 5.6°C above the temperature of the water in the Savannah River during the spring and summer months. The temperature difference at the limit of the present mixing zone does not exceed 2.8°C.[1]

With the restart of L-Reactor, the monthly average temperature difference between Steel Creek and the Savannah River will nominally be about 8.8°C in the warmer months, with a maximum of 14°C. Historic data indicate that the thermal plume from Steel Creek remains essentially on the South Carolina side of the Savannah River until it becomes completely mixed with the river about 2.4 kilometers downstream from the mouth of the creek (du Pont, 1982).

Computer simulations were used to predict the temperatures in the Steel Creek thermal plume downriver from the mouth of Steel Creek for 2.4 kilometers. Figure 4-2 shows the results of modeling for a river flow of 175.5 cubic meters per second and thermal discharges of 15.6 (L-Reactor) and 27.4 (K- and L-Reactors) cubic meters per second, respectively. The upper curve in each figure relates to the temperature difference between the plume and the river along the 25-percent cross-sectional area boundary; the lower curve relates to the temperature difference along the 33-percent surface area boundary. The cross-sectional area is estimated to be the limiting criterion of the NPDES thermal effluent permit for the Steel Creek plume in the river (du Pont, 1982).

The temperature increase of the Savannah River will depend on several factors: the time of the year, flow rates of the river, and SRP operating conditions. The following table lists the projected increases in water temperature from L-Reactor during August as a function of flow with three reactors discharging to the river (extrapolated from data in du Pont, 1982):

Savannah River flow[a] (m^3/second)	L-Reactor contribution to mixed river temperature increase (°C)	Maximum allowable creek-river ΔT to meet SCDHEC thermal criteria (°C)
127.4[b]	0.73	7.0
166.0[c]	0.66	8.6
175.5	0.64	9.1
295.0[d]	0.41	15.7

a. Immediately upstream from the mouth of Steel Creek.
b. Minimum daily flow (1955-1976).
c. 7-day, 10-year low flow.
d. Average river flow.

[1]The South Carolina Department of Health and Environmental Control (SCDHEC) NPDES thermal effluent criteria for flow at or above the 7-day, 10-year low flow specify a maximum plume-to-river delta-T of 2.8°C at the mixing zone boundary, which can be no larger than 25 percent of the cross-sectional area of the river at any point downstream and 33 percent of the total surface area within any length increment downstream. The time interval over which temperature measurements are averaged for comparison with the criteria is not specified.

L-Reactor, even in the warmer months, is expected to comply with the NPDES thermal effluent criteria for river flows at or above the 7-day, 10-year low flow.

Ecological impacts. The restart of L-Reactor is expected to have a thermal impact on the Savannah River only near the mouth of Steel Creek. Downriver from the confluence of Steel Creek with the river, no adverse impacts are anticipated on reptiles, birds, or mammals that inhabit the river's riparian habitats.

The temperatures near the mouth of Steel Creek are expected to be high enough to exclude the creek and its floodplain as potential spawning areas for riverine and anadromous fish such as the blueback herring during the late spring and early summer spawning season. However, temperature measurements in the river (du Pont, 1982) and thermal modeling indicate that the thermal plume will remain close enough to the South Carolina shore to permit a zone of passage for migrating fish such as American shad, blueback herring, and striped bass (du Pont, 1982).

Studies were conducted by the Academy of Natural Sciences of Philadelphia (ANSP, 1953, 1957, 1961, 1967, 1970, 1977) to monitor the effects of SRP operations on the general health of the Savannah River. The Academy studies indicate that no major changes in the presence of species should occur from the addition of heat and cooling water from L-Reactor.

Wastewater discharges

Chemical discharges to Steel Creek. Liquid effluents from L-Reactor area will have chemical compositions that are similar to those from other SRP reactor areas; the sources of the chemicals and effluent flow rates at each outfall are listed in Table 4-3 (du Pont, 1982).

A portion of the chemicals discharged through these outfalls to Steel Creek originates from the Savannah River water pumped to the reactor. Table 4-4 lists estimated L-Reactor area liquid effluent chemical loads and compares them with the corresponding water quality or drinking-water standard and with concentrations measured in Steel Creek and in the Savannah River above, at, and below the Savannah River Plant.

The concentrations of these chemicals will be relatively low. High flows of the cooling water will transport most chemicals from Steel Creek through the swamp to the Savannah River at concentrations close to those found in the river. Impacts on the swamp water quality are expected to be small, particularly during flooding by the Savannah River, which occurs about 23 percent of the time. The slow movement of water through the swamp is expected to allow flocculated suspended sediments to settle from the water and accumulate in the swamp.

Sanitary discharges. Sanitary wastewater from a packaged treatment plant will contain chlorine (NaOCl) and will be discharged through the L-Reactor area wastewater sewer to Steel Creek. The sanitary wastewater-treatment plant is designed for a maximum flow of 132 cubic meters per day. These discharges will meet NPDES permit requirements and will have no major impact on Steel Creek (du Pont, 1982). Sewage sludge will be placed in an existing basin near the Central Shops. Samples of sludge from similar treatment facilities indicate that it is not hazardous (du Pont, 1982).

Table 4-3. Sources of chemical discharges to Steel Creek from L-Reactor area[a]

Liquid effluent sources	Approximate flow rate (m^3/year)
Cooling water, process water, cooling reservoir, sanitary wastewater	2.2×10^8
Heating/cooling, offices	3.7×10^4
Water-treatment plant	9.0×10^5
Cooling water for engine building	1.1×10^6

a. du Pont, 1981a.

Cooling-water reservoir (186-Basin). The 95,000-cubic-meter cooling-water processing basin (186-Basin) is cleaned annually during periods of reactor shutdown to control the Asiatic clam. About 110 metric tons of the 5530 metric tons of suspended solids that will enter the 186-Basin are expected to be deposited annually in the basin. This is flushed to Steel Creek over a period of several days. During flushing, the suspended solids concentrations in the effluent will be about 60 to 160 parts per million. Most of the suspended solids released from the 186-Basin will settle in the streambed before reaching the swamp (Kiser, 1977; Geisy and Briese, 1978; du Pont, 1981a; Ruby et al., 1981). When L-Reactor discharges resume (about 11 cubic meters per second), the resuspension of some of this sediment and other creekbed sediment is expected to contribute to delta growth.

4.1.1.4 Atmospheric releases

Atmospheric releases from the operation of L-Reactor will be caused by the production of additional steam at the K-Area coal-fired power plant and by diesel generators in the L-Reactor area. The steam-plant releases are described in Section 4.2. Fourteen diesel generators are located in the L-Reactor area. Based on a consumption rate of about 940 cubic meters of fuel per year, the six generators that will operate continuously are expected to produce total annual atmospheric releases of about 3.6 metric tons of total suspended particulates, 3.6 metric tons of sulfur dioxide, and 53.5 metric tons of nitrogen oxides. The emissions are not expected to cause any adverse impacts.

A mobile backup boiler will be used in L-Reactor area if the K-Area power plant cannot supply enough steam to both K- and L-Reactors. This mobile boiler is a 261-kilowatt, oil-fired package unit that burns Number 2 fuel oil; it is expected to be operated fewer than 30 days per year. Annual pollutant releases and emission rates will be low and within the standards of the South Carolina Department of Health and Environmental Control.

4.1.1.5 Solid wastes

Solid nonradioactive wastes generated by the resumption of L-Reactor operation will consist of trash and sanitary waste sludge. Trash will be disposed of in the SRP sanitary landfill, which is designed and operated in accordance with guidelines of the South Carolina Department of Health and Environmental Control. The current permit allowed the expansion of this landfill from about 10 to 32 acres, which ensures sufficient space to accommodate the trash generated by the L-Reactor area during its operation (du Pont, 1982). Ten wells monitor the effluent from the landfill to the ground water of the McBean Formation. Quarterly analyses of water from these wells showed little impact on the McBean ground water.

4.1.2 Radiological impacts--L-Reactor

There are four principal sources of radiological discharges due to the resumption of L-Reactor operation: (1) atmospheric releases; (2) liquid releases to surface streams and ground water; (3) the remobilization of radiocesium entrained in Steel Creek sediments; and (4) solid radioactive wastes. This section characterizes their source terms for normal reactor operations and for postulated accident conditions, and presents the expected radiological doses.

4.1.2.1 Dose commitments from releases from reactor operation

The resumption of L-Reactor operation will result in additional releases of radionuclides from the Savannah River Plant. Appendix A describes the methods and assumptions used for estimating the doses to man from these sources.

Atmospheric releases

Source terms. Radionuclides will be released to the atmosphere as a result of routine operation of L-Reactor from three release points: (1) the 61-meter stack, (2) at ground level from the evaporation of water from the disassembly basin, and (3) at ground level from the evaporation of water from the L-Reactor area seepage basin. The releases from the stack consist of radionuclides that enter the reactor ventilation system from the evaporation of process water, from leaks in the pressurized blanket gas system, and from leaks from the airspace between the reactor vessel and the thermal shield.

Table 4-5 lists the expected first year and tenth year (equilibrium) annual atmospheric releases from the routine operation of L-Reactor. The values are based on the average annual releases from P-, K-, and C-Reactor operations for 1978, 1979, and 1980; however, the values for tritium and iodine evaporated from the disassembly basin and for tritium evaporated from the seepage basin have been adjusted for more frequent target discharges expected at the L-Reactor (du Pont, 1982).

Table 4-5. Expected annual atmospheric releases from L-Reactor operation[a,b] (curies/year)

Radionuclide	First Year Operation	Tenth Year Operation
H-3	5,500	54,900
C-14	12	12
Ar-41	19,500	19,500
Kr-85m	600	600
Kr-87	540	540
Kr-88	800	800
I-131	0.00414	0.00414
Xe-133	1,700	1,700
Xe-135	1,400	1,400
Unidentified beta-gamma[c]	0.0002	0.0002
Unidentified alpha[d]	0.000001	0.000001

a. Source: du Pont, 1982.

b. The expected annual average concentrations at the SRP boundary would be well within the maximum permissible concentrations given in DOE 5480.1A for an uncontrolled area.

c. Assumed evenly divided between I-129 and Sr-90.

d. Assumed evenly divided between Pu-239 and Am-241.

Maximum individual dose. The individual who would receive the highest dose from atmospheric releases from L-Reactor was assumed to live continuously on the SRP boundary about 12.6 kilometers west of the reactor. The selection of this location was based on considerations of the distance to the SRP boundary and on meteorological dispersion characteristics. Doses were calculated for the total body and for various organs.

The maximum total body dose to an individual was calculated to be about 0.22 millirem to a child in the first year of L-Reactor operation, and about 1.2 millirem in the tenth year. In addition, the child was calculated to receive the highest organ doses; the dose to the child's thyroid is about 0.22 millirem in the first year, and about 1.2 millirem in the tenth year. About 90 percent of the total-body dose is from tritium.

Population dose. The highest dose to the population of 852,000 (year 2000) that is estimated to live within 80 kilometers of the Savannah River Plant is received from inhalation. The total body dose is calculated to be about 7.4 man-rem in the first year of L-Reactor operation and about 56 man-rem in the tenth year.

