ENVIRONMENTAL INFORMATION DOCUMENT L-REACTOR REACTIVATION

MASTER

**E. I. du Pont de Nemours & Co.
Savannah River Laboratory
Aiken, SC 29808**

PREPARED FOR THE U. S. DEPARTMENT OF ENERGY UNDER CONTRACT DE-AC09-76SR00001

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Compiler

Halkard E. Mackey, Jr.

Approved by

**T. V. Crawford, Research Manager
Environmental Analysis and Planning Division**

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FOREWORD

The purpose of this Environmental Information Document (EID) is to provide background for assessing environmental impacts associated with the renovation, restart, and operation of L Reactor at the Savannah River Plant (SRP). SRP is a major U. S. Department of Energy (DOE) installation for the production of nuclear materials for national defense. The purpose of the restart of L Reactor is to increase the production of nuclear weapons materials, such as plutonium and tritium, to meet projected needs in the nuclear weapons program.

This report consists of ten chapters dealing with the following subject areas.

Chapter 1, "Introduction and Summary," presents a summary of the proposed action and environmental impacts of that action.

Chapter 2, "The Site," describes the environment in which L Reactor will function. Regional demography and water use are characterized. The geology, hydrology, and meteorology of the site are discussed. The plant and animal life of the impacted floodplains and wetlands is described. Radiological levels from natural background and cesium deposition are characterized.

Chapter 3, "Facility Description," contains a brief description of the reactor area and its function and the expected source terms during operation.

Chapter 4, "Environmental Effects of Site Renovation and Upgrading," identifies the resources to be committed and the environmental effects to be expected during upgrading and renovation of L Reactor.

Chapter 5, "Environmental Effects of Facility Operation," presents and discusses the projected effects on the environment from operating L Reactor. The effects of radiological discharges and of discharge of once-through cooling water are discussed.

Chapter 6, "Effluent and Environmental Measurements and Monitoring Programs," summarizes the existing SRP monitoring program and expected changes for L-Reactor restart.

Chapter 7, "Environmental Effects of Accidents," describes potential accidents for operation of L Reactor and summarizes the radiological consequences.

Chapter 8, "Socioeconomic Effects of Reactivation and Operation," summarizes the projected work forces and probable effects on the region.

Chapter 9, "Alternative Mitigation Measures for L-Area Operations," describes potential mitigation measures for release of once-through cooling water, steam supply for L-Area, sanitary waste discharge, and containment and/or confinement improvements.

Chapter 10, "Environmental Compliance Plan," includes a listing of state and Federal approvals needed for L-Reactor restart.

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1. INTRODUCTION AND SUMMARY OF IMPACTS

1.1 INTRODUCTION

The proposed action is to resume the operation of L-Area Reactor at the Savannah River Plant (SRP) to produce special nuclear materials. The need for L Reactor operation is based upon long-range resource planning studies which indicate that the demand for nuclear weapons materials, such as plutonium and tritium, will exceed the production capability of the three currently operating production reactors (C, K, and P Reactors) at SRP as well as that of the single production reactor (N Reactor) at Hanford, subsequent to 1985. Although a number of other actions are being taken to increase special materials availability, L Reactor is the only addition production reactor which can be added to the system in time to alleviate the production shortage. The return of L Reactor to operation to produce additional weapons materials for national defense is planned for October 1983. The purpose of this document is to present information necessary for assessing the impacts of the resumption of L-Reactor operation.

L Reactor is of the same design as the three operating reactors of SRP, which are heavy-water (D_2O) moderated and cooled nuclear production reactors (Section 3.3). L Reactor began operation in 1954 and operated until 1968, at which time, due to decreasing demand for special nuclear materials, it was placed in standby status. L Reactor has been in standby status for about 14 years, and was not modified and upgraded during this period as have been C, K, and P Reactors. These modifications were made to enhance safety and operational reliability. Prior to operation, L Reactor will be upgraded and modified to the present conditions of the C, K, and P Reactors, and extensive inspection and maintenance of L Reactor will be performed. These upgrading and renovation activities will cost about 160 million (1981) dollars.

Prior to startup, special studies will be conducted to evaluate and identify potential environmental impacts and to determine whether mitigation measures are necessary to ensure compliance with environmental requirements. Environmental compliance requirements and mitigation measures will be instituted as appropriate.

1.2 EXISTING ENVIRONMENT

L Reactor and its associated support buildings are within the fenced 82-acre 100-L Area (Figure 3.1-1) on the 300-square-mile, controlled access SRP (Figure 2.1-2). L Reactor is located at a minimum of 8.6 miles from the SRP boundary. The SRP site occupies parts of Aiken, Barnwell, and Allendale Counties, South Carolina. It is 25 miles southeast of Augusta, Georgia, and is bounded on the southwest by the Savannah River. The surrounding communities are mostly rural or residential with Augusta, Georgia, being the only major metropolitan area within a 50-mile radius (Figure 2.2-1).

The SRP site has a humid, mild, temperate climate (Section 2.4) and consists mainly of upland pine forest and floodplain swamps. The site is a National Environmental Research Park where the land is managed by the U.S. Forest Service for the Department of Energy (DOE).

L-Reactor cooling water will be drawn from the Savannah River (Section 5.2.2.1) and after passing through the heat exchangers will be discharged into Steel Creek which enters the Savannah River through a large swamp (Section 5.2.1.1). When the Savannah River is below flood level, Steel Creek water enters the Savannah River about nine miles to the south of L Area. When flooding occurs, about 20-25% of the time, the river overflows the natural levee that separates the swamp and the river. During flood stages, the water from Steel Creek will flow parallel to the Savannah River past the southeastern corner of the SRP boundary and across about four miles of offsite swamp (Creek Plantation Swamp, Section 2.5.1.3). The water then enters the Savannah River at an oxbow of the river, Little Hell Landing.

1.3 EXPECTED ENVIRONMENTAL IMPACTS

L Reactor began operation in 1954 and operated for 14 years before being placed on standby in early 1968. Installation of modernized equipment will be mainly in existing buildings and operating areas. Experience with previous upgrading activities at the three operating reactor areas indicates that the upgrading activities at L Area will have the following effects: occupational exposure, socioeconomic impact of additional workers, and commitment of resources. These effects of renovation and upgrading are considered to have minimum environmental consequence (Chapters 4 and 8) and will reduce the environmental impact of operating L-Reactor to less than the impact of previous operations from 1954-1968.

Operation of L Reactor and associated facilities at SRP will release radionuclides, nonradioactive effluents, and once-through

cooling effluent to the environment. The expected impacts of these environmental releases are summarized below.

1.3.1 Incremental Radiation Exposure Due to Routine and Abnormal Operations

Releases of radioactive materials from SRP operations will be in compliance with DOE Order 5480.1.¹ The environmental impact analyses of present SRP releases are given in ERDA-1537.² Environmental releases and estimated impacts are also published in annual SRP reports.³

The sum of the total body dose commitment during the initial years following L-Reactor startup to offsite population groups is 37.1 man-rem per year, of which 92% is from atmospheric releases and 8% is from liquid releases (Table 1.3-1 and Section 5.1.2). The operation of L Reactor and the associated SRP facilities represents about 37% increase in radiological impact over current (1978-1980) SRP operations. In addition to routine releases, the resuspension of cesium-137 from Steel Creek to the Savannah River could add an additional 36.5 man-rem to the offsite population dose during the first year of operation under projected "worst case" conditions of low river water flow (Table 1.3-1). This dose would decline during subsequent years of operation by about 20% per year. The total offsite radiological impact from SRP operations after startup of L Reactor is expected to be only about 0.2% of the population dose of about 80,800 man-rem per year from natural radiation sources.

1.3.1.1 Atmospheric Releases

About 90% of the calculated offsite population dose commitment from SRP releases is due to atmospheric releases. The main dose contributors are tritium (78%) and argon-41 (13%). No unusual radiological releases will be presented by the normal operation of L Reactor. About 25.5 man-rem per year will result from L-Area atmospheric releases and 5.4 man-rem per year from releases due to throughput in the separations areas (Section 5.1.1.1). This represents about a 31% increase over present SRP operations.

1.3.1.2 Aqueous Releases

1.3.1.2.1 Surface Stream Releases

The calculated offsite population dose commitment from aqueous releases to surface streams is estimated to be about 2.1 man-rem for an average year due to the operation of L Reactor

TABLE 1.3-1

Radiological Impact - Comparison of L-Reactor with Current SRP Operation

	Maximum Total, Body Dose Commitment to the 80 km Population, <u>Man-Rem/Year of Operation</u>
L-Reactor Operation	
Atmospheric Releases (each year)	30.9
Liquid Releases to Streams (each year)	2.1
Seepage Basin Migration (fourth year)	4.1
Total Routine L-Reactor Operation	37.1
Cesium from Steel Creek (first year)*	36.5
Cesium from Steel Creek (tenth year)*	4.4
Current SRP Operation	99.4
Natural Radiation Exposure	80800

* Under projected "worst case" conditions of low river water flow 6100 cfs.

and processing throughput in the separations area (Table 1.3-1). Most of the dose commitment will be due to tritium release (Section 5.1.1.2). This represents about a 2% increase over present SRP operations.

1.3.1.2.2 Seepage Basin Releases

The calculated maximum offsite dose commitment from aqueous releases of radioactive materials to seepage basins occurs at 4.4 years as a result of discharges primarily to the L-Area seepage basin (Section 5.1.1.2.7). The highest total body dose is 2.7 man-rem per year plus 1.4 man-rem per year from tritium evaporation for a total of 4.1 man-rem per year (Table 1.3-1). This represents about a 4% increase over present SRP operations.

1.3.1.2.3 Cesium-137 Dose Estimates

The calculated offsite population dose commitment from cesium resuspension and movement offsite to the Savannah River is estimated under "worst case" conditions to be about 36.5 man-rem during the first year of L-Reactor operation. This dose is expected to decrease about 20% per year with subsequent years of operation and is estimated to be about 4.4 man-rem in the tenth year (Appendix D).

The calculated maximum adult individual whole body dose from cesium release and transport from Steel Creek will be about 8.2 mrem for the first year of L-Reactor operation under "worst case" conditions of low river water flow or 4.8 mrem under average flow conditions. The cesium-137 maximum adult individual whole body dose will be greater than that from current SRP operations for the first 7 years of operation (Section 5.1.1.3.2). The "worst case" maximum is about equal to the SRP Technical Standard limit of 10 mrem/year the first year, but is expected to be less than this guideline the second year of L-Reactor operation. The NRC limit via the aquatic pathway for a multireactor site is 5 mrem/year. This limit will be exceeded for the first two years of operation only if "worst case" conditions exist.

Cesium-137 transport onto Creek Plantation Swamp may also increase the external cesium-137 radiation field on Creek Plantation Swamp from about 92 mrem/year to about 115 mrem/year or about 25%. The average individual whole body dose would be increased by 13% to about 230 mrem/year (Section 5.1.1.3.3). The external dose rates in Creek Plantation Swamp now range from 40 to 480 mrem/year (Section 2.7.2.3).

1.3.2 Potential Accidental Releases

SRP reactors have operated for a total of 115 reactor-years without any unusual operating incidents (accidents) that resulted in the release of radioactivity to the public. Thus, the accident consequences described in Chapter 7 are highly unlikely "worst case" types of analyses. Accidents of this type also provide the design bases for the reactor shutdown systems, the airborne activity confinement systems, and the emergency cooling systems as described in Chapter 3.

The hypothesized SRP reactor accidents cover a spectrum of unlikely events leading to release of radioactivity (Section 7.5). Accidents are discussed which give a range of consequences. These accidents include a moderator spill, a discharge mishap in which an irradiated fuel assembly is dropped and melts, a misloading criticality in which seven fuel assemblies melt, and a loss-of-coolant accident in which it is assumed that 2% of the reactor core melts. A 2% core melt is twice as high as the 1% melting that would be expected if only one of the three top addition systems of the Emergency Cooling System is operative. A 1% core melt is the "design basis" for SRP reactors. In addition, the consequences of a postulated 10% core melt are assessed.

The effects of each accident are compared with the criterion given in 10 CFR 100.⁴ For the postulated accident at the 10% core melting level, the estimated dose is 1.0 rem whole body or 1/25 and 7.4 rem to the thyroid or 1/40 of the guideline value (Section 7.5.4). The risks from the postulated accidents range from less than 1×10^{-5} millirem per year to 4×10^{-3} millirem per year (Section 7.5.6).

1.3.3 Cooling Water Impacts

1.3.3.1 Thermal Discharges to the Savannah River

SRP routinely discharges cooling water from a coal-fired power plant (D Area) and two reactors (C Reactor and K Reactor) to the Savannah River floodplain and then to the river itself (Section 5.2.1). Part of the C-Reactor effluent to Four Mile Creek combines with the D-Area effluent to Beaver Dam Creek before discharging to the Savannah River. Part of the C-Reactor effluent discharges via Four Mile Creek to the river, and the remainder flows through the floodplain swamp combining with the K-Reactor effluent. K-Reactor effluent flows via Pen Branch through the swamp where it discharges to the Savannah River via the Steel Creek mouth. A third operating reactor (P Reactor) discharges into an onsite cooling reservoir; thus, this cooling water system is effectively a closed loop; however, occasionally, a small

discharge to Steel Creek is necessary. L-Reactor cooling water effluent will flow via Steel Creek to the Savannah River.

Computer modeling studies (Section 5.2.1.2.3 and Appendix E) and monitoring data indicate that a mixing zone at least 1.5 miles long will occur downstream of the Steel Creek mouth in the Savannah River with the startup of L Reactor.⁵ This mixing zone is not expected to exceed one-third of the surface area nor one-fourth of the cross-sectional area of the river under typical flow conditions (Section 5.2.1.2.3). A "zone of passage" for anadromous fishes will remain in the river. Historic data indicate that present and past SRP operations increase the overall Savannah River water temperature from one to two degrees centigrade (Figure 5.2-16). L Reactor is expected to add less than 0.5°C to the Savannah River water temperature (Figures 5.2-17 and 5.2-18). Twenty-five years of biological monitoring data from SRP by the Academy of Natural Sciences of Philadelphia have not detected any biologically significant effects in the Savannah River from SRP operations, including the previous period of L-Reactor operations. The overall thermal effect on the river is expected to be minimal.

1.3.3.2 Cooling Water Intake Effects — Impingement and Entrainment

L-Reactor operations will increase cooling water withdrawal from the Savannah River by about 40 to 50% above current uses (Section 5.2.2). The present SRP use is about 7% of the average flow of the Savannah River of about 10,200 cfs. Increasing water volume by 50% would lead to an additional 1,715 fish being impinged per year or about 5 fish per day (Section 5.2.2.3.2).^{6,7}

An impingement and entrainment study in 1977 demonstrated that the most commonly entrained fish eggs at the SRP river pump-houses were eggs of American shad, an important commercial fish from the Savannah River.⁶ From 1970 to 1979, the yearly catch ranged from 19,000 to 127,000 pounds. Most of the catch is near the coastal regions of the river, and most of the spawning is probably upstream of SRP.⁶ Assuming a 50% increase in water withdrawn, all of SRP reactors, including L-Reactor, would remove about 10.0 million eggs or 13.9% of the number in the vicinity of the SRP pumphouses. This represents the reproductive capacity of 27 to 28 female American Shad.

The most commonly entrained fish larvae are those of another anadromous fish, the blueback herring, which spawns in swamp floodplains along the Savannah River. Under conditions similar to those of the 1977 survey, a 50% increase in cooling water pumping for all SRP reactors could result in a total of 29 million larvae being entrained or 13.5% of the total larvae in the river near SRP pumphouses.

These assessments of impingement and entrainment indicate that additional pumping with L-Reactor restart should have little impact on fisheries in the Savannah River (Section 5.2.2).

1.3.3.3 Wetlands/Floodplains Impacts

Steel Creek and its floodplain received thermal effluents from both P and L Reactors. P Reactor cooling water effluent was diverted to PAR Pond reservoir in 1963, and L Reactor was placed on standby in 1968. Since thermal discharges to Steel Creek were discontinued in 1968, the stream and swamp have been repopulated with a variety of invertebrates and vertebrates. The Steel Creek delta and floodplain have been revegetated and stabilized with extensive herbaceous and shrub growth. The delta and swampland now provide habitat for about a hundred wood ducks and several hundred waterfowl overwinter in the swamp near the Steel Creek delta. Wading birds, such as the potentially endangered wood-stork, are occasionally attracted to the Steel Creek delta area for feeding. A small reproducing American alligator population is found along Steel Creek and in the Steel Creek delta.