Liquid releases

Source terms. Liquids will be discharged routinely from the disassembly basin to a low-level liquid seepage basin in the L-Reactor area; this purge of water will be necessary to keep the tritium concentration in the disassembly-basin water below the level that ensures safe working conditions. The water in the disassembly basin will become contaminated when fuel and target assemblies are discharged from the reactor; some tritium and other radionuclides will be carried over as process water adhering to the assemblies, and some as tritiated heavy water (DTO) contained as water of hydration in aluminum oxide on the assemblies. The disassembly-basin water is filtered, deionized, and monitored before it is discharged to the seepage basin. Radionuclides will also be discharged to Steel Creek as a result of the small process-water leaks into the cooling water in the reactor heat exchangers, and by releases into the process sewer.

During the first year of L-Reactor operations, 360 curies of tritium and less than 0.2 curie of other radionuclides are expected to be discharged to Steel Creek. Table 4-6 lists the expected tenth year (equilibrium) releases of radionuclides from L-Reactor to Steel Creek, to the seepage basin, and to Steel Creek by ground-water transport from the seepage basin. The releases directly to Steel Creek and to the seepage basin are based on average annual releases from P-, K-, and C-Reactors during 1978, 1979, and 1980, but have been adjusted for the more frequent assembly discharges expected from L-Reactor operation. The releases of radionuclides to Steel Creek from ground-water transport from the seepage basin are listed for the 30th year of L-Reactor operation. The expected annual average concentrations at the Steel Creek mouth would be well within the maximum permissible concentrations given in DOE 5480.1A for an uncontrolled area.

The annual amount of tritium expected to be discharged to the seepage basin in L-Reactor area is about 10,500 curies. Of this amount, about 3200 curies will be released each year at ground level by evaporation. The remaining inventory, 7300 curies, eventually will seep into the ground below the basin and reach the water table at a depth of about 6 meters in the Barnwell Formation. As shown in Table 4-6, small quantities of other radionuclides will be discharged to the seepage basin with the tritium; they also will gradually reach the water table beneath the basin.

Potential contamination of the water-table aquifer and neighboring surface-water systems from the operation of the L-Reactor will result from the migration of contaminants from the seepage basin. Contaminant migration in the subsurface is controlled by the rate and direction of ground-water flow, the absorptive capabilities of the water-bearing materials, and hydrodynamic dispersion.

As a result of the deposition process, the sediments at the Savannah River Plant exhibit greater horizontal than vertical hydraulic conductivities, enhancing lateral movement. Thus, radioactive contaminants entering the water table in the Barnwell Formation from the seepage basin probably would flow to a point of outcrop on Steel Creek (see Figure 3-8). In addition to the horizontal-vertical hydraulic conductivity contrasts, the hydrostatic pressure gradients and low-conductivity clay units tend to preclude the contamination of the prolific Ellenton and Tuscaloosa aquifers (Figure 3-7), which are used as potable water supplies.

Computer modeling was performed to calculate the source terms of the radioisotopes that reach the outcrop as a function of time (Table 4-6). Ground-water travel time from the basin to the outcrop at Steel Creek, hydrodynamic dispersion, radionuclide retardation, and radioactive decay were considered when performing these calculations (Appendix A).

Table 4-6. Expected average annual liquid radioactive releases from L-Reactor (curies/year)

Radioisotope	Steel Creek[a]	Seepage basin[a]	To Steel Creek from ground water[b]	Total to Steel Creek Ci/yr
H-3	3.6×10^3	1.1×10^4[c]	5.7×10^3	9.3×10^3
P-32		1.2×10^{-3}		
S-35		9.5×10^{-3}	2.8×10^{-8}	2.8×10^{-8}
Cr-51		1.8×10^{-1}		
Co-58,60	4.5×10^{-2}	3.7×10^{-4}	(Co-60) 2.1×10^{-4}	4.5×10^{-2}
Sr-89		7×10^{-5}		
Sr-90	1.6×10^{-4}	2×10^{-4}		1.6×10^{-4}
Y-91		5.1×10^{-3}		
Zr-95		1.1×10^{-2}		
Ru-106		3.4×10^{-4}	1.7×10^{-5}	1.7×10^{-5}
Sb-125		8×10^{-3}	2.6×10^{-3}	2.6×10^{-3}
I-131		6.9×10^{-3}		
Cs-134		5.1×10^{-3}		
Cs-137	4.1×10^{-4}	4.4×10^{-2}		4.1×10^{-4}
Ce-144		1.9×10^{-2}	3.8×10^{-4}	3.8×10^{-4}
Pm-147		2.8×10^{-3}	8.8×10^{-4}	8.8×10^{-4}
I-129			4.5×10^{-2}	4.5×10^{-2}
Unidentified beta-gamma[d]	1.1×10^{-1}	8.9×10^{-2}		1.1×10^{-1}
Unidentified alpha[e]	2×10^{-5}	3.2×10^{-4}		2×10^{-5}

a. Source: du Pont, 1982.
b. *Outcrop activities after 30 years of L-Reactor operation.* Due to long transport times in ground water, Sr-90, Pu-239, and Am-241 do not reach outcrop in the 30-year period.
c. 3200 curies of this tritium is expected to evaporate.
d. Assumed to be evenly divided between I-129 and Sr-90.
e. Assumed to be evenly divided between Pu-239 and Am-241.

Maximum individual dose. The individual who would receive the highest dose from liquid effluents from the L-Reactor is assumed to live near the Savannah River, downstream from the Savannah River Plant. This individual is assumed to use river water regularly for drinking, to consume fish from the river and shellfish from downstream estuarine areas, and to receive external exposures from shoreline activities, swimming, and boating.

The total-body dose to the individual receiving the maximum exposure from liquids was calculated to be about 0.025 millirem to a child in the first year of L-Reactor operation and about 0.13 millirem in the tenth year. About 94 percent of this dose was from drinking water, which had about equal contributions from both ground- and surface-water sources. The highest calculated organ dose was about 0.06 millirem to the adult thyroid in the first year of L-Reactor operation and about 0.2 millirem in the tenth year. About 74 percent of this dose came from drinking water, and about 26 percent from eating fish and shellfish. Tritium and iodine-129 are the major contributing radionuclides to the adult thyroid dose; tritium and strontium-90 are the major contributors to the total-body dose.

Population dose. Savannah River water is not used for drinking within 80 kilometers of the Savannah River Plant; therefore, the dose to the population in this area will come from eating fish and shellfish, from shoreline activities, and from swimming and boating.

The dose to the population of 852,000 who will be living within 80 kilometers of the Savannah River Plant in the year 2000 was calculated to be about 0.04 man-rem in the first year of L-Reactor operation and about 0.05 man-rem in the tenth year. About 98 percent of this dose is from eating fish from the Savannah River.

Dose to Port Wentworth and Beaufort-Jasper water consumers. The Port Wentworth and Beaufort-Jasper communities use the Savannah River as a source of potable water. While these groups are beyond the 80-kilometer radius of the Savannah River Plant (about 160 river kilometers downstream), the drinking water doses to them have been calculated.

The total-body dose delivered to these populations (about 70,000 people) from drinking water was calculated to be about 0.4 man-rem in the first year of L-Reactor operation and about 3 man-rem in the tenth year. About 90 percent of this dose is from tritium.

Radiocesium redistribution

The reactivation of L-Reactor will transport a portion of the radiocesium inventory that remains in the Steel Creek channel and floodplain (see Figure 3-16) with the resuspended sediments, vegetation, and water when the thermal effluent is discharged to Steel Creek. This remobilization of radiocesium will augment the small amount that is currently being transported from the creek, about 0.2 curie per year.

The amount of radiocesium transported from Steel Creek to the Savannah River and to an offsite swamp (Creek Plantation Swamp) as the result of L-Reactor operations was calculated using empirical models based on monitoring in 1976 and 1980 of sediment and radiocesium transport in Steel Creek and on the historic flooding record for the swamp (du Pont, 1982; Langley and Marter, 1973). The model assumed that the transport of radiocesium in suspended sediment followed a two-step process analogous to storm-water runoff; the initial resuspension of loosely held sediment would be followed by the transport of suspended solids comparable to Savannah River concentrations. The radiocesium concentrations of the suspended sediments were assumed to come into equilibrium with the Steel Creek radiocesium values through a repeated process of deposition and resuspension (du Pont, 1982).

Radiocesium transport during the initial 12-day startup period is predicted to be approximately 0.5 curie. The transport of radiocesium associated with suspended solids is estimated to be 7.2 curies per year for the first 2 years of operation (du Pont, 1982). Data acquired during 1976 were used to model the desorption of radiocesium from the sediments of Steel Creek. A total of 1.7 curies is expected to be released from the Steel Creek sediments by desorption during the first year of L-Reactor operation. About 0.4 curie of radiocesium is tied up in the vegetation found on the Steel Creek floodplain. The radiocesium transport analyses assumed that all vegetation would be destroyed during the first year after the resumption of L-Reactor operation.

Thus, in the first year, approximately 9.8 curies of radiocesium was calculated to be discharged from Steel Creek. After the first year of L-Reactor operation, the anticipated radiocesium transport from Steel Creek is expected to decrease to about 7.2 curies. A 20-percent annual decrease in radiocesium transport is assumed in the third and subsequent years. Thus, in the tenth year of L-Reactor operation 1.2 Ci of radiocesium will be discharged (du Pont, 1982).

The rate of radiocesium discharge to the Savannah River will depend on the year after restart and on the river stage. During the first year of resumed operations, the radiocesium concentrations in the river are projected to be about 1.9 picocuries per liter if the flow is 166 cubic meters per second (the 7-day, 10-year low flow). During flooding, SRP streams flow across the Creek Plantation Swamp and discharge to the Savannah River at Little Hell Landing. Radiocesium will be deposited in this portion of the swamp as the result of flooding, thereby reducing the amount of radiocesium transported to the river. If normal river flow and flooding of the swamp are assumed, then 7.5 curies of radiocesium can be expected to be released to the Savannah River and 2.3 curies to Creek Plantation Swamp during the first year; concentrations would be about 0.8 picocurie per liter in the river under these conditions. Table 4-7 compares the current radiocesium transport with predicted values for the first, second, and tenth years after resumption of L-Reactor operation.

Dose calculations for the remobilization of radiocesium in Steel Creek sediments assumed that all radiocesium released would reach the Savannah River, and that complete mixing in the river would occur within 2.4 kilometers of the mouth of Steel Creek, and at an annual average flow rate of 295 cubic meters per second. The dose associated with the first year of L-Reactor operation was analyzed because the first-year release of 9.8 curies will decrease continuously in subsequent years.

Maximum individual dose. The maximum total-body dose to an individual was calculated to be about 5 millirem to an adult for the first year of L-Reactor operation and about 0.6 millirem for the tenth year; 98 percent of this dose would be from eating Savannah River fish. The maximum dose to an organ was calculated to be about 8 millirem per year to the liver.

Population dose. The total-body dose to the population within 80 kilometers of the Savannah River Plant was calculated to be about 20 man-rem in the first year of L-Reactor operation, 99 percent of which would be due to eating Savannah River fish, and about 2.5 man-rem in the tenth year.

Dose to Port Wentworth and Beaufort-Jasper water consumers. The total-body dose to Savannah River water consumers in the Port Wentworth and Beaufort-Jasper population groups was calculated to be about 1.7 man-rem in the first year of L-Reactor operation and about 0.2 man-rem in the tenth year.

Solid radioactive waste

About 570 cubic meters of solid radioactive waste will be generated annually at the L-Reactor. This waste will be packaged and transported to the SRP low-level waste burial ground. No offsite releases are expected as a result of solid radioactive waste generated at the L-Reactor.

Summary--dose commitments from L-Reactor operation

Table 4-8 summarizes the maximum individual and population dose commitments resulting from the resumption of L-Reactor operation. The numbers listed as totals for individual and population doses are conservative maximums; to receive these doses, the "cumulative" individual (or population) would have to occupy several locations simultaneously. In addition, the dose for radiocesium transport is calculated for the first year and will decrease continuously in subsequent years.

The composite maximum individual dose of 5 millirem occurs in the first year of L-Reactor operation which is about 20 times less than the average dose of 93 millirem (du Pont, 1982) received by an individual living near the SRP site from natural radiation. The maximum population dose of 62 man-rem in the tenth year of L-Reactor operation is less than 0.1 percent of the exposure of about 80,000 man-rem to the population living within 80 kilometers of the Savannah River Plant from natural radiation sources.

4.1.2.2 Occupational dose

At the L-Reactor, occupational doses will be maintained as low as reasonably achievable. All personnel who work in or enter areas that have radiation-exposure potential receive personal monitoring devices. In addition, a comprehensive bioassay program is maintained for all employees who work in areas where there is a potential for a biological uptake of radioactivity.

Table 4-9 lists the total whole-body dose commitments to workers in the P-, K-, and C-Reactor areas for 1976 through 1980. Based on these data, the total average annual dose commitment to workers in the L-Reactor area will be about 69 man-rem per year. The average workforce in the reactor areas is about 375 people; thus, the average annual individual dose to workers in the L-Reactor area will be about 185 millirem per year.

The dose commitment to workers during this recent period can be compared to the experience of the 1960-1968 period, during which the annual occupational dose commitment in the P-, K-, C-, and L-Reactor areas averaged about 200 man-rem per reactor year (du Pont, 1982).

4.1.2.3 Accidents

Reactor accidents

The L-Reactor uses heavy water as a neutron moderator and as a circulating primary coolant to remove heat from the nuclear fission process. The reactor will be operated at near-atmospheric pressure and below boiling-water temperature.

L-Reactor will operate at a power limit that is determined separately for each reactor charge and each fuel and target cycle. This limit is the highest power at which the reactor can operate with the protective instrument systems able to terminate all anticipated transients without damaging reactor fuel, the reactor tank, or the radioactivity confinement system. The transient conditions are analyzed for two broad categories of transients:

1. Reactivity addition (equivalent to the removal of the neutron absorber) that increases reactor power or power in a local region of the reactor

2. Flow reduction, caused by a loss of pumping power, a reduction of circulation, or a loss of coolant, that reduces the cooling capacity of the reactor or individual heat-producing assemblies

For any anticipated transient, operation at or below the operating limit would prevent release of radioactivity to the environment from those transients.

Besides the analysis of anticipated transients, this section describes the consequences and risks of five hypothetical accidents that cover a spectrum of events postulated to release radioactivity. The accidents include (1) a moderator spill; (2) a discharge mishap in which an irradiated assembly is dropped and melts; (3) a misloading accident during charge-discharge operations in which seven fuel assemblies form a critical mass and melt; (4) a loss-of-coolant accident resulting in the melting of 1 percent of the reactor core; and (5) an accident resulting in the melting of 10 percent of the reactor core. The effects of each accident are compared with the standards for exposure of individuals in uncontrolled areas for accidental releases.

1. Moderator spill--Tritium in the moderator could become airborne and be partially released to the confinement system following Emergency Cooling System actuation or any loss-of-coolant accident. Tritium released into the confinement system is discharged from the stack, because the confinement system has no mechanism for tritium removal.

   Five million curies of tritium is assumed to be present in the moderator of the L-Reactor; this is the equilibrium value of tritium in the moderator and is 30 to 40 percent higher than present actual values for operating SRP reactors. The full moderator inventory of tritium is unlikely to evaporate and discharge to the atmosphere through the confinement system following any accident because the moderator would flow first into the 227,000-liter tank and then to the 1,900,000-liter tank of the liquid activity confinement system. Three percent of the tritium is expected to evaporate during the 2-hour period after the postulated accident and to be released from the stack during that period.

2. Melting of a single assembly during discharge--One irradiated fuel assembly could melt during a discharge operation under certain adverse (and improbable) conditions and release noble gases, iodine, and particulates. Fifty percent of the iodine and 100 percent of the noble gases available for release are assumed to escape the assembly and become airborne within the confinement system. More than 99 percent of that iodine reaching the carbon filter beds would be removed by the filter; 100 percent of the noble gases would pass through the filter. More than 99 percent of the particulates released to the confinement system would be removed by HEPA filters.

3. Melting of seven assemblies caused by a misloading--Criticality could result from a misloading event. As many as seven assemblies could melt following this accident; melting would release iodine and fission products into the moderator. For purposes of analysis, 50 percent of the iodine and all the noble gases were assumed to become airborne. Before the accident, the fission products would have decayed for a minimum of 14 hours. However, more fission products would be formed during the postulated criticality accident, and it was assumed that the fission product content of the seven assemblies would be the equilibrium concentration at full power.

4. One-percent core melting due to a loss-of-coolant accident--The design basis accident (DBA) for the SRP reactors is a double-ended pipe break in one of the six primary lines supplying heavy water to the reactor plenum. To compound this accident, the break is assumed to occur in one of the three primary lines having an emergency cooling-water line. Furthermore, a second emergency cooling-water addition system is assumed to be disabled. These assumptions of system operability are made to account for any potential common mode failure. SRP reactors are operated at power levels that limit core damage to 1 percent with only one of the three ECS addition systems operating. If the ECS system operates as designed, no melting would occur. The amount of radioactivity available for release would be 1 percent of the noble gas and the iodine inventory in the core at the time of the accident. Fifty percent of the released iodine would be airborne. The iodine would be trapped on the carbon filters; some would desorb later and be released from the stack.

5. Ten-percent core melting due to a loss-of-coolant accident--A 10-percent core melt was postulated as an accident beyond design basis. In this case, the amount of radioactivity available for release would be 10 percent of the core inventory of iodine and noble gases.

<u>Results of calculations</u>. The results of the calculations are listed in Table 4-10 in the order of increasing severity. These doses are calculated for median (50-percent) meteorological conditions.

Table 4-10. Calculated radiation dose to a person at the SRP site boundary during the 2-hour exposure period following accident

Accident	Calculated dose (rem)	
	Whole body	Thyroid
Reactor siting criteria	25	300
Moderator (D_2O) spill	0.005	0
Discharge mishap (one fuel assembly melts)	0.04	0.3
Misloading criticality (seven fuel assemblies melt), mixed lattice charge	0.22	2.0
LOCA with two top addition systems inoperative, 1% core melt	0.1	0.75
Postulated accident resulting in 10% core melt	1.0	7.5

Risk evaluation. The dose values listed in Table 4-10 are the consequences that would result at the site boundary. An emergency response plan has been implemented at the Savannah River Plant to initiate actions or evacuation of employees during an emergency. The following sections describe estimates on the probability for each of the accidents discussed above (du Pont, 1982).

1. Moderator spill--A sizeable moderator spill occurred once at the Savannah River Plant during the early stages of operation. At the time of the spill, the moderator contained very little tritium. Since then, more than 100 years of reactor operation have occurred at the Savannah River Plant without a major moderator spill, suggesting that the probability of a spill is about 0.01 per reactor year. In addition, an estimate of the probability for spilling all the moderator is 10^{-4} per reactor year.

2. Discharge mishap--More than 300,000 fuel or target assemblies have been discharged without a failure of the cooling water or the holding mechanism in the discharge machine. No assembly has been dropped. Melting did occur in one element, a source rod, during this time because of procedural error, not because of mechanical or cooling-water failure. The estimated probability for melting during discharge, based on improved control mechanisms at the Savannah River Plant, is equal to or less than 10^{-4} per reactor year.

3. Misloading error leading to criticality--The probability of a misloading error ocurring during discharge operations has been estimated to be 3×10^{-6} per reactor year. The estimate is based on fault-tree analyses combined with the expected number of unit operations per year. A misloading error leading to criticality can occur in only one thirtieth of the reactor locations in the outer regions of a mixed-lattice charge, or through repeated errors in assembling the tritium-producing assemblies. Therefore, a misloading leading to criticality has a probability of about 10^{-7} per reactor year.

4. One-percent and 10-percent core melts--A literature search on pipe breaks in pressurized systems (L-Reactor is not pressurized) indicates probabilities on the order of 3×10^{-5} per year for massive failures. The probability of a partial failure of the Emergency Cooling System, leading to 1-percent core melting, has been estimated to be 3×10^{-2}. Thus, the probability of failure leading to the design-basis accident of 1-percent core melting would be about 10^{-6} per reactor year. The probability of the accident progressing to a 10-percent melt would be still less.

The risk posed by an accident is defined as the accident probability times its consequences and can be expressed as a dose to an individual per a specified time period. Table 4-11 lists the risks of the postulated accidents. These risks were calculated by multiplying the calculated whole-body doses in Table 4-10 by the corresponding probabilities in Table 4-11; they range from about 2.2×10^{-5} to 4×10^{-3} millirem per year. All values are much less than the risk that could be associated with a natural radiation dose of 93 millirem per year.

Table 4-11. Risk evaluation of accidents

Accident	Probability (y^{-1})	Estimated whole-body risk (mrem/year)
Moderator spill	10^{-4}	5×10^{-4}
Discharge mishap	10^{-4}	4×10^{-3}
Misloading criticality	10^{-7}	2.2×10^{-5}
Loss-of-coolant, 1% core melt	10^{-6}	2×10^{-4}
Postulated accident resulting in 10% core melt	$\ll 10^{-6}$	$\ll 1 \times 10^{-3}$
Natural radiation		93

The consequences and risks of the hypothetical postulated accident in an SRP reactor are considered low because:

- SRP reactors operate at low temperatures and low pressures, thus reducing stress on coolant pipes.
- The large carbon and HEPA filters are always online during operation.
- The SRP reactors have established 115 reactor years of operation without an accidental release of radioactivity.
- The distance to the site boundary is large--greater than 8 kilometers.