Release of cooling water effluent from L Reactor will impact the existing fauna of Steel Creek. Vegetational cover will be removed from 1010 acres along the creek and in the delta area. The species and ecosystem of the impacted area would revert to a condition similar to that before L Reactor was placed on standby in 1968.

Evaluation of these effects on the swamp floodplains will be performed in order to demonstrate compliance with Executive Orders 11988 (Floodplain Management)⁸ and 11990 (Protection of Wetlands)⁹ and 10 CFR 1022 (DOE Compliance with Floodplain Wetlands Environmental Review Requirements).¹⁰

Alternative methods for cooling the L-Reactor thermal discharge are described in Chapter 9. The once-through cooling alternatives provide little if any mitigation over the planned mode of operation, that is, direct discharge of once-through cooling water to Steel Creek. The once-through diversion alternatives could reduce the redistribution of cesium-137 in the Steel Creek sediments; however, other wetlands would be impacted. Cooling towers, recirculation to PAR Pond, and new recirculation cooling ponds (L Pond and/or KAL Pond) could mitigate the wetland/floodplain impacts. However, these recirculation cooling alternatives could not be implemented before October 1983 and would cost in excess of 39 million dollars.

1.3.3.4 Species of Special Concern — Endangered Species

A population of over 100 adult American alligators is found on SRP. The largest population is found on PAR Pond, a 2650-acre

cooling reservoir. American alligators are also found in the Savannah River floodplain, the Beaver Dam Creek area, and in the revegetated areas of Steel Creek and the Steel Creek delta. Two nest sites, a few adults, and about two dozen juveniles have been found in the Steel Creek area. A biological assessment is currently under way to provide the necessary information for consultation with the U.S. Fish and Wildlife Service under the Endangered Species Act.¹¹

The operation of L Reactor is expected to reduce the Steel Creek habitat available for American alligators on SRP, but to have no long-term effect on their continued survival on SRP or the recovery of the species in the southeastern United States.

A few other species of "special concern" are known from the Steel Creek area (Section 2.6.2.5). L-Reactor startup should have no significant effect on these species.

1.3.3.5 Resuspension of Cesium-137 in the Steel Creek Area

During a period when failed fuel elements were stored in disassembly basins with once flow-through circulation in P and L Areas, about 268 curies of cesium-137 was released to Steel Creek (Section 2.7.2). An estimated 160 curies or less* is still deposited in the sediments of the Steel Creek floodplain or the Steel Creek delta. Aerial radiological surveys in 1974¹² and SRP monitoring data reveal that the cesium has moved very little since L Reactor was placed on standby. With the restart of L Reactor, it is estimated that 9.8 curies of cesium-137 will be transported from Steel Creek into the Savannah River during the first year of operation. During the second year, it is estimated that about 7.2 Ci will be transported to the Savannah River. A 20% decrease per year is expected in subsequent years. Based upon these cesium-137 releases, the concentrations in the Savannah River will be about 1.8 pCi/L the first year and about 1.3 pCi/L the second year under conditions of low river water flow (Section 5.1.1.3.1). The highest concentration measured previously in the Savannah River was 2.7 pCi/L in 1966. An estimated 2.2 Ci of cesium-137 could be deposited on Creek Plantation Swamp the first year of L-Reactor operation and possibly 1.7 Ci the second year. It is not expected that the cesium-137 inventory in Creek Plantation Swamp would exceed the previous levels of about 28 Ci. Current inventory is 21 Ci as a result of radioactive decay.

1.3.4 Other Liquid Discharges

The existing SRP National Pollution Discharge Elimination System (NPDES) permit for SRP discharges to streams expired in

* Estimates range as low as 67 curies.

November 1981. Application for permit renewal⁵ was submitted in May 1981. In the application for permit renewal, L-Area discharges were listed as inactive. Examples of L-Area effluents subject to NPDES permit limitations are sewage effluent, process sewers, cooling water effluent and sediment release from the cooling water retention basins (186-basins). All routine discharges will meet permitted NPDES requirements and are expected to have minimal chemical impact on Steel Creek and the Savannah River (Section 5.4). The existing 100-yard mixing zone (established after L Reactor was placed on standby) in the present SRP NPDES permit at the mouth of Steel Creek is expected to be modified to accommodate an increased mixing zone length (Section 5.2) in the Savannah River below the mouth of Steel Creek. A sufficient zone of passage for fish moving up and down stream will exist.

1.3.5 Waste Management Impacts

Depending upon the mode of operation, the additional throughput of nuclear fuel from the operation of L Reactor will generate between 0.3 to 0.6 million gallons of high-level liquid waste per year. This waste will be stored in double-shelled waste tanks on SRP, as with other SRP high-level waste.² The waste will be concentrated by evaporation to about 0.1 to 0.2 million gallons to minimize storage capacity. Waste generation and storage plans indicate that no additional waste tanks will be required beyond the tanks already planned for construction (Section 5.6.5.1).

The current plan for disposal of SRP high-level waste is to convert it into a canister and solid disposable form for geological disposal.¹³ The extra waste from L Reactor will generate an additional 6300 to 12,000 cubic feet of solidified waste per 10 years of operation (borosilicate glass is the current reference matrix form for this waste).¹³ This much solid waste corresponds to about 250 to 500 additional canisters, compared to 8000 canisters projected to be required for other SRP wastes (Section 5.6.5.3).

The concentrated decontaminated salt from the proposed SRP high-level waste solidification program is expected to be buried as a solid waste, "saltcrete." The saltcrete from all SRP wastes will occupy about 25 acres of land. The saltcrete from additional operation of L Reactor for ten years would commit an additional 0.75 acre of burial site (Section 5.6.5.3).¹³

Operation of L Reactor and associated facilities at SRP will generate about 200,000 cubic feet of low-level waste for burial at SRP. This volume of waste will occupy about one acre of the burial ground space for each year of operation of L Area. The low-level waste burial ground at SRP is a 195-acre site centrally located on SRP,² of which about 35 acres can be used for future burial.

References 2 and 13 contain detailed information on waste management operations at SRP, proposed plans for future disposal, and descriptions of environmental impacts.

1.3.6 Air Quality Impacts

L Area will operate on purchased electrical power produced by coal-fired plants operating offsite (Section 5.3.1). Process steam will be provided by an interarea steam line from the K-Area power plant. The K-Area power plant will consume an additional 7000 tons of coal per year to meet L-Area steam demands. It will release an additional 130 tons of SO₂, 52 tons of NO_x, and 28 tons of suspended particulates to meet L-Area demands. The particulates should be deposited onsite because the nearest SRP boundary is over eight miles. In addition, the continuously operated emergency diesels in L Area will produce about 4 tons of SO₂ and 59 tons of NO_x. An additional 150 tons of NO_x will be added from related process operations in the F, H, and M Areas. In total, L Area and related operations will contribute about 1.1 µg/m³ NO_x to the ambient air at the SRP boundary. This compares to 15-23 µg/m³ NO_x estimated for all other SRP sources in 1985. Total SO₂ and suspended particulates will add less than 1 µg/m³ each at the SRP boundary.

No significant changes in ambient air quality are expected from SRP operations related to L Reactor restart (Section 5.3.6).

1.3.7 Socioeconomic Impacts

The current socioeconomic profile of the local communities surrounding SRP is given in Reference 14. These data make it possible to evaluate the effect of L Reactor operation on other large projects in the area, such as the Vogtle Nuclear Plant in Georgia and the proposed Defense Waste Processing Facility.^{15,16} It is anticipated that upgrading of L Reactor will provide continued employment for the SRP onsite construction force (Chapter 8). Manpower requirements should not interrupt ongoing SRP activities. Eventually, the SRP work force would increase by about 510 individuals or by about 7%. Most of this work force is expected to be from the local region. New hires from outside the region are expected to relocate in Aiken, North Augusta, and Augusta with little effect on the local region. The manpower requirements for upgrading and operation of L Reactor are expected to have a modest economic benefit to the local regional economy with no significant negative impacts anticipated.

1.4 CONCLUSIONS

SRP has operated as many as five production reactors at various times over the last 28 years with no serious offsite impacts. L-Reactor operation will cause impacts to floodplains and wetlands along Steel Creek and its delta on the SRP site similar to those experienced during previous L-Reactor operations from 1954-1968. About 1010 acres of wetlands which have revegetated since L Reactor was placed on standby in 1968 will be re-impacted by cooling water effluent and will no longer function as viable ecosystems during renewed L-Area operations. These wetlands would be expected to recover again after L Reactor ceases operation. Some cesium-137 redistribution is expected along Steel Creek and its delta and remobilization to the Savannah River and offsite onto Creek Plantation Swamp are likely. These impacts can be mitigated, but costs are high, environmental tradeoffs would be experienced and delays in reactor startup would be likely.

The other impacts of L Reactor startup are considered small incremental increases to present SRP operations.

1.5 REFERENCES

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2. SITE

2.1 SITE LOCATION AND LAYOUT

The Savannah River Plant (SRP) occupies a site in South Carolina of about 300 square miles bounded on the southwest by the Savannah River and centered approximately 25 miles southeast of Augusta, Georgia (Figure 2.1-1). The SRP site has an elevation between 90 and 340 feet above mean sea level (msl) with operating areas draining toward the Savannah River. The grade level elevation of L-Area Reactor at SRP is 251 feet above msl. The SRP lies on the Atlantic Coastal Plain physiographic province and is underlain by the Tuscaloosa aquifer from which wells supply water to several operating areas of SRP including L Area.

The locations of the production areas are shown in Figure 2.1-2 along with the general drainage pattern for runoff water from the site. Cooling water from reactors is discharged to a cooling impoundment, Par Pond, or through streams and swamps that drain to the Savannah River.

The location of L Area is shown in Figure 2.1-2. L Area is about 3 miles (5 kilometers) from public Road 125 and about 5.6 miles (9 kilometers) from the SRP boundary. Normal radioactive atmospheric discharge from L Area is by way of a stack (200 feet above grade), Figure 2.1-3. Normal liquid radioactive discharges from the reactor building will occur to Steel Creek and to a seepage basin shown in Figure 2.1-3. The basin has no overflow or outfall. Nonradioactive liquid discharges from L Area are to Steel Creek.

Steam and electricity will be supplied to L Area from remote facilities. Steam will be delivered to L Area from K Area by a pipeline (Section 3.2.3). Electricity will be supplied by two 115-kV transmission lines (Section 3.2.2).

FIGURE 2.1-1. Location of SRP Relative to Surrounding Population Centers

FIGURE 2.1-2. The Savannah River Plant Site

FIGURE 2.1-3. L Area and Vicinity

2.2 DEMOGRAPHY

2.2.1 Regional Demography Within Fifty Miles

L Area is approximately five miles southeast of the proposed site for the Defense Waste Processing Facility (DWPF). L Area is located closer to more sparsely populated rural areas than the DWPF. Therefore, the population data developed for the DWPF can be applied to L Area with only minor adjustments.¹

In 1970, there were 21 urban centers with populations of more than 2500 persons within a 50-mile radius of SRP (Table 2.2-1). Augusta, Georgia, is the only urban center in that radius with more than 25,000 persons. Four centers had populations between 10,000 and 25,000.

2.2.1.1 Estimation of Population Distribution

Population data were developed for geographical divisions formed by subdividing the 50-mile radius circle of the SRP site into 22.5 degree compass-sector segments as shown in Figure 2.2-1. The 1970 population distribution by compass sector segments is given in Table 2.2-2. Projected distributions for 1980 through 2020 are given in Tables 2.2-3 through 2.2-7. The source of the basic data and the method used to develop population data for 1970 and to project population data are described in References 1-5.

2.2.1.2 Residential Population

The residential population within 50 miles of the site was estimated to be 553,000 in 1980. More than 50% of the population is in the Augusta, Georgia - South Carolina Standard Metropolitan Statistical Area (SMSA) which includes Richmond and Columbia Counties, Georgia, and Aiken County, South Carolina.

Between 1980 and 2020, the residential population is projected to increase from 553,000 to 845,000 (153%). The cities of Aiken and North Augusta, South Carolina are expected to become major urban centers with populations over 25,000. No other major urban centers are expected to develop in this period.

The estimated distribution of age groups in the 50-mile population is shown in Table 2.2-8 for each of the decennial years (1980-2020).⁵ The percent distribution projected remains fairly constant during the period.

SRP is closed to the public except for permitted transients. The residential population cannot get closer than about five miles from L Area.

TABLE 2.2-1

1970 Urban Centers (Population Greater than 2500) Within 50 Miles of SRP

<u>Urban Center</u>	<u>County & State</u>	<u>Distance, Miles*</u>	<u>Sector</u>	<u>Population</u>
Augusta**	Richmond GA	20	WNW	59,864
Fort Gordon†	Richmond GA	28	WNW	15,589
Aiken	Aiken SC	16	NNW	13,436
Orangeburg	Orangeburg SC	44	ENE	13,252
North Augusta	Aiken SC	20	NW	12,883
Waynesboro	Burke GA	25	WSW	5,530
Barnwell	Barnwell SC	16	ESE	4,439
Batesburg	Lexington SC	42	N	4,036
Millen	Jenkins GA	37	SSW	3,713
Allendale	Allendale SC	27	SE	3,620
Denmark	Bamberg SC	28	E	3,406
Bamberg	Bamberg SC	34	E	3,406
Sylvania	Screven GA	37	S	3,199
Grovetown	Columbia GA	33	WNW	3,169
Hampton	Hampton SC	42	SE	2,845
Edgefield	Edgefield SC	37	NNW	2,750
Louisville	Jefferson GA	48	WSW	2,691
West Aiken††	Aiken SC	20	NNW	2,689
Williston	Barnwell SC	14	ENE	2,594
Johnston	Edgefield SC	38	NNW	2,552
New Ellenton	Aiken SC	8.3	NNW	2,546

* Approximate distance from the center of SRP to the nearest edge of urban center.

** Central city of an urbanized area (Augusta, GA-SC; population 148,953).

† U.S. Military reservation.

†† Unincorporated community.

FIGURE 2.2-1. Fifty-Mile Vicinity of SRP Site

TABLE 2.2-2

1970 Population Distribution Within Fifty Miles of Site

Total Population by Sector		Miles from SRP Site					
		0-5	5-10	10-20	20-30	30-40	40-50
N	25214	0	823	3076	4037	4923	12355
NNE	11161	0	39	614	1631	2168	6709
NE	14318	0	162	710	3081	4797	5568
ENE	44348	0	18	4695	3572	5494	30569
E	21159	0	0	2230	8043	4193	6693
ESE	13607	0	0	4038	3399	2973	3197
SE	17165	0	0	315	5041	4159	7650
SSE	5932	0	0	552	863	432	4085
S	11528	0	0	878	1322	6044	3284
SSW	10600	0	0	217	2047	5714	2622
SW	8284	0	0	479	3420	1907	2478
WSW	12734	0	0	392	4939	1576	5827
W	17940	0	241	1383	5362	2301	8653
WNW	173798	0	2225	3131	130159	31734	6549
NW	49644	0	617	8404	35527	3487	1609
NNW	46837	0	2309	22327	9407	9510	3284
Total	484,269	0	6434	53,441	221,850	91,412	111,132

TABLE 2.2-3

Projected 1980 Population Distribution Within Fifty Miles of Site

Total Population by Sector		Miles from SRP Site					
		<u>0-5</u>	<u>5-10</u>	<u>10-20</u>	<u>20-30</u>	<u>30-40</u>	<u>40-50</u>
N	28200	0	950	3550	4650	5500	13500
NNE	15000	0	44	710	1900	2800	9500
NE	17300	0	185	790	3400	5700	7200
ENE	45700	0	18	4800	3650	5700	31500
E	21700	0	0	2300	8200	4250	6900
ESE	13900	0	0	4150	3500	3000	3250
SE	17000	0	0	325	5200	4150	7300
SSE	5690	0	0	560	850	425	3850
S	10800	0	0	850	1250	5600	3050
SSW	10300	0	0	205	1950	5500	2600
SW	7900	0	0	450	3200	1800	2450
WSW	12400	0	0	380	4650	1500	5800
W	19700	0	275	1650	6300	2550	8900
WNW	219000	0	2550	3750	159000	44500	8700
NW	56400	0	710	9700	40500	3750	1700
NNW	<u>52900</u>	<u>0</u>	<u>2650</u>	<u>26000</u>	<u>11000</u>	<u>9800</u>	<u>3400</u>
Total	553,000	0	7400	61,000	260,000	107,000	120,000

TABLE 2.2-4

Projected 1990 Population Distribution Within Fifty Miles of Site

Total Population by Sector		Miles from SRP Site					
		0-5	5-10	10-20	20-30	30-40	40-50
N	31200	0	1050	3900	5100	6100	15000
NNE	17700	0	49	780	2100	3250	11500
NE	19500	0	200	870	3700	6400	8300
ENE	48100	0	19	5100	3900	6000	33000
E	23000	0	0	2450	8700	4500	7300
ESE	14600	0	0	4350	3700	3200	3350
SE	17700	0	0	340	5500	4300	7500
SSE	5860	0	0	590	880	440	3950
S	10800	0	0	830	1200	5600	3100
SSW	9800	0	0	200	1850	5200	2550
SW	7530	0	0	430	3000	1700	2400
WSW	12100	0	0	375	4350	1450	5900
W	21100	0	305	1850	6800	2700	9400
WNW	249000	0	2850	4100	175000	56000	11000
NW	62900	0	780	11000	45000	4200	1900
NNW	<u>58100</u>	<u>0</u>	<u>2950</u>	<u>28500</u>	<u>12000</u>	<u>11000</u>	<u>3650</u>
Total	609,000	0	8300	66,000	283,000	123,000	130,000

TABLE 2.2-5

Projected 2000 Population Distribution Within Fifty Miles of Site

Total Population by Sector		Miles from SRP Site					
		<u>0-5</u>	<u>5-10</u>	<u>10-20</u>	<u>20-30</u>	<u>30-40</u>	<u>40-50</u>
N	34900	0	1200	4450	5900	6800	16500
NNE	21200	0	56	890	2350	3900	14000
NE	22700	0	225	970	4150	7400	9900
ENE	51500	0	20	5400	4100	6400	35500
E	24200	0	0	2550	9100	4800	7700
ESE	15300	0	0	4600	3900	3350	3450
SE	18500	0	0	360	5800	4500	7800
SSE	6020	0	0	610	910	450	4050
S	10900	0	0	860	1250	5600	3150
SSW	10400	0	0	210	1900	5500	2750
SW	7840	0	0	440	3100	1800	2500
WSW	12500	0	0	395	4500	1450	6100
W	22800	0	350	2050	7500	2950	9900
WNW	285000	0	3200	4600	197000	67000	12500
NW	71000	0	890	12500	51000	4600	2000
NNW	<u>64800</u>	<u>0</u>	<u>3350</u>	<u>32500</u>	<u>13500</u>	<u>11500</u>	<u>3900</u>
Total	679,000	0	9300	74,000	316,000	138,000	142,000

TABLE 2.2-6

Projected 2010 Population Distribution Within Fifty Miles of Site

Total Population by Sector		Miles from SRP Site					
		<u>0-5</u>	<u>5-10</u>	<u>10-20</u>	<u>20-30</u>	<u>30-40</u>	<u>40-50</u>
N	38700	0	1350	5100	6700	7500	18000
NNE	24900	0	63	1050	2700	4500	16500
NE	25900	0	255	1100	4650	8300	11500
ENE	55000	0	21	5700	4350	6900	38000
E	25700	0	0	2700	9600	5100	8300
ESE	16000	0	0	4850	4050	3500	3550
SE	19100	0	0	375	6000	4650	8000
SSE	6260	0	0	640	950	470	4200
S	11400	0	0	910	1300	5800	3300
SSW	10600	0	0	220	2000	5500	2850
SW	8220	0	0	470	3300	1850	2600
WSW	13100	0	0	425	4800	1550	6300
W	24900	0	395	2300	8400	3250	10500
WNW	325000	0	3650	5200	221000	80000	15000
NW	79200	0	1050	14000	57000	5000	2150
NNW	<u>71900</u>	<u>0</u>	<u>3800</u>	<u>37000</u>	<u>15000</u>	<u>12000</u>	<u>4100</u>
Total	756,000	0	11,000	83,000	352,000	156,000	155,000

TABLE 2.2-7

Projected 2020 Population Distribution Within Fifty Miles of Site

Total Population by Sector		Miles from SRP Site					
		0-5	5-10	10-20	20-30	30-40	40-50
N	42900	0	1550	5800	7600	8400	19500
NNE	28500	0	72	1150	3050	5200	19000
NE	29200	0	285	1250	5200	9400	13000
ENE	58700	0	23	6100	4650	7400	40500
E	27600	0	0	2900	10500	5400	8800
ESE	16900	0	0	5200	4350	3700	3650
SE	20100	0	0	405	6500	4950	8200
SSE	6940	0	0	690	1000	495	4300
S	11500	0	0	970	1300	5800	3400
SSW	10800	0	0	235	2050	5500	2950
SW	8650	0	0	495	3500	1950	2700
WSW	13800	0	0	460	5100	1650	6500
W	27400	0	450	2550	9300	3550	11500
WNW	372000	0	4150	5800	248000	96000	18000
NW	90100	0	1150	16000	65000	5600	2350
NNW	<u>80800</u>	<u>0</u>	<u>4350</u>	<u>42000</u>	<u>17000</u>	<u>13000</u>	<u>4400</u>
Total	845000	0	12,500	93,000	395,000	178,000	169,000

TABLE 2.2-8

Relative Distribution of Age Groups in Fifty-Mile Population

Year	Percent of Population		
	Infants and Children, 0 to 11 years	Teenagers, 11 to 17 years	Adults, 17 years and older
1980	18.6	11.1	70.3
1990	22.7	9.0	68.3
2000	20.8	11.8	67.4
2010	20.9	10.5	68.6
2020	21.9	10.9	67.2
Average, 1990 to 2020*	21.3	10.8	67.9

* Thirty-year population-weighted average, assuming population changes linearly between decennial years (Tables 2.2-4 through 2.2-7).

2.2.1.3 Industrial Population

The industrial population within ten miles of L Area consists almost entirely of the SRP work force (approximately 9180 daily transients). The Alvin W. Vogtle Nuclear Plant currently has 3420 construction workers and another 460 people make up the work force at Allied-General Nuclear Services and Chem-Nuclear Systems, Inc. Table 2.2-9 shows the industrial population within ten miles of L Area as of April 1981 (see Figure 2.2-2 for locations). These workers are on the plantsite about 36 hours per week with approximately 80% of them working Monday through Friday from about 8 a.m. until 4 p.m.¹

The SRP work force is expected to increase by up to 5000 additional construction personnel from about 1983 through 1989 because of construction of the proposed DWPF. Therefore, in the mid-1980's, the SRP work force could be near 12,600, decreasing to 8500 in the mid-1990's. The work force at Vogtle is expected to increase to over 5000 by the end of 1981. The work force at Allied-General Nuclear Services and Chem-Nuclear Systems, Inc., is assumed to remain at its present level in the 1980's.

2.2.1.4 Recreational and Transient Population

Recreational hunting and camping account for about 10,000 visitor-days within a 15-mile radius of L Area. Travelers crossing SRP on U.S. Route 278 and S.C. Route 125 and on the Seaboard Coast Line Railroad add about 20,800 person-days to the 10-mile transient population.¹

There are no schools, military reservations, hospitals, prisons, or airports within the 10-mile radius.

2.2.2 Land Use

2.2.2.1 SRP Land Use

The SRP industrial and support facilities use less than 5% of the 192,000 acres of SRP. An additional 200 acres will be used by the proposed DWPF. About 900 acres are reserved for research sites and/or natural areas, while reservoirs and ponds occupy another 3000 acres. The remainder of SRP is managed by the U.S. Forest Service under a cooperative agreement with the Department of Energy (DOE). As of 1980, over 107 million pine seedlings had been planted, and 48 million board-feet of timber and over 636,000 cords of pulpwood had been harvested.

TABLE 2.2-9

Industrial Population Within Ten Miles of L Area*

Operating Area at U.S. Department of Energy, Savannah River Plant	Daily Transients**	Distance from L Area	
		Miles	Direction
A, M, SREL***	3025	11.2	NNW
H	1350	5.5	N
F	1290	6.2	NNW
D	480	6.9	W
Central Shops	450	3.2	NNW
C	400	4.1	NW
P	385	2.8	ENE
K	340	2.3	W
CMX-TNX	245	8.4	W
L	235	-	-
TC-1, U	105	8.2	NW
Railroad Yard	35	4.3	ENE
Forest Service****	25	11.2	NNW
Burial Ground	10	5.8	NNW
General†	805	-	-
Total	9180		
Vogtle††	3420	9.6	WSW
Allied-General Nuclear Services			
Barnwell Nuclear Fuel Plant	350	9.0	ENE
Chem-Nuclear System, Inc.†††	110	9.5	ENE

* Data as of April 1981 except as noted.

** Personnel nominally at work 8 hours per day, 5 days per week.

*** Outside the ten-mile radius but included because of the large population.

**** Headquarters is outside the ten-mile radius, but workers are included because employees work inside the ten-mile radius a large portion of the time.

† Includes (1) permanent employees and co-ops who work at various SRP locations
 (2) about 95 daily visitors
 (3) an estimated calendar year average of 175 subcontractor employees cutting and removing timber who nominally work a 4-day week.

†† As of January 1981.

††† As of January 1980.

FIGURE 2.2-2. Ten-Mile Vicinity of L Area

L Area is located about two miles south of the geographical center of SRP and occupies 82 acres of industrial site. The area was used from 1954 until 1968 when L-Area Reactor was placed on standby. About an additional 20 acres will be used in the vicinity of L Area for construction of support facilities, such as a steam line, power lines, weather tower, and rubble pit prior to startup.

2.2.2.2 Other Nearby Land Use

Four nuclear facilities are either planned, under construction or in use adjacent to SRP (Figure 2.1-2). The Alvin W. Vogtle Nuclear Plant is being constructed by the Georgia Power Company on the Savannah River southwest of SRP. The Barnwell Nuclear Fuel Plant of Allied-General Nuclear Services is east of SRP. Chem-Nuclear Systems, Inc. operates a low-level radioactive burial ground adjacent to the Allied-General facility. Carolina Metals, Inc. will begin operation of a new plant in October, 1982, at a site east of SRP.

Other industrial, commercial, and agricultural activities in the counties surrounding SRP have been described previously.¹

2.2.3 Water Uses

2.2.3.1 Surface Water

The Savannah River forms the boundary between Georgia and South Carolina (Figure 2.1-2). Upstream of SRP the river supplies water for Augusta, Georgia and North Augusta, South Carolina. It also receives treated waste water from these cities and Horse Creek Valley (Aiken County, South Carolina)^{6,7} It also, until recently, provided a channel for barge traffic between Savannah, Georgia and Augusta, Georgia.

At SRP, the river supplies water for cooling the production reactors and for use in the coal-fired power plants.^{1,8} SRP effluents and waste water are discharged into the tributaries which flow across the SRP site to the Savannah River.

2.2.3.1.1 Domestic Use

Downstream from SRP, the Beaufort-Jasper Water Authority in South Carolina withdraws about 5.2 million gallons per day to supply domestic water for a population of about 51,000 (Table 2.2-10). The Cherokee Hill Water Treatment Plant at Port Wentworth, Georgia, withdraws about 45 million gallons per day

TABLE 2.2-10

Beaufort - Jasper Water Authority

Water Treatment Capacity: 8 million gal/day
 Average use: 5.2 million gal/day

South Carolina population served:

<u>Group</u>	<u>Population</u>
Beaufort-Port Royal	18,000
Navy Installations	23,000
Rural Areas	10,000
Total	51,000

<u>Year</u>	<u>Million gal/day</u>	<u>Month in 1980</u>	<u>Million gal/day</u>
1970	4.45	January	4.65
1971	4.41	February	4.43
1972	4.83	March	4.53
1973	5.57	April	4.38
1974	4.73	May	4.83
1975	4.66	June	6.19
1976	4.50	July	6.24
1977	4.85	August	6.10
1978	4.74	September	6.74
1979	4.99	October	5.32
1980	5.25	November	4.99
		December	4.42

from the river to supply a business-industrial complex near Savannah which has an estimated consumer population of about 20,000 (Table 2.2-11).

2.2.3.1.2 Fisheries

Commercial fisheries in South Carolina and Georgia are important to the economy of the coastal region of both states. Fishermen in the two states earned about 29 million dollars in 1978.¹ Shad, shrimp, blue crabs and oysters are the most important cash species. Table 2.2-12 lists the species and catches of fish from the Savannah River for 1970-1979. Table 2.2-13 lists the total weight of shellfish caught in the Savannah River and its environs near the Atlantic Coast for the years 1972-1979. Figures 2.2-3 through 2.2-5 summarize the commercial catches of American shad for South Carolina, Georgia, and the Savannah River.

2.2.3.1.3 Miscellaneous Use

Recreational uses of the Savannah River are mostly upstream of SRP near Augusta or downstream of SRP near the coast. Recreational activities include sport fishing and limited water contact activities such as swimming or skiing. No uses of the Savannah River for irrigation have been identified in either South Carolina or Georgia.¹ A recent aerial survey of land for one mile on each side of the Savannah River downstream from SRP showed that about 100 beef cattle have free access to the river.

2.2.3.1.4 Savannah River Plant

The Savannah River Plant is a major user of surface water from the Savannah River presently with the capacity to remove 3.6 million cubic meters of water a day (1470 cfs, 41.6 m³ per second) (Table 2.2-14). This water is used primarily for cooling C and K Reactors and to provide makeup cooling water for Par Pond and P Reactor.

Under the worst conditions, the removal of the full 41.6 m³ per second would consume about 25% of the usual minimum flow of 170 m³ per second (6100 cfs) at SRP.¹⁰ During 1974-1976, the maximum fraction of river discharge which was withdrawn for cooling water was 12%. The average amount withdrawn for the same period was about 7% of the average river discharge.

TABLE 2.2-11

Use of Water from Cherokee Hill Water Treatment Plant

Water Treatment Capacity: 45 million gal/day

<u>Customers (Primarily Industrial)</u>	<u>Million gal/day</u>
Continental Can Corp. (paper plant)	8.9
Union Camp (paper plant)	13.1
American Cyanamid	6.2
Kaiser Agricultural Chemical Co.	1.3
Savannah Electric Co.	0.11
American Oil Co.	0.10
Georgia Port Authority*	0.072
Coca Cola Bottling Co.**	0.043
Royal Crown Cola Bottling Co.**	0.011
Atlantic Creosoting Co.	0.041
Savannah Sugar Refinery	0.79
Continental Roofing Co.	0.022
Johns Mansville Co.	0.022
Chevron Oil Co.	0.022
Koppers Co.	0.015
Hubson Battery Mfg. Co.	0.003
St. Regis Paper Co.	0.00028
Allied Chem. Co. - Indust. Chem. Div.	<u>0.00017</u>
Total	30.8
<u>Estimated Number of Customers</u>	<u>Persons</u>
Industrial Workers	1,000
Seamen (effective man-year users)	2,000*
Beverages (effective man-year users)	<u>17,000**</u>
Total	20,000

* Fresh water for ships entering Savannah Harbor.

Assumes 1% of water delivered is consumed by crewmen.

** Assumes 10% of water delivered is used for preparing bottled beverages.

TABLE 2.2-12

Commercial Catches of Fish from the Savannah River

Species	Combined Catches in Georgia and South Carolina, lb									
	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979
Carp	-	551	555	3,314	1,300	2,200	300	1,000	300	800
Catfish	1,200	347	489	1,142	1,600	4,000	2,300	2,300	800	2,300
Drum, Black	-	-	-	-	-	500	600	-	-	-
Drum, Red	-	-	-	-	100	0	400	1,100	300	-
Hickory Shad	700	846	641	1,598	200	500	200	300	400	200
Sea Trout (Spotted)	-	-	-	714	500	2,500	1,800	400	400	
American Shad	96,100	56,367	56,082	74,761	57,900	45,000	19,000	45,900	120,000	127,000
Sturgeon	1,600	50	4,337	1,215	300	100	800	1,900	1,000	500
Suckers	-	-	-	-	-	-	200	-	-	-
Eels, Common	-	-	-	-	-	200	-	100	-	100
Mullet	-	-	-	-	-	500	-	200	-	-
Striped Bass	1,800	1,621	2,234	2,361	-	-	-	-	-	-

TABLE 2.2-13

Commercial Catches of Shellfish from the Coastal Environs
of the Savannah River

Year	Shellfish Catch, lb*			
	Clams	Blue Crabs	Oysters	Shrimp
1972	-	924,800**	3,200*	255,600*
1973	1,900**	1,199,200**	6,300*	489,700*
1974	-	2,760,300††	15,000††	2,516,600††
1975	-	38,000†	7,600††	2,788,400††
1976	-	-	-	-
1977	-	140,000†	42,000††	1,380,700††
1978	4,100†	150,000†	-	1,612,600††
1979	1,000†	231,000†	20,000†	-

* References 1 and 9.