Non-nuclear hazards

Toxic gas release. In past operations, the effects of toxic gas releases have been analyzed, and provisions have been made for shutdown, building evacuation, and remote control of coolant flows, pumps, and valves. The two toxic gases considered were the chlorine used to prevent biofouling of reactor heat exchangers, and the hydrogen sulfide (H_2S) used in the heavy-water production area. Two recent changes in plant operation have reduced the hazards from these gases:

1. L-Reactor will use sodium hypochlorite rather than chlorine as the cooling-water biocide. Sodium hypochlorite presents no health hazard and will provide the same biological protection as chlorine.

2. Heavy-water production at the Savannah River Plant has stopped. The large quantities of H_2S gas stored in the heavy-water production area have been removed.

Fire. Fire from natural, accidental, or deliberate acts is an ever-present consideration in any facility. The L-Reactor will use a fire-alert and fire-fighting system identical to the systems used at other reactor areas; the application of established parameters for the selection and installation of structural materials and engineered equipment minimizes fire potential.

Natural phenomena

Earthquakes. Reactor building design and revisions to the structure made following a comprehensive analysis in 1969 are calculated to make the reactor building and its main components resistant to earthquakes with maximum potential accelerations as high as 0.2g. These revisions included:

1. Strengthening the base of the control-rod actuator tower.

2. Strengthening the 61-meter building exhaust stack.

3. Improving the anchors on the 12 track-mounted process heat exchangers.

4. Improving the lateral support for the piping for the Emergency Cooling System and the Supplementary Safety System.

The highest horizontal acceleration ever experienced in the SRP area was estimated to be about 0.07g during the September 1, 1886, Charleston, South Carolina, earthquake (DOE, 1982). Seismic recorders installed in the reactor buildings are set to alarm at 0.002g and to shut down the reactor at 0.02g. In more than 28 years of reactor operation, there has never been a seismic alarm.

Tornado and hurricane effects. About 10 tornadoes strike the Georgia-South Carolina area each year (du Pont, 1982). Maximum wind speeds in the extreme tornadoes would be about 116 meters per second. A study for the Savannah River Plant on tornado risk indicates that the probability of a specific reactor building encountering tornadoes with wind speeds greater than 125 meters per second is 10^{-7} per year (The 10^{-7} per year probability is derived from the annual occurrence of tornadoes and the probability of a tornado striking a specific point as discussed in Section 3.5.4.2). Such a tornado is capable of creating a pressure drop across a building surface of 10,000 pascals. The reactor building itself is resistant to a pressure of about 50,000 pascals. An analysis of the Disassembly Area indicated it could withstand a pressure drop of 20,700 pascals.

Exceptions to the wind-resistance capability are the existing 61-meter exhaust stack (capable of withstanding winds of 56 meters per second), the confinement system filter compartments, the diesel motor for the booster pump used in the emergency cooling-water system, and the exhaust fan casings. The falling stack would not damage critical areas of the reactor building and would not result in a reactor accident. A tornado causing damage to the filter compartments or the stack after an independently caused reactor accident would increase offsite dose effects. Such multiple-series accidents are not considered in this analysis because of the extremely low probability of the simultaneous occurrence of a reactor accident and a tornado striking the reactor. The booster pump is one of three independent emergency cooling-water systems for the reactor; damage to it from a tornado would not significantly affect the mitigation of an independently caused reactor accident.

Hurricanes damaging to South Carolina can be expected about once in 7 years. The Savannah River Plant is about 160 kilometers inland from the coast, and hurricane winds are diminished over land. Winds of 34 meters per second from a hurricane have been measured only once at the SRP site (Hurricane Gracie in 1959). The wind velocity expected from a hurricane would be less than that from a tornado.

Floods. The L-Reactor area is not subject to being flooded. It is well-drained, being 75 meters above sea level. Pen Branch on the west and north and Steel Creek on the east and south each have an elevation of 60 meters and provide adequate drainage. The Savannah River elevation is controlled partially by Clarks Hill Dam, located above the SRP site. Dam failure analysis shows that only the river pumphouse, which supplies cooling water to the reactor, would be flooded. The onsite storage of cooling water in 186-Basins (95 million liters in each area) is adequate to remove shutdown heat from the reactors; this cooling water can be recirculated. Each reactor has enough onsite power generation to maintain it in a safe shutdown condition if flooding should cause the loss of offsite power.

4.2 INCREMENTAL SRP IMPACTS FROM L-REACTOR OPERATION

The resumption of L-Reactor operation will increase the fabrication and chemical processing of fuel and target assemblies at the Savannah River Plant incrementally by a factor of about 33 percent; this represents the difference between operating three or four production reactors. Other SRP facilities that will be affected by L-Reactor operation are the separations areas, the waste management operations, and an onsite steam-generating station. This section describes the incremental impacts of SRP facilities due to the resumption of L-Reactor operation.

4.2.1 Nonradiological impacts

L-Reactor operation will not result in additional surface water usage for the other SRP facilities. Nonradioactive releases from the processing of L-Reactor fuel and target assemblies will consist of liquid releases--discharges to seepage basins and surface streams--and atmospheric releases. The additional burning of coal to produce steam will also result in an incremental release of pollutants to the atmosphere.

4.2.1.1 Socioeconomics

Approximately 160 employees are expected to be hired by 1984 for existing SRP facilities in support of the resumption of L-Reactor operation. The potential effects of this incremental employment on the SRP area are not expected to affect community facilities or services because of the small number of supporting personnel. For comparison, the potential effects on the SRP area from the support personnel would be less than one-half of the effects described in Section 4.1.1.

4.2.1.2 Liquid releases

Seepage basins

The chemical separations of the irradiated L-Reactor fuel and target assemblies will result in additional discharges to the seepage basins at the chemical separations areas. Based on past experience, about 1.5 kilograms per year of mercury (primarily as an impurity in sodium hydroxide) and larger quantities of other chemicals are expected to be discharged to seepage basins in the F- and H-Separations Areas due to the operation of L-Reactor (ERDA, 1977; Horton and Carothers, 1974). In addition, 200 kilograms per year of chlorinated degreasing solvents and quantities of other chemicals will be discharged to the seepage basin in the Fuel and Target Fabrication Area (M-Area; Figure 3-2). Estimated incremental releases to these seepage basins resulting from L-Reactor operations are expected to approximate a 33-percent increase over existing releases (see Table 4-12).

Nonradioactive pollutants in F- and H-Area seepage basins have entered the shallow ground-water system and are migrating out through outcrops (Fenimore and Horton, 1972; Horton and Carothers, 1974; Horton, 1974). Pollutants in the M-Area basin have also entered the shallow ground-water system and could eventually discharge through outcrops along Tims Branch (a tributary of Upper Three Runs Creek) and along Hollow Creek near Jackson, South Carolina. The discharge to surface streams through outcrops depends on the length of the travel path, the ground-water flow rate, and the retardation by ion exchange. Control methods are planned to ensure that liquid-effluent streams to seepage basins are within discharge limits (SCDHEC, 1979). According to these plans, the chemical pollutants will be controlled so concentrations in the effluent will be less than 100 times the EPA drinking-water standard and the pH will be in the range of 2 to 12.5. The incremental discharges of chemicals to the seepage basins in

Table 4-12. Estimated nonradioactive incremental releases to the separations areas and the fuel/target fabrication area seepage basins

Cation/ anion	F-Area seepage basins (kg/year)	H-Area seepage basins (kg/year)	M-Area seepage basin (kg/year)
Ammonium	10	5	--
Calcium	80	470	--
Magnesium	40	170	--
Sodium	480	5,150	20,710
Iron	240	140	50
Copper	10	30	20
Aluminum	30	430	4,140
Lead	30	120	20
Zinc	80	310	10
Carbonate	0	2,450	--
Chlorine	20	430	3,110
Nitrite	5	70	--
Nitrate	11,450	25,740	33,140
Sulfate	380	1,150	1,030
Phosphate	20	3,210	6,210
Chromium	30	580	--
Mercury	0.1	1.4	--
Cadmium	--[a]	--	1
Nickel	--	--	130
Fluorine	--	--	80
Barium	--	--	80
1, 1, 1 TCE	--	--	200

a. Data not available

the chemical separations and fuel fabrication areas are expected to result in only minor impacts to surface streams.

The sediments on the Savannah River Plant exhibit hydraulic conductivity that is greater horizontally than vertically, thus enhancing lateral movement in the direction of discharge (toward the outcrop). A downward hydraulic gradient generally exists between the Barnwell and McBean Formations (see Figure 3-7). Therefore, a potential contaminant from a F- or H-Area seepage basin, on reaching the bottom of the Barnwell hydrogeologic unit and crossing the tan clay, could be transported into the McBean Formation. A downward gradient usually exists between the McBean and Congaree Formations, but pollutants would have to cross the green clay to enter the Congaree. However, the vertical gradient is upward between the Congaree and the underlying Ellenton Formation; these formations are also separated by a low-conductivity clay unit. Therefore, any potential contaminant that reached the Congaree Formation would be restricted to that formation due to the higher hydrostatic pressure in the underlying Ellenton and Tuscaloosa Formations. These higher pressures would prevent the contamination of the potable water supplies of the prolific Ellenton and Tuscaloosa aquifers.

Ash basin

Additional discharges of bottom ash will be sluiced to the K-Reactor area ash basin for disposal as a result of the production of steam for L-Reactor operation. The additional burning of coal with an ash content of about 13 percent will produce approximately 815 metric tons of ash per year. Incrementally, this ash will increase the K-Reactor area steam-plant discharge to the ash basin by about 15 percent. A proposed project would adjust the pH of the sluicing water so it is within discharge limits (SCDHEC, 1979). Leachate from the ash basin will enter the shallow ground-water system of the Barnwell Formation, from which it will migrate to Pen Branch. Ground-water monitoring wells are to be installed at this ash basin, but little impact is anticipated to the ground water of the Barnwell Formation.

Releases to surface streams

The operation of L-Reactor will cause an incremental increase of about one-third in the discharge of liquid effluent from the separations areas and the fuel and target fabrication area to surface streams. As listed in Table 4-13, F-Area will discharge an additional 890 liters per minute to Four Mile Creek; the increment to Four Mile Creek from H-Area will be about 1040 liters per minute (du Pont, 1981a). An M-Area outfall will discharge an additional 120 liters per minute to an unnamed tributary to Tims Branch, which flows into Upper Three Runs Creek. Table 4-13 also lists the expected concentrations of pollutants in the liquid effluents to these streams and compares the concentrations to applicable drinking-water standards or water quality criteria.

In general, these releases at the outfall will meet the requirements of Class B streams (SCDHEC, 1981). However, the pH of these discharges will occasionally exceed standards and require treatment (SCDHEC, 1979). Nickel, nitrates, and iron concentrations in the M-Area discharging to Tims Branch will not reach levels that could be classified as hazardous to aquatic life (Federal Register, Part V, Vol. 45, No. 231, 28 November 1980).

The flow from these streams will transport most of the chemicals through the swamp to the Savannah River. Impacts on the swamp water quality are expected to be small, particularly during flooding by the Savannah River. Chemicals reaching the river will be diluted further by river water.