** Wassaw Sound plus Ossabaw Sound.

† Savannah River landings.

†† Northern District, Georgia.

FIGURE 2.2-3. American Shad Catches from the State of South Carolina, 1880 - 1980

FIGURE 2.2-4. American Shad Catches from the State of Georgia, 1880 - 1980

FIGURE 2.2-5. American Shad Catches from the Savannah River, 1964 - 1979

TABLE 2.2-14

Present Savannah River Plant Pumping Station Capacities

<u>Pumping Station</u>	<u>No. of Pumps</u>	<u>Rated Pump Capacity, gal/min</u>	<u>Maximum Sustained Capacity</u>	
			<u>m³/sec</u>	<u>m³ x 10⁶/day</u>
1G	8*	32,500	16.4	1.4
3G	10	32,500	20.5	1.8
5G	6	12,500	<u>4.7</u>	<u>0.4</u>
Total SRP capacity			41.6	3.6

* Two additional pumps will be placed in service before L-Reactor startup.

Figure 2.2-6 shows the total maximum possible flow pumped from the river and the total reactor cooling water flow from 1954-1980. At present, C and K Reactors each receive about 400 cfs cooling water flow from the river. Par Pond receives about 20 cfs to compensate for seepage and evaporation. Par Pond, the closest reservoir to L Area, is used for cooling P Reactor and is not accessible to the public. After the river water is used to cool C and K Reactors, it is discharged to Four Mile Creek and Pen Branch, respectively, which flow to the Savannah River.

L Reactor will require about 400 cfs cooling water from the Savannah River, with proposed discharge to Steel Creek and thus to the Savannah River.

2.2.3.2 Ground Water

2.2.3.2.1 Industrial Use of Ground Water

The most heavily used geological formation for industrial water supplies in the SRP area is the Tuscaloosa. Ground water from the formation is used by SRP, J. M. Huber Corporation, Augusta Sand & Gravel Company, and the Sandoz Company in Allendale County (Table 2.2-15).¹ Municipal usage is shown in Table 2.2-16.¹

In the future, additional water may be withdrawn from the Tuscaloosa formation at and near SRP by the proposed DWPF, the Alvin W. Vogtle Nuclear Power Plant in Georgia, and the Barnwell Nuclear Fuel Plant (Table 2.2-15).

The maximum yield of the Tuscaloosa Formation in the southeast is estimated to be $19 \times 10^6 \text{ m}^3$ per day without depleting the approximately 21-billion-acre feet of water in storage.¹¹ Hydrographs of the region show no effects from past and present withdrawals at SRP.¹ Future needs are apparently within the capacity of the Tuscaloosa Formation.¹¹⁻¹⁶

2.2.3.2.2 Miscellaneous Use of Ground Water

Numerous small communities, mobile home parks, state parks, schools, and small commercial interests use ground water near SRP. The wells are usually equipped with pumps which have capacities of .04 to 0.23 m^3 per minute and do not reach the Tuscaloosa Formation.

FIGURE 2.2-6. Total Reactor Cooling Water Flow, 1954 — 1980

TABLE 2.2-15

Industrial Ground Water Use from the Tuscaloosa Formation
at and in the Vicinity of SRP

<u>User</u>	<u>Average Daily Use, m³/day</u>
-------------	---

Aiken County

SRP A-Area	6,100
F-Area	6,800
H-Area	5,600
U-Area	19
Central Shops	4,100*
CMX-TNX	400*
Classification Yard	400*
U.S. Forest Service	**
Graniteville Co.	**
J. M. Huber Co.	8,400
Augusta Sand and Gravel	3,600
Cyprus Mines Corp.	1,400
Florida Steel Corp.	75
Valchem	400

Allendale County

Sandoz Co., Inc.	11,000
------------------	--------

Barnwell County

E. T. Barwick, Inc.	950
---------------------	-----

Projected

DWPF	4,000 -
Barnwell NFP	15,000†
A. W. Vogtle NPS	11,000†

* Pump capacity.

** Not available.

† Projected future pumpage.

TABLE 2.2-16

Municipal Ground Water Use in the Vicinity of SRP

<u>User</u>	<u>Average Daily Use, m³/day</u>	<u>Water-Bearing Formation</u>
Aiken County		
City of Aiken	7,600	Tuscaloosa
Town of Jackson	660	Tuscaloosa
Town of New Ellenton	1,100	Tuscaloosa
Town of Langley	490	Tuscaloosa
College Acres	250	Tuscaloosa
Bath Water District	1,200	Tuscaloosa
Beech Island	1,100	Tuscaloosa
Talatha	150	Tuscaloosa
Breezy Hill	880	Tuscaloosa
Burnettown	570	Tuscaloosa
Montmorenci	1,600	Tuscaloosa
Warrenville	550	
Johnstown	1,100	Tuscaloosa
Howlandville	380	Tuscaloosa
Gloverville	550	
Belvedere	1,400	Tuscaloosa
Barnwell County		
Barnwell	15,000	Congaree
Williston	2,700	McBean
		Tuscaloosa
Blackville	1,100	Tuscaloosa
Hilda	35	McBean
Elko	380	McBean
Burke County, Ga.		
Girard	75	Tuscaloosa

2.2.4 Archeology

2.2.4.1 Introduction

During January and February of 1981, an intensive archeological survey of the Steel Creek floodplain below L Area (Figure 2.2-7) was conducted by the Institute of Archeology and Anthropology, University of South Carolina. The survey was required as part of the project plan to reactivate L-reactor in order to comply with historic preservation regulations (Section 10.7). The survey resulted in the recovery of data for 18 archeological sites in the potential impact area.¹⁷

The data collected from the 18 sites indicate occupation in the Steel Creek watershed extending back to at least 8,000 B.P. Analyses of the data resulted in the recommendation that one site, 38BR55, be considered eligible for nomination to the National Register of Historic Places.

2.2.4.2 Survey Methods

The survey area was limited to a stretch of Steel Creek approximately 8 miles long and 300 meters wide. Twenty-five archeological sites were known to be within 1/4 mile of Steel Creek.¹⁸ Based on the 100-year floodplain, eleven of these sites within 200 meters of Steel Creek were examined to determine if higher water flow would pose a possible danger.

Sites were located by ground raking of 2 by 2 meter squares up to 125 meters from the creek along its entire length; other methods were used, where appropriate, including the inspection of cleared ground at clear cuts, fire breaks and roads.

2.2.4.3 Results and Recommendations

The survey area indicating site locations is shown in Figure 2.2-8. A brief evaluation of each site is presented in Table 2.2-17. The only significant prehistoric site, 38BR55, is situated at the confluence of Steel Creek and Meyer's Branch in close proximity to the Steel Creek floodplain. This site has a relatively uninterrupted prehistoric occupation beginning in the Early Archaic and continuing through the Mississippian which makes it a valuable resource for clarifying the occupational history of the region. Aerial photographs from 1961 of high water levels when both L and P reactors discharged to Steel Creek illustrate the presence of water adjacent to the terrace which could pose a threat to the integrity of the site. The site extends for almost

FIGURE 2.2-7. Map of the Steel Creek Basin Indicating the Area of Intensive Survey

FIGURE 2.2-8. Map of the Survey Area Indicating Site Locations

Table 2.2-17

Archeological Resource Summary for Sites Located During the Steel Creek Survey

SITE	TEMPORAL RANGE*	FUNCTIONAL TYPE	ELIGIBLE FOR NOMINATION	POTENTIAL EFFECT	RECOMMENDED ACTION
38BR438	MA, LA, W	Habitation	Possible	None	None
38BR44	EA, LA, 1780-1930	Limited Activity	No	--	None
38BR45	Ceramic	Limited Activity	No	--	None
38BR55	EA, MA, LA, EW, MW, LW, M	Habitation	Yes	Possible	Monitor Erosion
38BR102	LA, EW, 1780-1900	Limited Activity	No	--	None
38BR112	Lithic, 1780-1940	Limited Activity and Mill dam	Possible	Possible	Preserve vegetation cover and monitor
38BR187	EW, MW, LW	Habitation	Possible	None	None
38BR259	EW	Habitation	Possible	None	None
38BR263	Ceramic	Limited Activity	No	--	None
38BR264	Lithic	Limited Activity	No	--	None
38BR265	LW	Limited Activity	No	--	None
38BR268	EW	Limited Activity	No	--	None
38BR269	Lithic, 1780-1840	Habitation and Mill dam	Possible	Possible	Preserve vegetation cover and monitor
38BR271	Lithic	Limited Activity	No	--	None
38BR286	1786-1940	Historic road	Possible	Possible	Preserve vegetation cover and monitor
38BR288	1800-1870	Mill dam	Possible	Possible	Preserve vegetation cover and monitor
38BR291	1760-1840	Historic scatter	No	--	None
38BR56	Lithic	Limited Activity	No	--	None

* EA - Early Archaic M - Mississippian
 EW - Early Woodland MA - Middle Archaic
 LA - Late Archaic MW - Middle Woodland
 LW - Late Woodland W - Woodland

600 meters along the terrace, therefore, the potential for erosion is considered important. Although no direct evidence of adverse erosive activity was noticed during field surveys at the site, it is recommended that the site be monitored to preserve its future integrity.

Four other sites in the floodplain are potentially significant (38BR112, 38BR269, 38BR288 and 38BR286) because the first three are historic earthen dams and the fourth is a historic road. Since no direct evidence of prior erosion at these sites was found in field surveys, erosion is not expected to result from the L-reactor discharges. Monitoring of these sites is recommended.

In the unlikely event that erosion occurs at any of the sites and stabilization measures fail, data recovery should be undertaken.

2.3 GEOLOGY

2.3.1 L-Area Geology

The L-Area site is located near the border of the Aiken Plateau and the Brandywine Terrace of the Coastal Plain physiographic subprovince and is underlain by a sequence of sedimentary deposits on the order of 1000 feet in thickness. This sequence consists of unconsolidated and semiconsolidated marine and alluvial sediments that dip gently to the southeast. The sediments range in age from Upper Cretaceous to Recent and are underlain by Precambrian or Paleozoic igneous and metamorphic rocks and Triassic/Jurassic age sediments of the Dunbarton basin, a structural basin within the crystalline basement. A stratigraphic column and cross section for the SRP site is presented in Figures 2.3-1 and 2.3-2. Stratigraphically, L Area is located within the Hawthorn/Barnwell Formations as shown on Figures 2.3-3 and 2.3-4. The Miocene Age Hawthorn Formation is included as part of the Eocene Age Barnwell Formation because the lithologies are similar and the contact between the formations is irregular making it difficult to distinguish one from the other.

Siple recognized the presence of the Hawthorn Formation which lies unconformably above the Barnwell Formation.¹⁵ The Hawthorn Formation, as defined by Siple, occurs as a thin veneer of sediment which covers crests of interstream divides at higher elevations. The Hawthorn is one of the most lithologically variable formations within the Tertiary system. It contains vari-colored intercalated and interfingering sands, clays, and gravel.

REFERENCE:

AFTER SIPLE, G.E., 1967, GEOLOGY AND GROUND WATER OF THE SAVANNAH RIVER PLANT AND VICINITY, SOUTH CAROLINA, U.S. GEOLOGICAL SURVEY WATER SUPPLY PAPER 1841, 113 PP.

PREPARED FOR

E.I. du PONT de NEMOURS & COMPANY
INCORPORATED
WILMINGTON, DELAWARE

IDAHO POLYMER

FIGURE 2.3-1. Stratigraphic Column for the Savannah River Plant Site

FIGURE 2.3-2. Profile of Geologic Formations Beneath the Savannah River Plant

FIGURE 2.3-3. Subsurface Geology of the L-Area Site(A)
(See Figure 2.3-4 for legend.)

CHARLESTON DISTRICT CORPS OF ENGINEERS
ELLENTON FIELD OFFICE

SAVANNAH RIVER PLANT
GEOLOGICAL INVESTIGATION
SECTIONS A-A' & B-B'
AREA L

DRAWN BY: E. J. M.
DATE: DWG. NO. SRP-FGR-18

FIGURE 2.3-4. Subsurface Geology of the L-Area Site(B)

The most significant characteristic of the Hawthorn Formation which distinguishes it from the Barnwell Formation is the presence of numerous clastic dikes which do not occur in the Eocene sediments, at least to the degree they do in the Hawthorn.¹⁵ The Barnwell Formation is characterized by brown, yellow, and buff sands and sandy clays. In the SRP area, the formation has been assigned an Eocene (Jackson) Age because of its stratigraphic position and the age of the fossil assemblages found within the sediments. However, there is some uncertainty concerning the origin and age of this formation. Alluvium of recent age occurs along the major streams that drain the area surrounding the L-Area site. These deposits consist of poorly sorted sands, clays, and gravels. The shallow subsurface geology of L Area is shown in Figures 2.3-3 and 2.3-4.

The Barnwell Formation unconformably overlies the McBean Formation of Eocene Age (Claiborne). The base of the Barnwell is a unit locally known as the "Tan Clay." Where present, the "Tan Clay" is about five feet thick and acts as an aquitard, hydrologically restricting the vertical movement of ground water between the Barnwell and McBean Formations. The top of the McBean is found between elevations 160 and 170 msl at L Area. A zone of calcareous material, soft spots, and drilling mud losses occurs between elevations 150 and 170, or at a depth of about 100 to 180 feet below the ground surface.¹⁹

The Congaree Formation (also Claiborne) underlies the McBean Formation. Typically, both the Congaree and McBean Formations consist of glauconitic quartz sands interbedded with clays, marbles, and limestones. The upper clay layer of the Congaree is locally known as the "Green Clay" which is at the contact of the two formations.

The Upper Cretaceous Ellenton Formation underlies the McBean Formation. This unit consists of dense to very dense sands, silty sands, and clays, with mica abundant in the sand layers. The formation is about 50 feet thick.

The Tuscaloosa Formation, also Cretaceous in age, underlies the Ellenton Formation and in turn overlies either a saprolitic clay developed on the crystalline basement or the Triassic rocks of the Dunbarton basin. The approximate location of the Dunbarton basin is shown on Figure 2.3-5. The Tuscaloosa is about 600 feet thick and consists of interbedded sands, clays, and gravels.

There are numerous shallow depressions in the vicinity of L Area, Figure 2.3-6. These depressions are similar to Carolina bays, being ellipsoidal in shape with the major axes trending predominantly north. The depressions are slightly lower than the surrounding Coastal Plain with some having standing water.

FIGURE 2.3-5. Dunbarton Basin

FIGURE 2.3-6. Shallow Depressions in the Vicinity of L Area¹⁹

There have been numerous theories over the years attempting to explain the origin of the Carolina bays; however, they remain a puzzling landform.²⁰ Similar features found on SRP may be collapse features associated with solution of calcareous material. An investigation of a large depression near R Area 5 miles northeast of L Area, which according to Siple¹⁵ is a typical Carolina bay, was conducted by the U.S. Army Corps of Engineers.¹⁹ The investigation indicated that there might be a collapse structure in the center of the bay caused by solution of calcareous material near the base of the McBean Formation. At least some of the larger depressions referred to as Carolina bays on the SRP site, may be in fact unusually wide, shallow sinks.

2.3.2 Seismicity

The SRP site is located in an area of low-to-moderate seismic activity based on earthquake risk predictions by the U.S. Coast and Geodetic Survey²¹ (Figure 2.3-7). Prior to the Charleston earthquake of 1886, the only events of significance felt in the area were those associated with the New Madrid, Missouri earthquakes of 1811-1812 (MM Intensity XI-XII). Only two earthquakes of MM Intensity VII or greater have occurred within 200 miles of the site: 1) the MM Intensity X Charleston, South Carolina event of 1886, and 2) the MM Intensity VII-VIII Union County, South Carolina earthquake of 1931.^{8,22} The epicenter of the Charleston earthquake was located some 90 miles from SRP and the Union County event some 100 miles from SRP. Site intensities and accelerations resulting from these and other major earthquakes are listed on Table 2.3-1.

2.4 METEOROLOGY

Meteorological data needed to characterize atmospheric dispersion are wind speed and direction, horizontal and vertical wind direction variability, vertical temperature profiles, and vertical mixed depth. The data applicable to SRP and L Area are collected at primary sources at SRP and at Bush Field Airport, Augusta, Georgia (Figure 2.4-1). Wind measurements are made at seven 61-meter meteorological towers at SRP and at the 335-meter WJBF-TV tower located near Beech Island, about 15 miles (25 kilometers) northwest of the center of SRP; temperature data are also collected at the WJBF tower.

The closest National Weather Service Station is at Bush Field, west of SRP. Surface measurements at Bush Field are supplemented by a standard instrument shelter located in A Area at SRP, which records the following:

ZONE 0 - No damage

Zone 1 - Minor damage; distant earthquakes may cause damage to structures with fundamental periods greater than 1.0 seconds; corresponds to Intensities V and VI of the modified Mercalli scale.

ZONE 2 - Moderate damage; corresponds to Intensity VII of the modified Mercalli scale.

ZONE 3 - Major damage; corresponds to Intensity VIII and higher of the modified Mercalli scale.

FIGURE 2.3-7. Seismic Risk Map for Conterminous United States

TABLE 2.3-1

SRP Intensities from Significant Earthquakes

<u>Date*</u>	<u>Location</u>	<u>Latitude</u>	<u>Longitude</u>	<u>Intensity</u>	<u>Distance From Site (km)</u>	<u>Reported or Estimated Site Intensity</u>	<u>Estimated Site Acceleration (g)</u>
1811-1812 (3 shocks)	New Madrid, MO	36.6	89.5	XI-XII	850	V-VI	0.05
Sept. 1, 1986	Charleston, SC	32.9	80.0	X	145	VI	0.07
Oct. 22, 1886	Charleston, SC	32.9	80.0	VII	155	III-IV	<0.02
June 12, 1912	Charleston, SC	33.0	80.2	VII	135	III-IV	<0.02
Aug. 1, 1920	Charleston, SC	33.1	80.2	VII	135	III-IV	<0.02
Nov. 22, 1974	Charleston, SC	33.9	80.1	VI	145	III-IV	<0.02
Jan. 1, 1913	Union Co., SC	34.7	81.7	VII-VIII	160	<IV	<0.02
May 31, 1897	Giles Co., VA	37.3	80.7	VIII	455	<III	<0.01
Nov. 2, 1875	Lincolnton, GA	33.8	82.5	VI	100	III-IV	<0.02
Aug. 2, 1974	Willington, SC	33.9	82.5	VI	105	IV	<0.02
Jan. 13, 1811	Burke Co., GA	33.2	82.2	V	55	III-IV	<0.02
Feb. 3, 1972	Bowman, SC	33.5	80.4	V	115	IV	<0.02

* Dates are based on Greenwich Mean Time.

FIGURE 2.4-1. SRP Site Map; T Denotes 61 m Tower; A Denotes Acoustic Sounder; WC-AL is the Weather Center Analysis Laboratory

- Maximum and minimum temperature
- Daily rainfall (also monitored at seven additional locations on SRP)
- Continuous measurements of temperature, relative humidity, and pressure.

2.4.1 Climatology

The climate in the SRP area is temperate with long summers and mild winters. The Blue Ridge Mountains to the north and northwest protect the area from the more severe winters occurring in the Tennessee Valley. The absence of extremes in temperature and precipitation prevents frost wedging, rapid erosion, and excessive drying of sediments. In general, weather changes proceed at a slow, uniform rate because of the moderate climate. A condensed description of the climate is given in Table 2.4-1.^{1,8,23}

2.4.2 Temperature and Humidity

The annual average SRP temperature is 64°F with an average daily variation of 22°F. Temperature averages and extremes at SRP from 1961 through 1976 are shown in Table 2.4-2, and a summary of temperatures at SRP from 1961 to 1972 is shown in Figure 2.4-2.

The SRP humidity at maximum and minimum temperatures is given in Table 2.4-3 for 1964 to 1978. The average daily humidity is about 66%; the average minimum is 43%, and the average maximum is 90%.¹

2.4.3 Precipitation

The average annual rainfall at SRP was about 47.5 inches from 1952 through 1978. The greatest rainfall occurs in March, and the least occurs in November (Table 2.4-4). Snowfall and freezing rain occur infrequently during the winter.

2.4.4 Wind and Dispersion Characteristics

Wind data are obtained from two locations in the vicinity of SRP, the National Weather Service at Bush Field in Augusta, Georgia, and an instrumented television tower near Beech Island about 15 miles (25 kilometers) from the center of SRP (Figure 2.4-1). Some differences in the data are expected because of differences in topography and the difference in heights of the instruments at Bush Field (130 feet above msl) and at the television tower (380 feet above msl).

TABLE 2.4-1

SRP and L-Area Climate

<u>Season</u>	<u>Features</u>
Spring (March-May)	Pleasant temperatures with an occasional cold snap; infrequent tornadoes; infrequent hail; rainfall 27% of annual total.
Summer (June-September)	Humid, frequent thunderstorms, 6-8 days with temperatures of 97°F or higher; rainfall 30% of annual total.
Fall (October-November)	Cool mornings with warm afternoons; about 50-60 thunderstorms per year; infrequent hail, rainfall 18% of annual total.
Winter (December-February)	Mild, about 30% of days with minimum temperatures below freezing; occasional snowfall with short periods of coverage (3 days average); rainfall 25% of annual total.

TABLE 2.4-2

Average and Extreme Temperatures at SRP, 1961 through 1976

<u>Month</u>	<u>Average Daily Temperature, °F</u>			<u>Extreme Monthly Temperature, °F</u>	
	<u>Maximum</u>	<u>Minimum</u>	<u>Monthly</u>	<u>Maximum</u>	<u>Minimum</u>
January	56	36	46	86	4
February	59	37	48	81	14
March	68	44	56	90	22
April	77	53	65	95	33
May	83	61	72	99	41
June	89	67	78	105	49
July	91	70	81	102	58
August	90	70	80	104	56
September	85	64	75	100	41
October	77	54	66	92	28
November	67	43	55	89	18
December	59	39	49	82	16

Average annual temperature = 64°F.

FIGURE 2.4-2. Summary of Temperatures at SRP from 1961 to 1972

TABLE 2.4-3

Relative Humidity at SRP, 1964-1978

<u>Month</u>	<u>Relative Humidity, %</u>	
	<u>Minimum</u>	<u>Maximum</u>
January	50	81
February	43	80
March	38	83
April	35	87
May	39	92
June	41	95
July	45	97
August	46	98
September	44	96
October	41	92
November	42	89
December	49	85
<hr/>		
Average	43	90

TABLE 2.4-4

Precipitation at SRP

	Average Monthly Rainfall, inches												
Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
1952	2.07	3.23	6.55	3.12	5.56	5.67	2.82	5.98	3.34	1.36	2.86	3.99	46.55
1953	2.69	5.48	3.83	2.96	4.42	5.38	3.63	3.61	8.53	0.11	1.04	7.51	49.19
1954	1.26	1.64	2.95	2.50	2.89	2.91	2.03	4.10	1.43	1.29	2.94	2.88	28.82
1955	4.75	2.62	2.21	5.57	4.53	3.31	3.94	5.07	3.42	1.32	2.93	0.46	40.13
1956	1.67	7.94	4.84	3.21	3.07	2.34	4.34	3.18	4.56	1.83	0.93	2.05	39.96
1957	2.05	1.58	4.29	2.75	8.02	4.17	3.51	2.41	5.04	6.12	6.46	2.24	48.64
1958	4.01	4.38	4.96	5.63	2.07	2.50	5.32	2.76	1.12	0.96	0.21	4.42	38.34
1959	3.54	6.06	6.44	2.03	3.81	4.06	5.80	2.93	8.71	10.86	1.97	3.54	59.75
1960	6.91	5.81	5.76	5.07	1.96	3.66	5.27	2.81	4.84	0.97	0.83	2.93	46.82
1961	3.59	5.76	7.23	8.20	3.88	3.01	3.09	7.15	1.00	0.07	1.83	6.60	51.41
1962	4.64	5.14	6.52	4.03	3.50	4.41	2.56	3.43	5.55	2.27	3.50	2.20	47.74
1963	5.96	3.64	3.34	3.70	2.98	8.42	3.18	1.04	5.37	0.00	3.68	4.47	45.78
1964	7.79	6.00	5.79	5.94	3.62	4.50	10.42	12.34	5.68	6.13	0.88	4.38	73.47
1965	2.00	6.39	8.67	2.43	1.33	5.04	8.04	1.94	2.83	2.59	2.17	1.41	44.84
1966	7.18	5.96	4.43	2.53	5.51	4.66	4.11	5.23	3.64	1.25	1.05	3.40	48.95
1967	3.66	3.80	5.68	2.82	5.01	3.74	7.52	7.32	1.70	0.64	2.51	3.13	47.53
1968	3.98	0.94	1.49	2.12	3.46	6.20	3.88	4.27	2.24	3.00	3.39	2.73	37.70
1969	2.00	2.46	3.38	4.09	3.02	3.95	2.71	5.42	4.56	1.16	0.40	4.19	37.34
1970	2.79	2.69	7.36	1.38	4.16	3.46	4.85	3.79	1.71	5.01	1.68	4.92	43.80
1971	5.11	4.16	8.68	2.92	2.98	5.92	10.53	8.76	3.80	5.95	2.31	2.89	64.01
1972	8.91	4.42	2.82	0.57	4.72	6.57	2.64	6.05	1.47	1.20	3.56	5.23	48.16
1973	5.36	5.26	6.38	4.58	3.50	10.89	6.04	3.81	3.71	1.22	0.31	4.64	55.70
1974	2.58	7.03	2.87	2.93	4.15	2.79	4.08	6.27	3.22	0.08	2.19	3.83	42.02
1975	4.98	6.54	5.91	4.42	5.15	3.84	8.55	3.83	5.18	1.74	3.41	2.03	55.68
1976	4.18	1.08	3.83	2.50	10.90	4.35	1.95	1.64	5.48	4.92	4.19	5.08	50.10
1977	3.72	1.52	6.86	1.27	1.79	2.47	3.42	7.30	5.50	4.27	1.63	3.86	43.71
1978	10.02	1.32	3.07	3.53	3.64	3.43	4.12	5.11	4.06	0.06	3.54	1.88	45.49
Average	4.35	4.19	5.04	3.44	4.06	4.51	4.75	4.72	3.99	2.46	2.31	3.59	47.46

There are also surface effects with respect to measured wind velocity. The velocity generally increases as a logarithmic function of height near the ground. Variations in atmospheric stability can cause departures from the logarithmic function.

2.4.4.1 Wind Speed

The average hourly wind velocity for Augusta, Georgia, was 6.4 mph (measured at a height of 20 feet) for the years 1950 to 1955. The wind frequency distribution for each quarter during the same period is shown in Figure 2.4-3. Poor dispersion conditions (calms and wind speeds below three mph) occur about one-third of the time, usually during late evening and early morning hours.

The frequency of wind speed as a function of height on the television tower near SRP is shown in Table 2.4-5. These data show that at 120 feet (37 meters) above ground level, wind speeds of less than four mph (two meters per second) occur 15% of the time with frequency decreasing with elevation. This speed-to-height ratio is much less than indicated for Augusta, Georgia, because of the more sensitive instruments on the television tower and greater height from the ground.

2.4.4.2 Wind Direction

Wind direction near SRP is shown in Figure 2.4-4 as the percent of time the wind was blowing from different directions.¹ The data represented in Figure 2.4-4 is valid for an elevation of 200 feet (61 meters) which is the height of the major SRP stacks. These data were interpolated from data of 120, 300, and 450 feet obtained from the television tower near SRP for 1976 and 1977. During that period, winds blew mostly from the west and southwest.

Table 2.4-6 shows the prevailing wind direction, by month, based on a nine-year record at Augusta, Georgia. The prevailing wind shifts direction as much as 180° from day to day (Table 2.4-7) with an average shift of 42° to 83°. Hourly observations show that the wind shifted from hour to hour during 1957.²⁴

2.4.4.3 Wind Persistence

Wind persistence is the length of time that the wind blows from one direction within a given azimuthal angle. The probability of wind persistence at SRP (1966-1968) for elevations of 300 and 800 feet and several angular widths are shown in Figures 2.4-5

0-1 mph
 1-3 mph
 3-12 mph
 12-18 mph
 more than 18 mph

FIGURE 2.4-3. Wind Frequency Distribution at Bush Field, Augusta, Georgia (1950-1955)

TABLE 2.4-5

Frequency of Wind Speed at Various Elevations
(2 Years Data from March 1966 to March 1968)

Wind Speed, m/sec	Frequency at each Elevation, in feet*						Fraction at each elevation, in feet						Accum Fraction by Speed and Elevation, in feet					
	1000	800	600	450	300	120	1000	800	600	450	300	120	1000	800	600	450	300	120
0 to 1	3054	4350	4530	7133	6655	11744	0.02	0.02	0.02	0.03	0.03	0.05	0.02	0.02	0.02	0.03	0.03	0.05
1 to 2	6634	9543	10370	9998	15345	26109	0.04	0.04	0.04	0.05	0.06	0.11	0.06	0.06	0.06	0.08	0.09	0.15
2 to 3	13042	18581	19837	18369	28575	47555	0.09	0.07	0.08	0.09	0.11	0.19	0.15	0.13	0.14	0.16	0.20	0.35
3 to 4	15266	24017	24782	22720	34373	56300	0.10	0.10	0.10	0.11	0.13	0.23	0.25	0.23	0.24	0.27	0.33	0.58
4 to 5	16158	25349	26490	23719	36510	46297	0.11	0.10	0.11	0.11	0.14	0.19	0.35	0.33	0.34	0.38	0.47	0.77
5 to 6	16207	26908	27726	26357	38747	29049	0.11	0.11	0.11	0.12	0.15	0.12	0.46	0.43	0.45	0.50	0.62	0.89
6 to 7	14218	23231	25474	24042	32190	12576	0.09	0.09	0.10	0.11	0.13	0.05	0.56	0.53	0.56	0.61	0.75	0.94
7 to 8	11780	21237	23311	21944	26761	6569	0.08	0.08	0.09	0.10	0.10	0.03	0.63	0.61	0.65	0.72	0.85	0.97
8 to 9	11222	20311	21970	20856	19411	3901	0.07	0.08	0.09	0.10	0.08	0.02	0.71	0.69	0.74	0.81	0.93	0.98
9 to 10	9836	17342	18055	15841	9688	2012	0.06	0.07	0.07	0.07	0.04	0.01	0.77	0.76	0.81	0.89	0.97	0.99
10 to 11	9738	16560	17454	12095	4526	1189	0.06	0.07	0.07	0.06	0.02	0.00	0.84	0.83	0.88	0.94	0.98	0.99
11 to 12	7463	13545	12417	6457	1963	585	0.05	0.05	0.05	0.03	0.01	0.00	0.89	0.88	0.93	0.97	0.99	1.00
12 to 13	5611	10098	8377	3321	992	318	0.04	0.04	0.03	0.02	0.00	0.00	0.92	0.92	0.96	0.99	1.00	1.00
13 to 14	4508	8055	5350	1522	615	165	0.03	0.03	0.02	0.01	0.00	0.00	0.95	0.95	0.98	0.99	1.00	1.00
14 to 15	3006	5093	2548	571	289	86	0.02	0.02	0.01	0.00	0.00	0.00	0.97	0.97	0.99	1.00	1.00	1.00
15 to 16	1940	3240	1194	281	144	41	0.01	0.01	0.00	0.00	0.00	0.00	0.98	0.99	1.00	1.00	1.00	1.00
16 to 17	1118	1826	539	150	82	13	0.01	0.01	0.00	0.00	0.00	0.00	0.99	0.99	1.00	1.00	1.00	1.00
17 to 18	610	879	181	51	43	11	0.00	0.00	0.00	0.00	0.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00
18 to 19	316	338	76	32	18	5	0.00	0.00	0.00	0.00	0.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00
19 to 20	172	144	36	10	5	1	0.00	0.00	0.00	0.00	0.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00
Over 20	120	111	41	46	52	65	0.00	0.00	0.00	0.00	0.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00
Totals	152019	250758	250758	215525	256984	244591												

* Number of records in this survey = 257292. Data from instrumented TV tower near SRP.