4.2.1.3 Atmospheric releases

Process steam for L-Reactor operations will be supplied by the existing coal-fired boilers at the K-Reactor area. With the higher loading on the K-Reactor area coal-fired boilers, which are equipped with the necessary pollutant control devices, the coal-fired boilers would operate more efficiently.

Table 4-14 summarizes incremental air pollutant releases resulting from L-Reactor operation. Overall, the L-Reactor startup will increase future SRP NO_x emissions by about 7 percent. SO_2 and TSP releases will add less than 1 percent. Total releases related to L-Reactor operation will contribute a maximum of 2 micrograms per cubic meter of nitrogen oxides to the ambient air at the SRP boundary. This is much less than the conservative estimate of 19 micrograms per cubic meter from all other sources in 1985. Total SO_2 and TSP releases from the L-Reactor restart will add much less than 1 microgram per cubic meter each at the SRP boundary. Table 4-15 compares the impact of the increased L-Reactor emissions from K-Area to the total SRP releases, including the incremental increases from L-Reactor operations, as well as with the South Carolina annual ambient air quality standards. No major changes in ambient air quality are expected from SRP operations related to L-Reactor restart.

Table 4-14. Incremental air pollutant releases resulting from L-Reactor operation

Area	Projected 1984-1985 emissions (metric tons/year)		
	SO_x	TSP	NO_x
F	–[a]	–	136
H	–	–	7
M	–	–	3
K	125	29	47
Total L-Reactor increment	125	29	193

a. Emissions less than 1 metric ton/year not listed.

Table 4-15. A comparison of impact on ambient air quality from increases at K-Area plant and from SRP total (micrograms/cubic meter)

Pollutant	K-Area[a]	SRP[b]	SCDHEC annual standard[c]
SO_2	<1	12-23	80
NO_x	<1	15-23	100
TSP	<1	NA	60

a. Based on contributions from C-Area, which burns a similar amount of coal and is a similar distance from the nearest site boundary (du Pont, 1982, Tables 5.2.2-5 and 5.2.2-7).

b. du Pont, 1982.

c. SCDHEC Regulation 62.5, No. 2.

4.2.1.4 Transportation effects

The transport of materials to and from the Savannah River Plant will increase because of the resumption of L-Reactor operations; the additional annual truck transportation distance is estimated to be 4.9 x 10^5 kilometers. The potential for transportation accidents involving shipments of materials is assumed to be comparable to that for general truck transportation in the United States. Based on accident rates and injury and fatality rates (WASH-1238 and SLA-74-0001 - U.S. AEC, 1972 and Clarke et al., 1976, respectively), 0.4 injury and 0.02 fatality are expected annually from truck accidents; these rates are extremely small compared to the injuries and fatalities caused annually by all highway accidents.

Pollutants are emitted during normal transport by the combustion of diesel fuel; the primary pollutants are particulates, sulfur dioxide, nitrogen dioxide, hydrocarbons, and carbon monoxide. L-Reactor truck shipments will account for about 0.00002 percent of the pollutants emitted from highway vehicles.

4.2.2 Radiological effects

4.2.2.1 Dose commitments from radioactive releases from support facilities due to L-Reactor operation

The resumption of L-Reactor operation will result in an increase of about 33 percent of radioactive discharges from the support facilities (F-, H-, M-, D-, and CS-Areas). During the first year of L-Reactor operation, however, the releases would be less than 50% of the expected annual average releases. This section presents maximum individual and population doses from the expected annual average releases due to the incremental operations of the support facilities. Appendix A contains details of the calculations for the combined doses from L-Reactor and its support facilities.

Atmospheric releases

Source terms. The restart and operation of L-Reactor will increase the releases of radionuclides to the atmosphere from the separations, fuel fabrication, and heavy-water rework areas. Table 4-16 lists the expected incremental average annual releases of radionuclides from these areas to the atmosphere; these releases are based on the average annual releases for these facilities for 1978, 1979, and 1980, and were adjusted for L-Reactor operation.

Maximum individual dose. The maximum individual total-body dose from airborne releases from L-Reactor support facilities was calculated to be about 0.9 millirem per year to the child. Nearly all the total-body dose (about 93 percent) is from tritium. The thyroid dose to the child was about 2 millirem per year.

Population dose. The total-body dose to the population of 852,000 within 80 kilometers of the Savannah River Plant from airborne releases from support facilities was calculated to be about 11 man-rem. The highest organ doses to this population were about 150 man-rem per year to the skin and about 60 man-rem to the thyroid. About 80 percent of the total-body dose is from tritium; about 80 percent of the thyroid dose is from iodine-129.

Table 4-16. Estimated incremental annual average releases of radionuclides to the atmosphere from operation of L-Reactor support facilities (curies/year)[a]

Radioisotope	Separations areas (F&H)	Fuel fabrication area (M)	Heavy-water area (D)	Total
Noble gases				
Kr-85	2×10^5	--[c]	--	2×10^5
Xe-131m	2×10^0	--	--	2×10^0
Xe-133	1×10^{-1}	--	--	1×10^{-1}
Other airborne				
H-3	8.6×10^3	--	7.9×10^2	9.4×10^3
C-14	8×10^0	--	--	8×10^0
Sr-90[a]	2×10^{-3}	--	--	2×10^{-3}
Zr-95	6×10^{-3}	--	--	6×10^{-3}
Nb-95	1×10^{-2}	--	--	1×10^{-2}
Ru-103	1×10^{-3}	--	--	1×10^{-3}
Ru-106	3×10^{-2}	--	--	3×10^{-2}
I-129[b]	7×10^{-2}	--	--	7×10^{-2}
I-131	2×10^{-2}	--	--	2×10^{-2}
Cs-134	1×10^{-4}	--	--	1×10^{-4}
Cs-137	1×10^{-3}	--	--	1×10^{-3}
Ce-141	8×10^{-5}	--	--	8×10^{-5}
Ce-144	8×10^{-3}	--	--	8×10^{-3}
U-235	2×10^{-3}	--	--	2×10^{-3}
U-238	--	9×10^{-7}	--	9×10^{-7}
Pu-238	2×10^{-3}	--	--	2×10^{-3}
Pu-239[b]	3×10^{-4}	1×10^{-6}	--	3×10^{-4}
Am-241[b]	4×10^{-4}	1×10^{-6}	--	4×10^{-4}
Cm-244	4×10^{-4}	--	--	4×10^{-4}

a. Based on du Pont, 1982.
b. Unidentified β, γ releases are assumed to be evenly divided between Sr-90 and I-129; unidentified α releases are assumed to be evenly divided between Pu-239 and Am-241.
c. Data not available

Liquid releases

Source terms. Liquid radioactive releases will increase from the chemical separations areas, the fuel fabrication area, the heavy-water rework area, and the Central Shops area as a result of the resumption of L-Reactor operation. Tables 4-17, 4-18, and 4-19 list the expected annual average releases from each area to surface streams, to seepage basins, and to surface water from the seepage basins, respectively. The values listed for the releases from these areas to surface streams and seepage basins are based on average releases from the areas for 1978, 1979, and 1980, and are adjusted for L-Reactor operation. The values for radionuclide releases to streams from ground-water migration from the seepage basins are based on the 30th year of L-Reactor operation (Section 4.1.2).

Table 4-17. Estimated incremental releases of radionuclides to surface streams due to operation of L-Reactor support facilities[a]

Radionuclide	Separations areas (F&H)	Fuel fabrication area (M)	Heavy-water rework area (D)	Total
H-3	3.9×10^{1}	--	5.2×10^{2}	5.6×10^{2}
CO-60	--[c]	--	--	--
Sr-90[a]	3.1×10^{-2}	--	1.8×10^{-3}	3.3×10^{-2}
I-129[a]	2.7×10^{-2}	--	1.8×10^{-3}	3.2×10^{-2}
Cs-134	1.9×10^{-2}	--	8.0×10^{-5}	1.9×10^{-2}
Cs-137	--	--	--	--
U-235	--	5.0×10^{-2}	--	5.0×10^{-2}
Pu-239[b]	1.5×10^{-3}	--	3.5×10^{-6}	1.5×10^{-3}
Am-241[b]	1.5×10^{-3}	--	3.5×10^{-6}	1.5×10^{-3}

a. Based on du Pont, 1982.
b. Unidentified β, γ releases are assumed to be evenly divided between Sr-90 and I-129; unidentified α releases are assumed to be evenly divided between Pu-239 and Am-241.
c. Data not available.

Maximum individual dose. The maximum total dose to an individual from liquid effluents from L-Reactor support facilities was calculated to be about 0.1 millirem per year to a child. The dose from these effluents to the adult thyroid was also about 0.1 millirem per year.

Population dose. The total-body dose to the population within 80 kilometers of the Savannah River Plant from liquid effluents from the L-Reactor support facilities was calculated to be about 0.1 man-rem per year; the thyroid dose was also about 0.1 man-rem per year.

Dose to Beaufort-Jasper and Port Wentworth water consumers. The total-body dose to the Port Wentworth and Beaufort-Jasper populations (about 70,000 people) from drinking Savannah River water was calculated to be about 1.3 man-rem per year; the maximum organ dose to this population was about 2.5 man-rem per year to the thyroid.

4.2.2.2 Waste management operations

Currently, 41 large subsurface tanks are used to store aqueous radioactive wastes generated in the chemical separations facilities (F- and H-Areas). An additional 10 are in various stages of readiness for operation, bringing the total to 51 tanks. Additional processing by the chemical separations facilities as a result of L-Reactor operation will generate 1.1 to 2.3 million liters of liquid waste per year. This volume of waste will be concentrated to about 0.4 to 0.8 million liters per year. With this additional volume of waste, a maximum of three tanks per decade of L-Reactor operation will be required, two for fresh waste and one for concentrated waste. Three of the 10 new tanks mentioned above would fill this requirement without creating a short-term need for additional tanks.

Table 4-18. Incremental radionuclide releases to seepage basins from support facilities (curies/year)[a]

Isotope	Fuel fabrication area (M)	Separations area (F&H)	Central Shop (CS)	Total
H-3[b]		5.7×10^{3}	2.0×10^{-1}	5.7×10^{3}
Cr-51		3.6×10^{-1}		3.6×10^{-1}
Co-58, 60		5.4×10^{-2}	3.0×10^{-6}	5.4×10^{-2}
Zn-65		3.0×10^{-2}		3.0×10^{-2}
Sr-89, 90		5.9×10^{-1}	1.0×10^{-6}	5.9×10^{-1}
Nb-95		8.2×10^{-1}		8.2×10^{-1}
Zr-95		1.3×10^{0}		1.3×10^{0}
Ru-103, 106		9.9×10^{0}		9.9×10^{0}
Sb-124, 125		1.1×10^{-2}		1.1×10^{-2}
I-131		1.3×10^{-2}		1.3×10^{-2}
Cs-134, 137		2.4×10^{0}	1.0×10^{-6}	2.4×10^{0}
Ce-141, 144		3.0×10^{0}		3.0×10^{0}
Pm-147		1.2×10^{-1}		1.2×10^{-1}
Am-241, 243		3.3×10^{-2}		3.3×10^{-2}
Cm-242, 244		1.0×10^{-3}		1.0×10^{-3}
U-235, 238	3.5×10^{-2}	7.3×10^{-2}		1.1×10^{-1}
Pu-238, 239		2.2×10^{-2}		2.2×10^{-2}
Other beta, gamma[c]		9.3×10^{-2}	5.0×10^{-6}	9.3×10^{-2}
Other alpha[c]			3.0×10^{-7}	3.7×10^{-7}

a. Based on du Pont, 1982.

b. Thirty percent of tritium is assumed to evaporate and be released to the atmosphere at ground level.

c. For calculational purposes, other (unidentified) β, γ releases were assumed to be evenly divided between Sr-90 and I-129; other (unidentified) α releases were assumed to be evenly divided between Pu-239 and Am-241.