FIGURE 2.4-4. Wind Direction Near SRP From 1976 to 1977

TABLE 2.4-6

Prevailing Wind Direction at Augusta, Georgia

<u>Month</u>	<u>Prevailing Wind*</u>	<u>Time at Given Direction, %</u>
January	Northwest	26
February	Northwest	26
March	Northwest	25
April	Northwest	19
May	Northwest	17
June	South	21
July	South	26
August	South	23
September	East	20
October	Northwest	21
November	Northwest	28
December	Northwest	22

* Direction from which wind blows.

TABLE 2.4-7

Daily Shift of Prevailing Wind Direction in Augusta (1957)

Date	Shift, Degrees*											
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
1	NNW	SSW	W	ESE	E	NE	NW	SW	NW	NE	NW	W
2	15	150	30	120	30	75	90	75	180	0	90	45
3	0	120	165	105	75	0	90	0	105	15	105	15
4	165	0	0	0	0	30	45	60	15	60	15	90
5	120	180	0	45	0	135	135	165	75	0	0	15
6	180	45	0	90	90	15	180	0	30	45	90	135
7	180	45	75	60	165	30	135	90	0	0	90	0
8	135	120	150	0	120	30	60	135	45	60	0	0
9	75	90	30	105	150	180	15	135	15	0	165	135
10	30	15	15	75	15	45	165	75	30	45	60	45
11	180	135	165	120	0	135	0	75	15	105	60	30
12	15	30	120	150	75	0	30	105	15	15	15	30
13	135	75	60	30	75	150	90	150	0	45	0	90
14	30	15	30	105	15	120	0	120	0	30	90	60
15	165	180	90	0	60	75	120	45	30	120	45	30
16	45	180	90	75	0	45	30	105	0	0	60	0
17	60	0	45	0	90	135	105	0	30	45	30	135
18	0	180	180	0	60	180	45	75	180	135	60	0
19	150	180	135	15	120	135	30	15	60	30	120	45
20	135	105	30	15	90	30	90	30	60	15	30	60
21	15	0	30	30	105	15	15	60	30	15	120	150
22	180	15	0	0	0	0	45	0	60	30	150	60
23	120	75	165	0	0	15	45	15	165	60	15	30
24	135	165	75	0	105	30	0	45	90	0	90	0
25	0	0	180	15	105	0	165	135	135	120	180	90
26	0	60	15	15	45	90	15	90	45	60	135	150
27	180	30	75	30	60	90	15	75	90	15	60	0
28	0	90	30	0	165	60	15	120	0	0	105	180
29	0	-	45	15	15	60	45	30	45	45	45	120
30	90	-	45	15	0	30	150	120	0	60	90	30
31	105	-	150	-	15	-	150	90	-	150	-	30
Average	83	81	74	42	62	67	71	75	54	45	73	60

* The change was taken as the smaller angular rotation from the previous day's prevailing wind. The actual change could be greater than indicated if the shift occurred through the larger angular rotation.

FIGURE 2.4-5. Probability of Wind Persistence at 300-Foot Elevation at SRP

and 2.4-6.²⁵ At the 300-foot elevation, the probability of wind persistence for a ten-hour period is 0.07, 0.125, and 0.23 for a 22.5, 30, and 45° sector width, respectively (Figure 2.4-5). Results are similar at 800 feet (Figure 2.4-6).

The wind persistence for the most populated sector (Sector 14) is shown in Figure 2.4-7 in hours versus probability of occurrence at 300 and 800 feet. The probability at the 300-foot elevation for a ten-hour period in this sector is only 0.025.

2.4.4.4 Severe Weather

2.4.4.4.1 Thunderstorms

The average number of thunderstorm days at Augusta from 1951 through 1977 varied from a minimum of one from October through January to a maximum of 13 in July. The summer thunderstorms occur mainly during the late afternoon and evening hours.

2.4.4.4.2 Tornadoes

Occasional tornadoes are to be expected in the SRP area. Weather Bureau records show that 278 tornadoes occurred in Georgia, and 154 occurred in South Carolina from 1916 through 1958.²⁶ More recent data show that South Carolina has an average of about ten tornadoes per year.^{27,28} Most tornadoes occur from March through June and travel in a southwest-to-northeast direction.

Georgia and South Carolina may have extreme tornadoes with maximum wind speeds up to about 260 mph. During the history of SRP, no production facility has suffered significant tornado damage. In two instances, light damage has occurred, such as window breakage and tree breakage. Other tornado funnels have been sighted in unpopulated areas of SRP, but investigations revealed no damage.

Tornado risks have been calculated for the local region surrounding the SRP site. The probability of exceeding threshold windspeeds in one year versus windspeed is shown in Figure 2.4-8.²⁹

2.4.4.4.3 Hurricanes

Hurricanes that affected South Carolina occurred predominantly in August and September.³⁰ The occurrence of a hurricane along the Coastal region does not mean that SRP will be subjected to winds of hurricane force (>75 mph). Winds diminish

FIGURE 2.4-6. Probability of Wind Persistence at 800-Foot Elevation at SRP

FIGURE 2.4-7. Percent Probability versus Wind Persistence
Between SRP and Augusta, Georgia (22.5° Sector)

FIGURE 2.4-8. Tornado Risk Model with 95 Percent Confidence Limits

as the storm passes overland, and SRP is about 100 miles inland. Winds of 75 mph have been measured only once at the SRP site during its history, when Hurricane Gracie passed nearby on September 29, 1959.

2.5 HYDROLOGY

2.5.1 Surface Hydrology

2.5.1.1 Regional Watershed

The Savannah River basin (Figure 2.5-1) is one of the major river basins in the southeastern United States. It has a surface area of 10,600 square miles, of which 8100 are above SRP.⁸ The Savannah River has its headwaters in the Blue Ridge Mountains. It borders SRP for 17 miles and empties into the Atlantic Ocean near Savannah, Georgia.

Two large reservoirs, Clarks Hill Reservoir and Hartwell Reservoir upstream of SRP provide power, flood control, and recreational areas. Operation of these reservoirs has stabilized the river flow in the vicinity of SRP to a yearly average flow of about 10,200 cfs for the water years 1970 to 1979. The normal monthly low flow is about 6100 cfs (Figure 2.5-2). Daily flows as low as 4500 cfs occur infrequently primarily in late summer and early fall.

Most of the surface water at SRP results from natural rainfall or water pumped from the Savannah River and used for cooling plant facilities. After use, the heated cooling water is discharged to streams to flow back to the river or to recirculate through Par Pond.

The main streams that flow through the SRP site are Upper Three Runs Creek, Beaver Dam Creek, Four Mile Creek, Pen Branch, Steel Creek and Lower Three Runs Creek (Figure 2.1-2). All of them except Beaver Dam Creek originate on the Aiken Plateau and descend 100 to 200 feet before emptying into the Savannah River. A large swamp borders the Savannah River and receives the flow from Beaver Dam Creek, Four Mile Creek, Pen Branch, and Steel Creek.

In addition to these streams, surface water is held in more than 50 artificial impoundments totaling over 3,000 acres. Par Pond (Figure 2.1-2) is the largest with an area of about 2,600 acres. Water is retained intermittently in wetlands and in over 200 natural basins including some Carolina bays.^{1,23}

FIGURE 2.5-1. The Savannah River Basin

FIGURE 2.5-2. Monthly Ranges of Savannah River Water Flow at SRP for the Water Years 1970-1979

2.5.1.2 Steel Creek

Steel Creek received the cooling water discharged from L and P Reactors. The headwaters of Steel Creek lie near P Area. From there, the creek flows southwesterly for about 4.5 miles, turns south for about 5.5 miles, and enters the Savannah River swamp about 1.5 miles from the river. In the swamp, it is joined by flow from Pen Branch and Four Mile Creek. The drainage area of Steel Creek and its main tributary, Meyers Branch, is about 35 square miles. Assuming 1 cfs per square mile of drainage area, the average natural flow of Steel Creek is about 35 cfs. About 15 cfs of process water is discharged from P Area also.

Steel Creek began receiving cooling water discharge from P and L Reactors in 1954. Flow rates varied as a result of reactor and pumping modifications, diversion of P-Reactor cooling water discharge to Par Pond in 1963, and placing L-Reactor on standby in 1968. The reactor cooling water flow history of Steel Creek is given in Table 2.5-1 and Figure 2.5-3. A comparison of stream characteristics before and after Steel Creek received heated discharges from L and P Reactors is given in Table 2.5-2. Table 2.5-3 summarizes typical temperature measurements made during periods of Steel Creek usage before, during, and after reactor cooling water discharge. The dissolved oxygen and temperature data for Steel Creek during the last half of 1968 and for October 1970 show a return to natural levels following the L-Reactor shutdown (Table 2.5-4).

2.5.1.3 Savannah River Swamp

The Savannah River floodplain lies along the southern boundary of SRP for a distance of about 10 miles and averages about 1.5 miles wide. The location of the swamp and its relationship to the SRP boundaries and to the three streams that carry reactor effluent water into the swamp is shown in Figure 2.1-2.

A small natural levee has built up between the swamp and the river. There are three breaches in the levee which allow water to flow to the river. The breaches are near the mouth of Steel Creek, Four Mile Creek, and Beaver Dam Creek. The combined flow of Pen Branch and Steel Creek enters the river near the southeast corner of the SRP site.

The river overflows into the swamp when river elevations are between 90 and 91 feet above msl as measured at the SRP boat dock. During flooding, the water from these streams flows through the swamp parallel to the river and enters the river at Little Hell Landing (Figure 2.5-4).

TABLE 2.5-1

Reactor Discharges to Steel Creek, cfs

<u>Years</u>	<u>P Reactor</u>	<u>L Reactor</u>	<u>Total</u>
1954 to 1958	200	200	400
1958 to Early 1961	330	330	660
1961	400	400	800
Late 1961 to Late 1963	330	400	730
Late 1963 to February 1968	15*	400	415
February 1968 to 1980	15*	0	15*

* Flow from miscellaneous P-Area sources at about ambient temperature.

FIGURE 2.5-3. Maximum Reactor Cooling Water Flow to Steel Creek

TABLE 2.5-2

Stream Characteristics at Road A

<u>Date</u>	<u>Width, ft</u>	<u>Average Depth, ft</u>	<u>Mean Velocity FPS</u>	<u>Flow Rate CFS</u>	<u>Temp, °C</u>
May 1951	16.8	1.0	0.7	21.0*	16.1
June 1972	54.0	1.2	0.4	28.0	24.6

* July 1951.

TABLE 2.5-3

Typical Steel Creek Temperature, °C

<u>Location</u>	<u>5/51</u>	<u>6/9/54, P*</u>	<u>6/7/55, P,L*</u>	<u>8/66, L*</u>	<u>10/26/71, None*</u>
Steel Creek at L Reactor	-	38.3	48.4	69.5	-
Steel Creek at Road A	1.61	31.4	37.0	52.5	19.7
Steel Creek at Discharge to Swamp	-	28.6	33.9	Not Measured	19.9

* Reactors discharging heated water to Steel Creek.

TABLE 2.5-4

Dissolved Oxygen and Temperatures in Steel Creek Following L Reactor Shutdown

<u>Location</u>	<u>Data</u>	<u>Temperature, °C</u>	<u>Dissolved Oxygen, ppm</u>	<u>Dissolved Oxygen, % Saturation</u>
Steel Creek, Road A	July - December 1968	24.0 (average)	8.8 (average)	105 (average)
Steel Creek, Road A	October 1970	18.5	8.8	93

FIGURE 2.5-4. SRP Thermal Effluent Flow During Swamp Flooding

Continuous records of river stage at the SRP boat dock show that the swamp has been flooded about 23% of the time from 1960-1980 (Table 2.5-5).

2.5.2 Subsurface Hydrology

SRP, including L Area, is underlain by approximately 1000 feet of unconsolidated Coastal Plain sediments which contain several prolific and important aquifers. From the surface down, the hydrologic units are 1) the Barnwell Formation (which includes the Hawthorn Formation where present), 2) the "Tan Clay" unit, 3) the McBean Formation, 4) the "Green Clay" unit, 5) the Congaree Formation, 6) the Ellenton Formation, and 7) the Tuscaloosa Formation. Underlying the Coastal Plain sediments are the hydrologic units associated with the buried crystalline metamorphic bedrock and the mudstones and sandstones of the Dunbarton Triassic Basin (Figures 2.3-1 and 2.3-2).

In the upland areas, the hydraulic head in each formation is lower than that in the overlying formation, until the Congaree Formation is reached; below this formation, the head is higher than that of the Congaree. The decrease in head with depth may be predominantly the result of the hydraulic impedance of the "Tan Clay," between the Barnwell and McBean Formations, and that of the "Green Clay" between the McBean and Congaree Formations. These two low permeability units retard the downward movement of water and cause a head gradient to develop between points above and below each clay layer.³¹ Also, the Congaree Formation is sandier and more transmissive than the Barnwell and McBean Formations allowing water to move more rapidly toward discharge points. The geology and hydrostatic head distribution near the center of SRP is shown in Figure 2.5-5.

The water table is usually within the Barnwell Formation. This unit consists of clays, sandy clays, and clayey sands, and does not generally yield water to wells except from localized sand lenses. In L Area, the water table is found at depths ranging generally from 10 to 40 feet below the ground surface, Figure 2.5-6. The Barnwell and McBean water bearing units are separated by the "Tan Clay," a relatively low permeability unit which generally consists of two thin clay beds separated by a sandy bed. Hydraulic conductivity values in the Coastal Plain sediments at SRP are given in Figure 2.5-7. Measured hydraulic conductivities for the Barnwell Formation range from 0.04 meter per day to 0.3 meter per day near the center of the plant.

TABLE 2.5-5

Swamp Flooding Summary, 1960-1980

<u>Month</u>	<u>Avg. Days/Year that River Stage Exceeded 91 ft</u>
January	13
February	13
March	16
April	15
May	6
June	7
July	3
August	1
September	1
October	2
November	2
December	<u>8</u>
Total	87

FIGURE 2.5-5. Geology and Hydrostatic Head Distribution Near the Center of SRP

FIGURE 2.5-6. Depth to Water Table in L Area

FIGURE 2.5-7. Hydraulic Conductivity Values in the Coastal Plains Sediments

The McBean Formation consists of an upper layer of clayey sands and lower calcareous clay and clayey sand containing small cavities. In upland areas, Piezometric levels for the McBean Formation are generally slightly lower than those of the overlying Barnwell, indicating a tendency for downward flow. Near the center of the plant, the median hydraulic conductivity of the upper sand unit is 0.13 meter per day and that of the lower calcareous clayey sand is 0.07 meter per day.³² Zones of high permeability are not continuous over large distances, and the hydraulic conductivity of the calcareous unit is lower than it appears from drilling operations.

The Congaree Formation consists of interlayered and interbedded sands and clays and is separated from the overlying McBean Formation by the "Green Clay" unit which appears to be an effective aquitard. Heads in the Congaree are substantially lower than those in the McBean. The Congaree Formation is more transmissive than the formations above with median hydraulic conductivities on the order of 1.5 meters per day.³³

The Ellenton Formation underlies and is hydraulically separated from the Congaree by clay confining beds. The unit consists of lignitic micaceous clays and coarse sands. The known Ellenton sediments are found entirely within the subsurface; therefore, there is no natural discharge to the surface. Water passing through the Ellenton Formation is primarily recharged from and discharged to the underlying Tuscaloosa Formation. Some of the sand lenses in the Ellenton may be as permeable as sands in the Tuscaloosa; however, they do not achieve the thickness of the Tuscaloosa sands; therefore, few wells pump exclusively from the Ellenton Formation. However, some wells that are screened in the Tuscaloosa are also screened in the Ellenton. Because there is no continuous clay bed separating the two formations, they act as one aquifer.

The Tuscaloosa Formation is the stratigraphically lowest of the Coastal Plain sediments found at SRP. The formation consists of approximately 600 feet of interbedded sands, gravels, and clays and is a prolific water-producing unit. The hydraulic heads in the Tuscaloosa and Ellenton Formations are higher than that in the overlying Congaree Formation indicating that at SRP these formations are not recharged from the formations above. Because the recharge and discharge controls on the Tuscaloosa are outside the SRP area, the water levels in the formation are independent of water levels in the formations above. The Tuscaloosa Formation is a major supplier of ground water within the Coastal Plain of South Carolina with wells commonly yielding more than 5500 m³ per day (1000 gpm) of good quality water.¹⁵

The water in the Coastal Plain sediments is generally of good quality and is generally suitable for industrial and municipal use. The water is generally soft, slightly acidic, and low in suspended and dissolved solids. Typical analyses of ground water at SRP are shown in Table 2.5-6.

The Tuscaloosa and Congaree Formations are the major sources of municipal and industrial water supplies within the SRP site. The McBean and Barnwell Formations generally yield sufficient water for domestic use only. The major uses within the SRP area are shown in Tables 2.2-15 and 2.2-16.¹ The projected ground water use at L Area is about 2000 m³ per day which will be supplied from two wells.

2.6 ECOLOGY

2.6.1 Terrestrial Ecology

2.6.1.1 Upland Ecology of SRP

SRP is located on the Upper Coastal Plain in South Carolina. Two distinct physiographic subregions are present on SRP: the Pleistocene Coastal Terraces (below 270 feet in elevation) and the Aiken Plateau (above 270 feet in elevation), Figure 2.6-1. The lowest terrace, the Wicomico, is the present floodplain of the Savannah River. The floodplain is largely covered by a dense swamp forest, which also extends along the floodplains of the major tributaries of SRP. The higher terraces, the Sunderland and Brandywine, have a level to gently rolling topography. The Aiken Plateau or Sandhills Region is hilly and dissected by small streams with scrub-oak-longleaf pine forest along the ridges.

At the time of Government acquisition, about 67% of the land area of SRP was forested, and 33% was in croplands and pastures. Cotton and corn were the chief crops. After acquisition, abandoned homesites and farms entered ecological successional stages. Abandoned fields passed through a herbaceous stage into perennial grasses and gradually became more wooded, mostly with pine. The invasion of pine into the abandoned fields was accelerated by an extensive planting program by the U.S. Forest Service. By 1962, nearly all of the fields had been planted and many of the early plantations consisted of closed stands of trees 20 to 30 feet high. Today, 90% of SRP is covered by forests.

Upland game and fur-bearing mammals and small nongame birds are common on SRP. These include whitetail deer, gray and fox squirrel, cottontail rabbit, raccoon, red and gray fox, opossum and bobcat. Smaller nongame animals such as mice, rat, voles, moles, and shrews are found also. The populations of many species

TABLE 2.5-6

Analysis of Ground Water at the SRP

Date Sampled	Source of Water			Properties*			Chemical Constituents, mg/L*																	Total Dissolved Solids
	Well Number	Screen Depth, ft	Formation	Temp, °C**	pH**	Specific Conductance, Micromhos	Ca+2	Mg+2	K+	Na+	Fe	Si	Al	Mn	HCO ₃ ⁻	Cl ⁻	SO ₄ ⁻²	NO ₃ ⁻	PO ₄ ⁻³	F ⁻	Dissolved Oxygen**			
12/16/66	HC1E	43 to 48	Barnwell Upper Zone	21.7	5.8	48	3.3	0.3	1.6	TR†	.52	6.8	TR	0.02	12	6.0	1.0	3.8	0.0	0.0	NM	34		
10/25/77	HC2F	43 to 48	Barnwell	23.0	5.04	NM	0.42	0.05	0.10	3.96	<0.2	3.9	<1	<0.02	NM	3.7	0.25	5.8	.32	<.01	3.1	20		
8/1/74	HC3F	55 to 60	Barnwell	NM	5.2	15	1.7	0.43	0.25	2.9	<0.1	2.9	NM	NM	4.0	3.3	1.0	0.78	NM	NM	NM	15		
10/18/77	HC6B	85 to 90	Barnwell	22.0	6.30	NM	3.72	0.03	1.91	2.20	<0.2	4.6	<1	<0.03	18.3	1.5	0.62	5.4	<.01	<0.01	4.0	30		
7/25/74	HC3E	93 to 98	Barnwell	NM	5.7	18	5.4	0.25	0.54	2.5	<0.1	4.6	NM	NM	16.3	3.0	1.8	<0.001	NM	NM	NM	26		
7/23/74	HC5D	121 to 126	McBean	NM	4.8	11	0.8	0.37	0.22	1.7	<0.1	5.5	NM	NM	2.1	3.0	1.0	<0.001	NM	NM	NM	14		
4/28/66	HC2H	134 to 144	McBean Calcareous Zone	23.2	7.1	103	11	0.4	3.0	TR	0.02	12	0.1	0.00	45	4.1	5.8	0.2	0.78	0.4	NM	66		
11/23/77	HC6A	139 to 144	McBean	21.2	6.93	NM	13.8	0.02	0.64	2.57	<0.2	5.4	<1	<0.02	49.3	2.3	0.62	<0.05	<0.01	<0.01	6.4	51		
7/19/74	HC3A	230 to 235	Congaree	NM	6.4	130	28	0.54	0.55	1.5	<0.1	9.4	NM	NM	72	2.8	2.2	<0.001	NM	NM	NM	81		
1/19/78	FC2A	231 to 235	Congaree	19.6	6.15	NM	11.1	0.07	0.94	1.45	<0.2	10.7	<1	<0.03	42.7	3.92	10.5	<0.05	0.42	<0.01	0.9	61		
2/21/72	905-31A	440 to 535	Tuscaloosa	NM	5.5	17	0.11	1.7	NM	1.75	0.01	0.56	NM	<0.05	5.4	0.8	2.3	<0.02	<0.03	NM	NM	10		
2/29/72	905-41D	335 to 490	Tuscaloosa	NM	6.6	NM	1.4	3.5	4.3	11.0	<0.05	0.6	NM	<0.05	9.9	0.59	15.0	0.26	0.3	NM	NM	42		
2/21/72	905-43H	660 to 850	Tuscaloosa	NM	4.3	54	0.82	1.52	1.15	1.82	0.14	0.9	NM	<0.05	0.97	0.60	14.3	0.09	<0.3	NM	NM	22		
2/21/72	905-67U	615 to 725	Tuscaloosa	NM	5.15	19	0.22	1.5	0.43	1.6	0.05	0.44	NM	<0.05	0.97	0.74	3.5	0.27	<0.3	NM	NM	10		
2/21/72	905-72G	110 to 160	Tuscaloosa	NM	7.0	NM	7.0	9.2	0.90	12.5	0.012	0.60	NM	<0.05	27.5	1.6	10.2	0.44	0.18	NM	NM	56		

*NM = not measured.

**Measured at well head.

†TR = trace.

FIGURE 2.6-1. Coastal Terraces on the Savannah River Plant

of mammals increased rapidly after SRP was closed to the public. In 1965, organized deer hunts began on SRP with about 1300 deer taken annually since 1972.

2.6.1.2 L Area and Vicinity

Nearly all of the L-Area site and vicinity is located on an upland area between Steel Creek and Pen Branch on the edge of the the Brandywine Terrace. Most of the site was farmland at the time of original L-Reactor construction in the early 1950's. Original construction impacts were limited primarily to an area bounded by SRP Roads B, C, and 7. Construction also occurred near the original ash basin, the 50-million-gallon retention basin, the thermal discharge canal and powerlines, railways, and river water lines (Figure 2.6-2). Most of the impact area except in the immediate fenced security area, the ash basin, and the retention basin had been planted by the early 1960's with pine under the U.S. Forest Service program. Thus, young pine stands of about 20 years of age surround L Area today. The upland vertebrate species of L Area and vicinity would be expected to be similar to that of two other upland sites surveyed recently at other potential SRP construction sites.³⁴ At least two upland wetlands were found at L Area prior to construction in the 1950's, but none are found in the immediate vicinity today. Nearly all of the renovation and construction activities will be confined within the fenced security area of L Area or its immediate vicinity (parking lots and laydown areas), the retention basin, or along existing right-of-ways. No significant impacts to wildlife are anticipated.

The L-Area vicinity and the proposed steamline from L Area to K Area were surveyed for red-cockaded woodpecker (Picoides borealis) (Figure 2.6-3). No red-cockaded woodpecker colonies nor suitable habitat were found (Appendix A).

FIGURE 2.6-2. 1951 Aerial View of L Area and vicinity

FIGURE 2.6-3. Area of Red-Cockaded Woodpecker Survey for L-Area Restart

2.6.2 Aquatic Ecology

2.6.2.1 Introduction

The aquatic systems most likely to be impacted by the startup of L Reactor are the Savannah River, Steel Creek, and their adjacent floodplains (Figure 2.6-4).

The Savannah River has its headwaters in the mountains of North Carolina, South Carolina, and Georgia. Two large reservoirs — Clarks Hill Reservoir and Hartwell Reservoir — upstream of SRP have stabilized the river flow and have influenced the biological and water quality of the Savannah River in the vicinity of SRP. Suspended sediment load has been reduced, and backwater and floodplain areas are flooded less frequently and for shorter durations.

The Savannah River has been subjected to other alterations in the last 30 years. Channel dredging was conducted in the 1950's, and both municipal and industrial waste water treatment has improved upstream of SRP in the last ten to fifteen years. The main use of water by SRP since operation began in the early 1950's has been for cooling of a coal-fired power plant and the five nuclear production reactors. Thermal effluents are returned from the power plant and production reactors via streams on SRP to the Savannah River.

The main streams on SRP which drain to the Savannah River are Upper Three Runs Creek, Beaverdam Creek, Four Mile Creek, Pen Branch, Steel Creek, and Lower Three Runs Creek (Figure 2.1-2). All of these streams except Upper Three Runs Creek have been influenced by reactor cooling water discharges. These discharges, 10 to 20 times the natural stream flows, cause the streams to overflow their original banks along much of their length. The original swamp bottomland forests have been eliminated along much of Four Mile Creek, Pen Branch, and Steel Creek.

Those sections of the Savannah River swamp bottomland which receive heated effluents have been modified, because of thermal loading, flooding, and increased movement of silt. About one square mile of bottomland hardwoods has been killed by reactor cooling water effluents (Figure 2.6-5). Slight-to-moderate damage has occurred in another 6.5 square miles.^{35,36}

2.6.2.2 Savannah River

The most complete biological data on the Savannah River are contained in a series of reports prepared by the Academy of Natural Sciences of Philadelphia (ANSP).³⁷⁻⁴⁹ These surveys have been conducted on a regular basis since 1951. The first survey

FIGURE 2.6-4. Steel Creek Area

FIGURE 2.6-5. Thermal Effects on Bottomland Hardwoods

was made by sampling selected river stations during all four seasons. In subsequent years, the practice has been to conduct cursory surveys annually and more complete surveys every three to five years. Table 2.6-1 is an inventory of the surveys and the season during which the survey was conducted. Water quality data for the Savannah River are summarized in Tables 2.6-2 and 2.6-3.

Biological components included in each ANSP survey include algae and diatoms, protozoa, macroinvertebrates, fishes, and bacteria (occasionally), plus some water quality and physical measurements. Emphasis was placed on obtaining as complete an inventory of species as possible at each station and on taxonomic identification. Initially, five stations were sampled by the ANSP. Stations were located on the Savannah River in a reach extending upstream and downstream from SRP. Detailed descriptions of the sampling stations are provided in each ANSP report and their present locations are shown in Figure 6.2-1.

2.6.2.2.1 Primary Producers

Algae, macrophytes (aquatic vascular plants), and detritus serve as the base of the food web in aquatic environments. In rivers such as the Savannah River, attached algae (periphyton) assume a greater role in food production than floating algae (phytoplankton). Much of the phytoplankton of the Savannah River consist of detached periphytic forms as well as free-floating forms that are discharged from the Clarks Hill Reservoir and from tributaries and backwater areas entering the river. The number of species of algae represented in ANSP collections are presented in Figure 2.6-6. Diatoms have been the dominant group in most years. Blue-greens are the second most common group, particularly in the more upstream stations which are influenced more by organic waste discharged from Augusta and Horse Creek Valley. The most diverse algal flora consistently occurs during the summer, coincident with lower flow and less turbid water.

The distribution of macrophytes along the Savannah River is spotty. Larger concentrations are found in areas of less current, in oxbows, behind sand bars, and around spur dikes.

2.6.2.2.2 Consumers

2.6.2.2.2.1 Macroinvertebrates

Macroinvertebrates typically include aquatic insects and other invertebrates. These groups occupy similar habitats; that is, they are associated with the substrate; they are relatively stationary except as movement may occur with downstream drift; and

TABLE 2.6-1

Academy of Natural Sciences Aquatic Collections
Reported, 1951-1977

Sampling Year	Sampling Stations by Quarter*																							
	1				2				3				4				5				6			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
1951-1952	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
1955-1956		x	x			x	x			x	x			x	x			x	x			x	x	
1960		x	x							x	x			x	x			x	x			x	x	
1965		x	x							x	x			x	x			x	x			x	x	
1968		x	x							x	x			x	x			x	x			x	x	
1972		x	x							x	x			x	x			x	x			x	x	
1976			x								x				x				x				x	

* First Quarter - Jan. 1 - Mar. 31.
 Second Quarter - Apr. 1 - June 30.
 Third Quarter - July 1 - Sept. 30.
 Fourth Quarter - Oct. 1 - Dec. 31.

TABLE 2.6-2

Water Quality Monitoring Data for the Savannah River
Above SRP for 1973-1980

Parameter	Units	January	February	March	April	May	June	July	August	September	October	November	December
Temperature	°C	11.2 (7.0-14)	9.3 (6-12)	10.5 (7-14.5)	13.6 (11-17)	17.5 (15-19.5)	20.5 (17-24)	22.7 (19-25)	24.6 (22.5-26)	24.7 (23.8-25.6)	23.1 (22-24)	19.4 (17-23)	15.0 (10-18)
pH	pH	11.0 (6.21-7.0)	11.5 (6.4-7.2)	11.3 (6.4-7.1)	10.5 (5.9-7.0)	9.7 (6.5-6.9)	9.1 (5.34-7.0)	8.66 (5.9-7.1)	8.43 (6.1-7.4)	8.21 (6.4-7.6)	8.52 (6.5-7.1)	9.29 (6.6-7.3)	10.01 (5.3-7.2)
Dissolved Oxygen	mg/l	10.4-12.2	10.8-12.4	10.2-12.3	9.7-11.08	9.3-10.14	8.5-9.6	7.7-9.35	8.2-8.74	6.32-8.7	7.4-9.12	8.7-9.7	9.0-11.3
Alkalinity (CaCO ₃)	mg/l	14.3 (10.6-16.0)	13.9 (7.0-19.1)	12.5 (6.7-18)	11.6 (0.70-18.7)	12.1 (7.0-15.7)	12.4 (5-22.8)	13.0 (11.2-18)	12.8 (7.0-18)	13.4 (3.1-18.5)	17.0 (6.0-29)	16.5 (11.4-25.7)	16.6 (9.55-25.7)
Hardness	mg/l	18.5 (12.0-51.0)	14.2 (9.1-20.2)	12.1 (9.6-17.2)	16.3 (7.2-29)	16.8 (12-24.6)	16.2 (10.1-42.3)	17.3 (10-37.3)	17.2 (8.0-39.7)	13.1 (6.2-35)	18.9 (8.0-34)	28.4 (10-86)	5.7 (4-38)
Conductivity	µmhos	63 (37-90)	50.9 (8.5-69)	58.7 (43-77)	59.6 (47-82)	57.3 (41-88)	58.8 (49-80)	65.3 (50-79)	68.7 (49-77)	69.5 (53-83)	71.5 (51-92)	66.1 (50-78)	66.8 (42-83)
Suspended Solids	mg/l	9.3 (1-22)	24.4 (10-44)	28.7 (5.0-115)	30.6 (4.0-74)	22.0 (10-40.9)	16.5 (5.0-28)	14.4 (3.0-25)	<15.1 (<1-33)	15.5 (5.5-40)	14.3 (2.0-53)	21.6 (5.0-90)	14.6 (3.0-31)
Volatile Solids	mg/l	21.7 (14-29)	24.3 (11-59)	23.0 (16-27)	<19.4 (<1-27)	19.8 (3-31)	24.9 (16-31)	22.4 (2.0-30)	19.3 (7.0-31)	23.9 (16-35)	32.4 (12-95)	21.9 (1-34)	26.9 (15-49)
Total Dissolved Solids	mg/l	98.7 (29-54)	43.6 (11-79)	41.6 (31-50)	37.2 (18-52)	40.3 (18.6-71)	47.1 (31-61)	43.5 (9-61)	38.4 (20-57)	43.9 (22-52)	56.0 (39-115)	47.1 (23-62)	50.6 (3.5-114)
Fixed Residue	mg/l	6.6 (2-27)	<19.4 (<1-31)	18.2 (7.4-34)	18.0 (8.0-31)	20.5 (0-41)	2.2 (14-30)	20.9 (7.0-38)	19.3 (3.8-44)	19.8 (5.5-26)	23.8 (20-30)	24.9 (10-38)	29.1 (1-79)
BOD	mg/l	<3.1 (<1-12)	<3.2 (<1-12)	<1.7 (<1-4.0)	<1.0 (<1-1.0)	<1.5 (<1-2.5)	<1.6 (<1-4.0)	<1.72 (<1-3.0)	<1.61 (<1-4.0)	<1.46 (0.5-3.7)	<1.56 (<1-2.0)	1.69 (1-2)	1.52 (0.67-2.0)
Lignin	mg/l	<1 (<1-1.2)	<2.0 (<1-5.5)	<1.4 (<1-2.9)	<1.7 (<1-4.2)	<1.5 (<1-3.2)	<3.1 (<1-17)	<3.3 (<1-19)	<1.95 (<1-8.5)	<1.18 (<1-19)	<2.54 (<1-11)	<2.79 (<1-15)	<5.41 (<0-19)
Chloride (Cl)	mg/l	4.0 (3.0-5.5)	7.03 (2.4-9.0)	4.69 (3.0-6.8)	3.62 (1.5-7.0)	3.71 (2.5-5.0)	5.43 (3.2-10)	6.45 (4.4-3.8)	5.66 (3.2-8.1)	6.11 (4.8-8.0)	5.21 (3.5-7.5)	5.90 (4.4-7.6)	6.94 (3.3-11.2)