Operation of the L-Reactor will result in the generation of about 570 cubic meters of solid waste annually from the reactor itself and about 5700 cubic meters, containing about 86,000 curies of radioactivity, from the fuel fabrication and fuel reprocessing areas.

Additional information on waste management operations, including the disposal of SRP high-level waste, is contained in DOE (1982) and ERDA (1977).

Solid waste generated by reactor operations contains radionuclides from fission products and induced activity. The waste is generated during maintenance work on pipes, valves, instruments, and other reactor components; by the accumulation of radionuclides on filters for the cooling-water basin; and by the partial disassembly of fuel, target, and control rod assemblies before they are transported to the fuel reprocessing areas. Solid waste from the reactor consists of stainless-steel end fittings on fuel and target components, aluminum housing tubes, and other miscellaneous reactor parts. Other solid waste associated with reactor operations includes contaminated work clothing and plastic suits.

Table 4-19. Estimated incremental releases of radionuclides to streams from seepage basins[a] due to operation of support facilities

	Annual release rates (Ci/year)			
Radionuclide	Central shops area (CS)	Fuel fabrication area (M)	Separations areas (F&H)	Total
H-3	1.7×10^{-1}	--	2.8×10^{3}	2.8×10^{3}
Co-60	2.0×10^{-6}	--	2.5×10^{-2}	2.5×10^{-2}
Zn-65	--[c]	--	2.9×10^{-4}	2.9×10^{-4}
Ru-106	--	--	3.4×10^{-1}	3.4×10^{-1}
Sb-125	--	--	2.7×10^{-3}	2.7×10^{-3}
I-129[b]	2.5×10^{-6}	--	4.7×10^{-2}	4.7×10^{-2}
Ce-144	--	--	5.0×10^{-2}	5.0×10^{-2}
Pm-147	--	--	2.8×10^{-2}	2.8×10^{-2}

a. Outcrop activities after 30 years of L-Reactor operation.

b. Unidentified β, γ releases are assumed to be evenly divided between Sr-90 and I-129; unidentified α releases are assumed to be evenly divided between Pu-239 and Am-241. Due to long transport times in ground water, Sr-90, Pu-239, and Am-241 do not reach the outcrop area in 30 years.

c. Data not available.

Work clothing, plastic suits, and other items of a similar nature are packaged in boxes and sealed before their disposal in the SRP Burial Ground. The highly radioactive stainless steel and aluminum parts are placed in shielded casks before transport. The Burial Ground is a 195-acre area near the center of SRP between the F- and H-Separations Areas. At present, about 17,000 cubic meters of solid waste containing 260,000 curies of activity is added to the Burial Ground each year. After L-Reactor restart, the expected input will increase gradually to about 22,650 cubic meters and 350,000 curies of radioactivity per year.

4.2.2.3 Occupational dose

The operation of L-Reactor is expected to cause an incremental dose increase in the total occupational dose equivalent of about one-third of the current SRP dose (i.e., an increase of about 360 man-rem per year or a total SRP occupational dose of about 1430 man-rem).

4.2.2.4 Transportation of radioactive materials

Due to the resumption of L-Reactor operation, additional radioactive material will be transported off the Savannah River Plant. Radioactive material that requires safeguarding will be shipped in the Department of Energy's existing safe-secure transporter (SST) system with a courier escort. This transporter is essentially a mobile vault with built-in deterrent and disabling devices and special electronically coded locks set in vault-type doors; it is operated by carefully selected, specially trained personnel. All shipments of radioactive materials to and from the Savannah River Plant caused by the resumption of L-Reactor operation will meet U.S. Department of Transportation requirements [49 CFR 173.393(j)]. The risk of potential release of material from the SST vehicle during transportation is essentially zero.

4.3 DOSE COMMITMENTS FROM L-REACTOR AND ITS SUPPORT FACILITIES

Table 4-20 summarizes the maximum individual and population dose commitments from radioactive releases from L-Reactor and its support facilities. The doses listed as totals for both individuals and populations are conservative maximums, as explained in Section 4.1.2.

The composite maximum individual total-body dose of about 6 millirem per year (listed in Table 4-20) is about 16 times less than the average dose of 93 millirem per year received by an individual living near the SRP site from natural radiation. The total-body dose to both the 80-kilometer and the Beaufort-Jasper water-consumer populations of about 92 man-rem is about 0.1 percent of the approximately 80,000 man-rem delivered from natural radiation sources to those populations. These results indicate that the radiological impact to the public as a result of the resumption of L-Reactor operation will be small.

The population doses described above are received by the regional population. Certain radionuclides, primarily tritium, carbon-14, krypton-85, and iodine-129, can be transported through the atmosphere for long distances and can result in doses to the rest of the U.S. population. Most radionuclides in particulate form are deposited in the regional area.

Table A-5 (in Appendix A) summarizes the 100-year environmental dose commitment to the U.S. population from the four radionuclides identified above. The sum of the doses to the total body is about 50 man-rem; an additional 1.7 man-rem to the thyroid will result from iodine-129 releases.

Table 4-20. Summary of maximum individual and regional population total-body doses from the operation of L-Reactor and SRP support facilities

Maximum individual dose (millirem per year)		
Source of exposure	First year Dose	Tenth year Dose
Atmospheric releases	1.1	2.1
Liquid releases	0.13	0.23
Radiocesium transport	4.8	0.6
TOTAL	6	3

Regional population dose (man-rem per year)				
	Dose within 80 kilometers of SRP		Port Wentworth and Beaufort-Jasper dose	
Sources of exposure	1st year	10th year	1st year	10th year
Atmospheric releases	18	67	--	--
Liquid releases	0.14	0.15	1.7	4.3
Radiocesium transport	20	2.5	1.8	0.22
TOTAL	38	70	3.5	4.5

The radiation-induced health effects that might be caused in the U.S. population by the operation of L-Reactor and its support facilities have been analyzed by the methods described in the BEIR III report (NAS, 1980). The estimated health effects due to a single year of L-Reactor operations would be less than 0.012 premature cancer death and 0.026 genetic disorders.

4.4 CUMULATIVE IMPACTS

This section describes the impacts from SRP facilities and from major facilities near the Savannah River Plant. The Savannah River Plant facilities include the proposed Fuel Materials Facility and the planned Defense Waste Processing Facility. Major facilities near the Savannah River Plant that were considered include the Vogtle Nuclear Power Plant in Burke County, Georgia, and the Urquhart Steam Station at Beech Island, South Carolina. Dose commitments from L-Reactor and incremental support facilities operations, from total SRP, from proposed SRP facilities, and from the Vogtle Nuclear Power Plant are discussed.

4.4.1 Socioeconomics

The potential cumulative socioeconomic and land-use impacts caused by the resumption of L-Reactor operation depend heavily on the schedule of other projects at and near the Savannah River Plant. These projects include the Georgia Power Company's Alvin W. Vogtle Nuclear Power Plant in Burke County, Georgia; capital improvements projects at the Savannah River Plant; the proposed Fuel Materials Facility (FMF) at the Savannah River Plant, which will convert enriched uranium into naval nuclear propulsion fuel form; and the planned Defense Waste Processing Facility (DWPF), which will immobilize SRP high-level wastes.

The average craft construction workforce at the Vogtle project is expected to reach about 5100 in 1983 and to decline slightly in 1984, coinciding with the buildup of the construction workforce for the Fuel Materials Facility. The SRP construction workforce is expected to remain relatively constant until 1983, with decreases offset by L-Reactor renovation activities. After 1983, the SRP construction labor force is expected to increase due to capital improvements and FMF and DWPF construction. Based on the latest 9-year forecast of construction activities, the labor force is expected to increase by 2800 persons between the end of the second quarter of 1982 and the end of the third quarter of 1984.

The projected construction craft workforce demand in the 110-kilometer area around the Savannah River Plant is expected to approach a level approximately 1.7 times that of the estimated 1979 workforce. Assuming that modeling results of a DWPF scenario--reference immobilization alternative, with the Vogtle project having a peak workforce in 1985 (DOE, 1982)--are applicable to the cumulative construction worker increase at the Savannah River Plant, about 735 total workers (including overhead personnel) are expected to relocate in the six-county area.

In addition to these 735 construction-related personnel, about 255 L-Reactor operating personnel (L-Reactor plus incremental) are expected to relocate in the six-county area by the end of 1984. Thus, the cumulative workforce that might relocate into the six-county area is 990. Table 4-21 lists the projected distribution pattern of the cumulative labor force increase at the Savannah River Plant and summarizes potential socioeconomic impacts.

The cumulative construction and operational workforce increase by the end of the third quarter of 1984 is not expected to have major impacts in the six-county area. The potential relocating workforce and its associated population is expected to account for less than 1 percent of the projected 1984 population of the area. Minor impacts in housing, schools, and other public services and facilities might occur where existing or projected 1984 demands exceed current service capabilities; however, the demands placed on these services by the potential relocating workers and their families will be relatively small in relation to the total indigenous demand.

The greatest effects associated with the multiple projects at the Savannah River Plant will be on the economy of the region. As listed in Table 4-22, these projects are anticipated to provide a total of about 5040 direct and indirect job opportunities and 42 million dollars in additional direct and indirect annual income based on an estimated 235 million dollars in direct payroll and overhead expenditures. These benefits, however, will be offset partially by local and state government expenditures to serve the relocating construction and operational workers.

The incremental impacts of the resumption of L-Reactor operation are not expected to have major impacts when viewed on a cumulative basis. Compared to other SRP projects, the resumption of L-Reactor operation is expected to have the least potential impact on the area due to the small number of potential relocating operational employees and provide a stable economic benefit to the area during its years of operation.

Table 4-22. Cumulative SRP economic impact analysis, end of third quarter 1986

Categories of cost and employment	1986
Employment	
Direct employment	3055
Indirect employment	1989
Income and expenditures	
Additional direct income (current $ millions)	22
Indirect income (current $ millions)	20
Local expenditures on materials and services (current $ millions)	57

4.4.2 Surface-water usage

At the Savannah River Plant, the Savannah River supplies water for cooling the production reactors and for use in the coal-fired power plants. For the 3-year period from 1974 to 1976, the withdrawal of water from the river by the Savannah River Plant averaged 20.5 cubic meters per second. This withdrawal represented about 7 percent of the river flow past the Savannah River Plant The maximum usage during the 3-year period was about 26 cubic meters per second.

When L-Reactor operation is resumed, water withdrawal from the river will be increased by about 11 cubic meters per second and the total withdrawal rate for the Savannah River Plant will be about 37 cubic meters per second. Under 7-day, 10-year, low-flow conditions (166 cubic meters per second), the Savannah River Plant will withdraw about 22 percent of the river flow; L-Reactor's increment would be less than 7 percent of the flow. Under average flow conditions, the Savannah River Plant would withdraw about 13 percent for all its operations, including about 4 percent for L-Reactor.

4.4.3 Thermal discharge

4.4.3.1 Wetlands

The Savannah River Plant contains approximately 39,000 acres of wetlands. Of this area, some 31,400 acres consist of bottomland hardwoods; the Savannah River swamp system covers 7800 acres, of which 2800 acres are unaffected. Current SRP operations have impacted about 2000 acres of the wetlands along Beaver Dam Creek, Four Mile Creek, and Pen Branch, and about 5000 acres of the Savannah River swamp with the proposed L-Reactor operation. The total impacted wetland area on the Savannah River Plant would be about 8000 acres, or about 20 percent of the total SRP wetland area.

4.4.3.2 Thermal discharge to the Savannah River

Both the Urquhart Steam Station at Beech Island and operations at the Savannah River Plant discharge cooling-water effluent to the Savannah River from South Carolina. Thermal blowdown from the small cooling towers servicing the proposed Fuel Materials Facility and the planned Defense Waste Processing Facility will be small and will not impact the Savannah River. In addition, the Alvin W. Vogtle Nuclear Power Plant, near Hancock Landing, Georgia, will discharge its cooling-tower blowdown to the river. These thermal discharges will be permitted by Georgia or South Carolina under the National Pollutant Discharge Elimination System (NPDES).

As the result of water storage in Clarks Hill Reservoir above Augusta and its mode of discharge, the temperature of the Savannah River is as much as 8°C below the temperature that would occur in the summertime if the reservoir did not exist (Neill and Babcock, 1971). The temperature of the river water generally is increasing as the water flows past the Savannah River Plant. The South Carolina Electric and Gas Company's Urquhart Steam Station, located above the Savannah River Plant, is expected to make a small contribution to the increase in Savannah River temperature.

At present, once-through cooling-water effluent is discharged from the Savannah River Plant via three streams--Beaver Dam Creek, Four Mile Creek, and Pen Branch/Steel Creek--to the Savannah River. Beaver Dam Creek has the smallest SRP thermal effluent, which originates about equally in D-Area and C-Reactor. The temperature at the mouth of Beaver Dam Creek typically ranges from 5.5° to 11.1°C above the temperatures of the Savannah River during the warmer months (du Pont, 1982).

Four Mile Creek receives once-through cooling-water discharges from C-Reactor. The temperature of thermal effluent discharged from Four Mile Creek ranges from 16.7° to 19.4°C above Savannah River water temperatures during the late spring and summer months (du Pont, 1982).

Pen Branch receives once-through cooling-water effluent from K-Reactor. This effluent is discharged to the Savannah River through the mouth of Steel Creek. The temperature of the water released at about 15.6 cubic meters per second from the mouth of Steel Creek typically is less than 5.6°C above the water temperature of the river during spring and summer. When both K- and

L-Reactors discharged via the mouth of Steel Creek, the creek-to-river delta-T ranged to a maximum of 13.9°C and the flow rate to the river averaged about 27.4 cubic meters per second (du Pont, 1982).

The thermal plumes in the Savannah River from Beaver Dam Creek, Four Mile Creek, and Steel Creek will not interact with each other. Analyses of upstream and downstream water temperature data for the 11-year period since L-Reactor was placed on standby (1968 to 1978) suggest a 1-in-10-year maximum increase of 1.6°C in the Savannah River (fully mixed) water temperature resulting from SRP operations. With the addition of L-Reactor thermal effluent in 1984, the 1-in-10-year maximum increase is projected to be about 2.3° to 2.4°C; it will probably occur in June, July, and August during periods of low river flow. This increase was exceeded three times (3.2°C) from 1959 to 1963, when four SRP reactors discharged to the river, and once in 1966 (2.7°C) when three reactors discharged to the river. The minimum daily river flow at the Savannah River Plant was about 135 cubic meters per second between 1959 and 1978. In winter, the maximum increase in river water temperature from the operation of three reactors will be about 0.7° to 1.3°C, depending on flow conditions (du Pont, 1982).

The Vogtle Nuclear Power Plant will use natural draft cooling towers to dissipate the heat generated by the two reactor units. The heated cooling-tower blowdown will be discharged to the Savannah River at temperatures below 33°C (Georgia Power Company, 1973). Because the blowdown will be from a submerged diffuser at River Mile 150.7 at a rate of only a few cubic meters per second, it is expected that the contribution of heat to the river by the Vogtle Plant will be very small compared to the contribution from C-Reactor via the mouth of Four Mile Creek. No thermal blockage of the Savannah River by the interaction of the Vogtle Plant and Four Mile Creek plumes is anticipated. The plume from Vogtle Plant operations will dissipate quickly. Calculations show that a plume-river delta-T of 1°C will extend only about 100 meters downriver from the diffuser and the 2.8°C plume-river delta-T will extend less than 20 meters downriver and approximately 30 meters across the 105-meter-wide river (Georgia Power Company, 1973). Thus, the Vogtle plume will have dissipated before reaching the plume from Four Mile Creek at River Mile 150.4. Measurements made during conditions of near 7-day, 10-year flow (du Pont, 1982) indicate that the Four Mile Creek plume met the NPDES thermal discharge criteria as discussed in Section 4.1.1.2.

4.4.4 Radiological effects

Existing and planned facility operations in the vicinity of the L-Reactor were reviewed to determine the potential cumulative effects and to understand how sensitive the analyses in this assessment are to incremental effects from other facilities. The radiological impacts from current and planned nuclear facilities are small and well within applicable standards. These facilities are described in the following paragraphs.

- Savannah River Plant--Future projects under consideration at the Savannah River Plant include the possible construction of a Fuel Materials Facility to produce fuel forms for the naval reactor program; this facility is expected to have negligible radiological impact and will result in only a very small increment to doses from existing SRP facilities (less than 0.5 percent). Another major project being planned is the construction of the Defense Waste Processing Facility to be used to immobilize high-level radioactive wastes currently stored in tanks on the Savannah River Plant.

- Alvin W. Vogtle Nuclear Power Plant--The Vogtle Power Plant is being constructed by the Georgia Power Company about 20 kilometers from the L-Reactor. This plant is licensed by the Nuclear Regulatory Commission and its emissions will be limited to the as-low-as-reasonably-achievable level.

- Barnwell Nuclear Fuel Plant--The only other major facility near the L-Reactor with potential incremental effects is Allied-General Nuclear Service's Barnwell Nuclear Fuel Plant. The future status of this facility is unknown; at present it is not operating.

The cumulative radiation dose is the sum of the maximum doses to the different individuals; these include those from the L-Reactor, its support facilities, the rest of the Savannah River Plant, the planned Defense Waste Processing Facility and the proposed Fuel Materials Facility, and the Vogtle Nuclear Power Plant. This dose is less than 10 percent of the dose from natural background radiation (93 millirem per year); it is also a conservative estimate of the maximum individual dose, because the defined "cumulative" individual would have to be a permanent resident of several different locations to receive it (du Pont, 1982; DOE, 1982).

4.5 STUDIES AND MONITORING

The safety of the public near the Savannah River Plant is a primary concern of SRP operations, and has been so for more than 28 years. Since 1951 (before the Savannah River Plant began operation), an intensive surveillance program has been maintained to measure the concentrations of effluents and radioisotopes at the Savannah River Plant and in its environs. This section describes the environmental studies and monitoring employed at the Savannah River Plant and those programs specific to the restart of L-Reactor.

4.5.1 SRP monitoring programs

4.5.1.1 Radiological monitoring programs

Air and water are the major dispersal media for SRP radioactive emissions. Most components of the environment that could be affected by such emissions are monitored and sampled. The radiation monitoring program includes the monitoring of air on and off the site, water from SRP streams and the Savannah River, and samples of soil, vegetation, food, animals, and fish for their radionuclide content. [The radiation monitoring program is described in the du Pont DPSPU 30-1 series (e.g., du Pont, 1981b and 1981c)].

4.5.1.2 SRP nonradiological monitoring programs

The monitoring of the water quality and biota of the Savannah River has been a continuing SRP program since 1951; SRP stream water quality and ambient air have been monitored since 1972 and 1977, respectively.

Since 1951, the Academy of Natural Sciences of Philadelphia has made quarterly water quality surveys at five stations in the Savannah River (du Pont, 1982).

Water quality analyses for nonradioactive materials in the Savannah River began in 1959 and routine water quality analyses began on SRP streams in 1972. Details of the water quality monitoring program are contained in annual reports (the du Pont DPSPU 30-1 series) from 1972 to the present.

Ambient air monitoring at the Savannah River Plant began in 1977 for hydrogen sulfide (H_2S) and sulfur dioxide (SO_2). A program to monitor total suspended particulates (TSP), nitrogen oxides (NO_x), sulfur dioxide, and ozone began in the fall of 1981 and will continue. The air monitoring program and the instrumentation meet the requirements for a Prevention of Significant Deterioration (PSD) monitoring program. The monitoring of sulfur dioxide and hydrogen sulfide will continue (du Pont, 1982).

An extensive monitoring program of ground-water conditions and pollutant transport has been conducted continuously at the Savannah River Plant. Approximately 500 wells are used for ground-water monitoring (du Pont, 1982).

Since 1959, the U.S. Geological Survey has monitored the temperature and flow of the Savannah River above and below the Savannah River Plant and at the mouths of Beaver Dam, Four Mile, and Steel Creeks. These data are used at the Savannah River Plant, and such monitoring is expected to continue.

4.5.2 L-Reactor monitoring programs

Several radiological and nonradiological monitoring programs will be undertaken for the resumption of L-Reactor operation. The following sections describe these programs.

4.5.2.1 Effluent monitoring

Air and water samples from L-Reactor will be monitored routinely to detect normal and abnormal radioactive releases. Du Pont (1982) describes monitoring points for atmospheric releases and for liquid releases to streams and seepage basins.

4.5.2.2 Ground water

Permanent wells will be established to monitor pollutant loads and transport in the ground water around the L-Reactor area seepage basin. Emphasis will be placed on monitoring any pollutant transport from the L-Reactor seepage basin. Radioactivity levels, both alpha and nonvolatile beta, will be determined, as will the levels of nonradioactive parameters from water samples. These data will be used as source terms for evaluating pollutant transport and for performing dose and health effect assessments.

4.5.2.3 Radiocesium

Special studies will be conducted to determine the movement and redistribution of radiocesium after L-Reactor startup to aid in assessing the fate of the inventory in the Steel Creek drainage and the doses to individuals and populations off the site.

4.5.2.4 Ecology

Several preoperational biological baseline surveys were conducted in Steel Creek and the delta area along the Savannah River in 1981 (Smith et al., 1981). Studies during 1982 and 1983 will emphasize the use of Steel Creek and swamp by resident and anadromous fishes, waterfowl, and the American alligator.

Ecological monitoring plans following L-Reactor restart will emphasize changes in the status of Representative and Important Species (RIS) populations in the Steel Creek ecosystem. Vegetation analyses will test for shifts in mortality, biomass, and species distributions in the delta and swamp regions and studies of changes in aquatic community structure will emphasize the lower regions of Steel Creek. Changes in patterns of utilization by selected resident avifauna will be examined with respect to alterations of preferred foraging and nesting areas. Monitoring studies will test for changes in the relative abundance of selected species of many amphibian and reptile species compared with the preoperational period.

The U.S. Department of Energy intends to work closely with the U.S. Fish and Wildlife Service of the U.S. Department of the Interior with regard to any possible mitigating measures for the American alligator as the result of the restart of L-Reactor. Environmental assessment studies conducted by the Savannah River Ecology Laboratory (SREL) during the summer of 1981 and winter of 1982 (Smith et al., 1981, 1982) documented the locations of alligators from the outfall of L-Reactor to the Steel Creek delta. These studies suggest than an October startup date would allow alligators to avoid the introduction of heated water to Steel Creek and move to similar peripheral habitat.

Waterfowl, which currently utilize the open areas of the Steel Creek delta, are mobile and would be able to move to habitat of similar characteristics available in the Savannah River swamp system without excessive stress to the population. SREL studies (Smith et al., 1981) confirm that an October startup date would be the best to minimize any impacts on the production of young and nesting waterfowl.

Fishery and entrainment and impingement studies were also conducted near the SRP intakes on the Savannah River in 1977 (McFarlane et al., 1978a). A new comprehensive sampling program designed to evaluate impingement, entrainment, and thermal plume impacts from L-Reactor on the aquatic life in the river will be conducted before and after L-Reactor begins operation. Meroplankton (fish eggs, larvae, and macroinvertebrate drift) will be collected and identified from river transects above and below the intake pumphouses, below Steel Creek, in the intake pumphouse canal mouths, and in the mouth of Steel Creek. Collections will be made during peak spawning periods. Quantitative collections will be made of the fish impinged at the pumphouses. Fish population estimates will be made near the pumphouses, thermal plumes, pumphouse canal mouths, and Steel Creek. Collections of macroinvertebrates and periphyton will be made in the transects across the thermal plume in the mouth of Steel Creek.

4.5.2.5 Archeology

An archeological and historic survey was conducted during January and February of 1981 on the Steel Creek terrace and floodplain system below the L-Reactor area. Five sites (one significant, four potentially significant) were determined to be of sufficient content, integrity, and scientific value to be covered by a protection plan to ensure their preservation. A monitoring plan will be developed for the approval of the South Carolina State Historic Preservation office before implementation to prevent the destruction of these sites by erosion caused by the increased water flow down Steel Creek from L-Reactor.

4.6 NO-ACTION ALTERNATIVE

The no-action alternative involves the continuation of L-Reactor in a standby mode, with none of the environmental effects associated with the reactor restart and continued operation. The environment conditions would be similar to those portrayed in Chapter 3, Affected Environment.

REFERENCES FOR CHAPTER 4

ANSP (Academy of Natural Sciences of Philadelphia), 1953. Savannah River Biological Survey, South Carolina and Georgia, June 1951-May 1952, Final Report.

ANSP (Academy of Natural Sciences of Philadelphia), 1957. Savannah River Biological Survey, South Carolina and Georgia, August-September 1955, May 1956, Progress Report.

ANSP (Academy of Natural Sciences of Philadelphia), 1961. Savannah River Biological Survey, South Carolina and Georgia, May-June and August-September 1960.

ANSP (Academy of Natural Sciences of Philadelphia), 1967. Savannah River Biological Survey, South Carolina and Georgia, May-June and September 1965.

ANSP (Academy of Natural Sciences of Philadelphia), 1970. Savannah River Biological Survey, South Carolina and Georgia, May and August, 1968.

ANSP (Academy of Natural Sciences of Philadelphia), 1977. Savannah River Biological Survey, South Carolina and Georgia, August, 1976.

Cherry, D. S., R. K. Gathrie, J. H. Rogers, Jr., J. Carins, Jr., and K. L. Dickson, 1976. "Response of Mosquitofish (Gambusia affinis) to Ash Effluent and Thermal Stress," Transactions of the American Fisheries Society, Volume 105(6), pp. 686-694.

Clarke, R. K., J. T. Foley, W. F. Hartman, and D. W. Larson, 1976. Severities of Transportation Accidents. SLA-74-0001. Sandia National Laboratory. Albuquerque, N.M.

DOE (U.S. Department of Energy), 1982. Environmental Impact Statement, Defense Waste Processing Facility, Savannah River Plant, Aiken, South Carolina, DOE/EIS-0082.

du Pont (E. I. du Pont de Nemours and Company), 1981a. Savannah River Plant NPDES Permit Application, compiled for the Department of Energy, Savannah River Plant, Aiken, South Carolina.

du Pont (E. I. du Pont de Nemours and Company), 1981b. Environmental Monitoring in the Vicinity of the Savannah River Plant--Annual Report for 1980, DPSPU-81-30-1, Savannah River Laboratory, Aiken, South Carolina.

du Pont (E. I. du Pont de Nemours and Company), 1981c. Environmental Monitoring at the Savannah River Plant--Annual Report for 1978, DPSPU-79-302, Savannah River Laboratory, Aiken, South Carolina.

du Pont (E. I. du Pont de Nemours and Company), 1982. Environmental Information Document, L-Reactor Reactivation, DPST-81-241 Savannah River Laboratory, Aiken, South Carolina.

ERDA (Energy Research and Development Administration), 1977. Environmental Impact Statement, Waste Management Operations, Savannah River Plant, Aiken, South Carolina (ERDA-1537), U.S. Government Printing Office, Washington, D.C.

Falke, J. D., and M. H. Smith, 1974. "Effects of Thermal Effluent on Fat Content of Mosquitofish," in J. W. Gibbons and R. R. Sharitz (eds.), Thermal Ecology, AEC Symposium Series (CONF-730505). pp. 100-108.

Fenimore, J. W., and J. H. Horton, 1972. Operating History and Environmental Effects of Seepage Basins in Chemical Separations Areas of the Savannah River Plant, DPST-72-548, E. I. du Pont de Nemours and Company, Savannah River Laboratory, Aiken, South Carolina.

Ferens, J. C., and T. M. Murphy, 1974. "Effects of Thermal Effluents on Regulations of Mosquitofish," in J. W. Gibbons and R. R. Sharitz (eds.), Thermal Ecology, AEC Symposium Series (CONF-730505). pp. 237-247.

Georgia Power Company, 1973. Alvin W. Vogtle Nuclear Plant, Applicant's Environmental Report, Amendment 1.

Geisy, J. P., and L. A. Briese, 1978. "Trace Metal Transport by Particulates and Organic Carbon in Two South Carolina Streams," Verh. Internat. Verein. Limnology, Volume 20.

Gibbons, J. W., and R. R. Sharitz, 1974. "Thermal Alteration of Aquatic Ecosystems," American Scientist, Volume 62. pp. 660-670.

Horton, J. H., 1974. Mercury in the Separations Area Seepage Basins, DPST-74-231, E. I. du Pont de Nemours and Company, Savannah River Laboratory, Aiken, South Carolina.

Horton, J. H., and G. A. Carothers, 1974. Nitrate in the Separations Areas Seepage Basins, DPST-74-293, E. I. du Pont de Nemours and Company, Savannah River Laboratory, Aiken, South Carolina.

Kiser, D. L., 1977. "Modeling of Sediment Transport in Reactor Effluent Streams", in T. V. Crawford (compiler), Savannah River Laboratory Environmental Transport and Effects Research, DP-1455, E. I. du Pont de Nemours and Company, Savannah River Laboratory, Aiken, South Carolina.

Langley, T. M., and W. L. Marter, 1973. The Savannah River Plant Site, DP-1323, E. I. du Pont de Nemours and Company, Savannah River Laboratory, Aiken, South Carolina.

Marter, W. L., 1970. Savannah River Water Quality Studies, 1965-1969, DPST-70-445, E. I. du Pont de Nemours and Company, Savannah River Laboratory, Aiken, South Carolina.

McFarlane, R. W., 1976. "Fish Diversity in Adjacent Ambient, Thermal, and Post Thermal Fresh-water Streams," in G. W. Esch and R. W. McFarlane (eds.), Thermal Ecology II, ERDA Symposium Series 40 (CONF-750425). pp. 268-271.

McFarlane, R. W., R. F. Frietsche, and R. D. Miracle, 1978a. Impingement and Entrainment of Fishes at the Savannah River Plant, DP-1494, E. I. du Pont de Nemours and Company, Savannah River Laboratory, Aiken, South Carolina.

McFarlane, R. W., R. F. Frietsche, and R. D. Miracle, 1978b. "Community Structure and Differential Impingement of Savannah River Fishes," in Proceedings of the Annual Conference of the Southeast Fisheries and Wildlife Agencies, Volume 33.

NAS (National Academy of Sciences, Committee on the Biological Effects of Ionizing Radiation), 1980. The Effects on Populations of Exposure to Low Levels of Ionizing Radiation: 1980, National Academy Press, Washington, D.C.

Neill, J. S., and D. F. Babcock, 1971. The Dissipation of Reactor Heat at the Savannah River Plant, DP-1274, E. I. du Pont de Nemours and Company, Savannah River Laboratory, Aiken, South Carolina.

Ruby, C. H., P. J. Rinehart, and C. L. Reel, 1981. Sedimentation and Erosion Trends of the Savannah River Plant Reactor Discharge Creeks, Research and Planning Institute Report RPI/R/8124-22, Columbia, South Carolina.

SCDHEC (South Carolina Department of Health and Environmental Control), 1979. Hazardous Waste Management Regulations, R.61-79 through R.61-79.11, Columbia, South Carolina.

SCDHEC (South Carolina Department of Health and Environmental Control), 1981. Water Classification Standards, Columbia, South Carolina.

Smith, M. H., R. R. Sharitz, and J. B. Gladden, 1981. An Evaluation of the Steel Creek Ecosystem in Relation to the Proposed Restart of L-Reactor, SREL-9/UC-66e, Savannah River Ecology Laboratory, University of Georgia, Aiken, South Carolina.

Smith, M. H., R. A. Sharitz, and J. B. Gladden, 1982. An Evaluation of the Steel Creek Ecosystem in Relation to the Restart of the L-Reactor: Interim Report, SREL-11/UC-66e, Savannah River Ecology Laboratory, University of Georgia, Aiken, South Carolina.

U.S. AEC (Atomic Energy Commission), 1972. Environmental Survey of Transportation of Radioactive materials to and from Nuclear Power Plants. WASH-1238.