TABLE 2.6-2 (Continued)

Parameter	Units	January	February	March	April	May	June	July	August	September	October	November	December
Nitrite ($\text{NO}_2\text{-N}$)	mg/l	<0.12	<0.03	<0.06	<0.02	<0.03	<0.03	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
		(<0.02-0.4)	(<0.02-0.07)	(<0.02-0.3)	(<0.02-0.04)	(0.01-0.08)	(<0.02-0.05)	(<0.02-0.09)	(<0.02-0.19)	(<0.02-0.1)	(<0.02-0.19)	(<0.02-0.21)	(<0.02-0.2)
Nitrate ($\text{NO}_3\text{-N}$)	mg/l	<0.54	<0.43	0.99	0.48	<0.35	0.42	0.46	0.66	0.72	0.90	1.03	<0.90
		(<0.02-1.1)	(<0.02-0.8)	(0.16-3.8)	(0.02-0.9)	(<0.02-0.8)	(0.06-0.8)	(0.2-1.3)	(0.27-1.6)	(0.05-2.5)	(0.2-3.1)	(0.4-3.8)	(<0.02-4.0)
Sulfate ($\text{SO}_4\text{-S}$)	mg/l	4.6	5.2	4.14	<4.4	<4.0	4.75	<4.94	<5.20	<4.69	5.38	5.35	4.66
		(3.25-6.9)	(3.8-6.4)	(2.9-7.1)	(<2-6.4)	(<2-6.9)	(3.0-6.4)	(<2-6.3)	(<2-6.1)	(<2-7.8)	(4.3-6.8)	(4.1-8.1)	(2.5-6.2)
Sulfide (S)	mg/l	<1	<1	<1	<1	<1	<1.2	<1	<1	<1	<1	<1	<1
		(<1-1.3)					(<1-5.9)	(<0.1-3.6)	(<0.1-1)	(<0.1-1.0)	(0.1-1)	(<0.1-1)	(<0.1-1)
Total Phosphate ($\text{PO}_4\text{-P}$)	mg/l	<1.1	<0.19	<0.19	<0.34	<0.44	<0.33	<0.5	<0.35	<0.13	<1.36	<0.21	<0.39
		(<0.02-3.6)	(<0.02-0.4)	(<0.02-0.6)	(<0.02-0.6)	(<0.02-1.0)	(<0.02-0.6)	(<0.02-0.5)	(<0.02-1.1)	(<0.02-0.3)	(<0.02-4.7)	(<0.02-0.46)	(<0.02-1.0)
Aluminum (Al)	mg/l	<0.5	<0.5	<1.4	<1.2	<0.95	<0.82	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
			(<0.5-1.0)	(<0.5-5.0)	(<0.5-3.3)	(<0.5-2.0)	(<0.5-3.0)						(<0.5-49)
Ammonia (NH_4)	mg/l	<10	<0.1	<0.23	<0.1	<0.1	<0.1	<0.17	<0.1	<0.1	<0.1	<0.13	<0.1
		(<0.10-10)	(<0.1-0.1)	(<0.1-0.9)	(<0.1-0.2)	(<0.1-1.5)	(<0.1-0.3)	(<0.1-0.6)	(<0.1-0.1)	(<0.1-0.12)	(<0.1-0.1)	(<0.1-0.3)	(<0.1-0.1)
Calcium (Ca)	mg/l	2.1	1.74	1.81	1.18	1.94	1.73	<1.88	2.16	2.09	2.31	2.19	2.08
		(1.4-2.75)	(1.1-2.3)	(1.4-2.5)	(1.6-2.6)	(1.2-4.0)	(1.15-4.0)	(<0.1-4.0)	(1.5-2.8)	(1.3-2.8)	(1.6-2.9)	(1.2-3.4)	(1.7-2.3)
Sodium (Na)	mg/l	6.1	6.2	5.6	6.0	5.5	6.8	7.78	7.28	7.23	7.56	7.61	7.38
		(4.3-7.7)	(4.0-12.5)	(3.5-7.5)	(4.1-8.4)	(2.5-8.7)	(2.9-9.2)	(4.4-11)	(5.2-9.85)	(5.9-9.3)	(4.9-10.4)	(6.65-9.7)	(4.4-11)
Total Iron (Fe)	mg/l	<0.24	<0.24	<0.53	<0.69	<0.61	<0.49	<0.31	<0.17	<0.12	<0.28	<0.19	<0.12
		(<0.1-0.7)	(<0.1-0.5)	(<0.1-2.0)	(<0.1-1.7)	(<0.1-1.5)	(<0.1-2.0)	(<0.1-0.5)	(<0.1-0.4)	(<0.1-0.2)	(<0.1-1.2)	(<0.1-0.5)	(<0.1-0.3)

TABLE 2.6-3

Water Quality Monitoring Data for the Savannah River Below SRP for: 1973-1980

Parameter	Units	January	February	March	April	May	June	July	August	September	October	November	December
Temperature	°C	11.0 (7.0-14.5)	9.32 (5.6-13)	10.8 (7.3-16)	14.6 (11.75-19)	18.3 (15-20.5)	21.2 (18-24)	23.1 (20.25-25.5)	25.2 (23-26)	24.9 (23.8-26.6)	23.3 (21-25)	19.2 (17-23)	15.3 (11-18)
pH	pH	6.36-7.3 (6.36-7.3)	6.35-6.95 (6.35-6.95)	6.5-7.0 (6.5-7.0)	5.51-7.0 (5.51-7.0)	6.0-6.8 (6.0-6.8)	5.8-6.9 (5.8-6.9)	5.48-7.0 (5.48-7.0)	6.35-7.0 (6.35-7.0)	6.35-7.0 (6.35-7.0)	6.0-7.09 (6.0-7.09)	6.4-6.8 (6.4-6.8)	6.4-7.01 (6.4-7.01)
Dissolved Oxygen	mg/L	11.1 (10.4-12.2)	11.2 (10.1-12.6)	11.2 (10-12)	10.6 (9.4-11)	9.68 (8.5-10.7)	8.86 (7.0-9.45)	8.42 (6.7-8.88)	8.31 (8.0-8.66)	8.10 (6.2-8.6)	8.60 (8.3-9.0)	9.23 (8.6-9.7)	9.98 (8.4-11.1)
Alkalinity (CaCO ₃)	mg/L	14.2 (12.2-21)	12.8 (8.7-16.8)	13.3 (9.0-17)	13.4 (0.8-19.9)	13.0 (9.0-17)	12.7 (5.1-19.5)	12.2 (3.1-16)	13.9 (12-17)	14.3 (7.8-18.8)	16.8 (5.0-38)	13.4 (0.8-26.9)	14.8 (0.55-2.1)
Hardness	mg/L	17.1 (12-28)	13.2 (9.1-16.5)	14.7 (9.6-18)	14.5 (7.2-27.2)	14.4 (10-20.2)	17.8 (8.1-38.3)	17.0 (11-35.3)	16.4 (6.0-34.3)	13.7 (6.0-26)	20.5 (8.1-48)	28.2 (9.1-78)	14.4 (8.1-30)
Conductivity	umhos	64.1 (4-89)	60.4 (39-89)	59.6 (46-80)	64.0 (48-84)	58.9 (42-77)	57.9 (41-76)	58.0 (31-77)	66.9 (54-86)	69.2 (54-90)	72.0 (42-102)	65.6 (50-81)	67.9 (43-80)
Suspended Solids	mg/L	28.64 (1-22.5)	13.9 (6.0-28)	22.6 (3.0-86)	31.4 (9.0-59)	17.9 (10-20.2)	15.0 (2-27)	15.7 (8.0-22)	20.0 (15.5-38)	17.8 (2.0-45)	19.0 (1.0-87)	9.43 (1-16)	9.96 (1-27)
Volatile Solids	mg/L	28.0 (16-30)	19.4 (10-31)	20.3 (15-26)	24.1 (14-28)	20.1 (5.0-30)	23.9 (16-32)	26.2 (4.0-40.7)	17.4 (6.0-26)	25.7 (19-32)	33.3 (1-90)	17.7 (5.0-22)	26.4 (13-55)
Total Dissolved Solids	mg/L	42.4 (29-47)	36.0 (17-60)	39.3 (21-55)	38.9 (14-57)	40.7 (7.0-76)	45.9 (27-51)	44.5 (14-63)	43.8 (31-61)	47.4 (39-52.5)	59.4 (42-120)	44.2 (27-56)	57.6 (36-110)
Fixed Residue	mg/L	20.6 (13-30)	17.3 (2.0-29)	25.8 (2.0-40)	<15.1 (1-30)	20.3 (2.0-51)	24.6 (6.0-36)	18.3 (10-26)	30.4 (8.0-47)	22.0 (16.5-34)	28.6 (7.0-53)	27.4 (11-38)	28.2 (1.0-65)
COD	mg/L	<3.0 (1-12)	<1.33 (1-2.0)	<2.0 (1-4.0)	<1.67 (1-3.0)	<1.88 (1-4.0)	<1.26 (1-3.0)						
BOD	mg/L	<1.03 (1-1.1)	<1.67 (1-4.6)	<1.36 (1-1.9)	<1.41 (1-2.3)	<1.45 (1-2.8)	<2.96 (1-15)	1.79 (1.0-4.0)	<1.51 (1-3.0)	<1.01 (1-1.5)	<1.25 (1-2.0)	<1.71 (1.0-3.0)	<1.68 (1-4)
Lignin	mg/L	5.09 (3.1-8.8)	4.10 (2.4-8.0)	4.40 (3.0-5.6)	4.01 (2.5-7.0)	4.04 (2.8-5.2)	5.68 (3.0-10)	<3.08 (1-17)	<2.69 (1-14)	<1.17 (1-2.0)	<2.10 (1-7.0)	<3.0 (1-14)	<3.13 (1-17)

TABLE 2.6-3 (Continued)

Parameter	Units	January	February	March	April	May	June	July	August	September	October	November	December
Chloride (Cl)	mg/l	5.09 (3.1-8.8) <0.05	4.10 (2.4-8.0) <0.04	4.40 (3.0-5.6) <0.02	4.01 (2.5-7.0) <0.03	4.04 (2.8-5.2) <0.03	5.68 (3.0-10) <0.03	5.19 (3.8-7.5) <0.03	5.22 (2.9-7.5) <0.03	6.06 (4.1-7.4) <0.04	5.66 (3.0-8.1) <0.03	5.65 (4.4-8.0) <0.03	7.06 (3.1-9.5) <0.08
Nitrite (NO ₂ -N)	mg/l	<(0.02-0.14) <0.57	<(0.02-0.08) <0.45	<(0.02-0.06) 0.91	<(0.02-0.1) <0.39	<(0.02-0.03) <0.39	<(0.02-0.07) 0.42	<(0.02-0.09) 0.37	<(0.02-0.07) 1.63	<(0.02-0.1) 0.92	<(0.02-0.1) 0.83	<(0.02-0.1) 0.90	<(0.02-0.3) <0.91
Nitrate (NO ₃ -N)	mg/l	<(0.02-1.1) 4.22	<(0.02-0.8) 5.61	(3.2-2.3) 5.49	<(0.02-0.9) 4.33	<(0.02-1.0) 4.59	(.05-0.6) 4.26	(0.07-1.1) 4.90	(0.2-8.715) 3.84	(0.05-2.5) 4.64	(0.11-3.1) 5.32	(0.4-3.4) 4.61	<(0.02-4.0) 4.92
Sulfate (SO ₄ -S)	mg/l	(3.0-6.4)	(2.3-10.6)	(3.5-9.4)	<(2-6.8)	(2.0-6.6)	<(2-7.4)	<(2-11)	<(2-5.3)	<(2-7.6)	(3.6-6.8)	(3.35-6.8)	(2.8-6.7)
Sulfide (S)	mg/l	<1 <0.64	<1 <0.14	<1 <1.38	<1 <0.20	<1 <0.38	<(1-8.3) <0.26	<1 <0.43	<1 <0.30	<1 <0.09	<1 <1.45	<1 <0.33	<1 <0.40
Total Phosphate (PO ₄ -P)	mg/l	<(0.02-2.7) <0.5	<(0.02-0.4) <0.80	<(0.02-8.3) <1.13	<(0.02-0.4) <0.91	<(0.02-0.9) <0.88	<(0.02-0.4) <0.69	<(0.02-1.5) <0.5	<(0.02-1.0) <0.5	<(0.02-0.375) <0.5	<(0.02-5.0) <0.5	<(0.02-0.6) <0.5	<(0.02-0.7) <0.5
Aluminum (Al)	mg/l		<(0.5-2.6) <0.16	<(0.5-3.6) <0.21	<(0.5-2.8) <0.11	<(0.5-2.0) <0.11	<(0.5-2.0) <0.11	<0.5 <0.11	<0.5 <0.1	<0.5 <0.1	<0.5 <0.14	<0.5 <0.14	<0.5 <0.1
Ammonia (NH ₄)	mg/l	<0.1 2.11	<(0.1-0.5) 1.93	<(0.1-0.9) 2.09	<(0.1-0.15) 2.13	<0.1 2.03	<(0.1-0.3) 2.09	<(0.1-0.2) <1.95	<0.1 2.32	<(0.1-0.12) 2.28	<0.1 2.42	<(0.1-0.3) 2.08	<0.1 2.36
Calcium (Ca)	mg/l	(1.7-2.8) 6.23	(1.3-2.6) 6.17	(1.6-2.9) 5.89	(1.9-2.6) 5.73	(1.3-3.0) 5.6	(1.6-3.0) 6.7	<(0.1-3.0) 7.04	(1.6-3.0) 6.64	(1.4-2.85) 7.13	(1.8-3.1) 7.10	(1.4-3.8) 6.73	(1.9-3.3) 7.31
Sodium (Na)	mg/l	(4.9-8.2) <0.33	(4.3-12) <0.33	(3.7-8.0) <0.49	(3.2-7.7) <0.62	(3.6-7.6) <0.52	(2.9-11) <0.44	(5.4-10.8) <0.29	(5.5-7.65) <0.19	(5.4-9.8) <0.125	(4.2-9.8) <0.29	(6.1-7.6) <0.20	(4.9-12) <0.13
Total Iron (Fe)	mg/l	<(0.1-0.6)	<(0.1-1.0)	<(0.1-1.8)	<(0.1-1.7)	<(0.1-1.5)	<(0.1-1.5)	<(0.1-0.75)	<(0.1-0.45)	<(0.1-0.2)	<(0.1-1.3)	<(0.1-0.5)	<(0.1-0.4)

FIGURE 2.6-6. Species of Algae Represented in ANSP Collections in the Savannah River

they are subject to impact from similar factors. Functionally, they are diverse and fulfill the niches of predators, grazers, filter feeders and, in the case of insects, are not confined to the water for their entire life cycle. The Savannah River supports a diverse benthic (bottom-dwelling) fauna in the vicinity of the SRP. Most of the suitable habitat is associated with areas of shallow water with silted substrate or in quieter backwaters. The river bottom consists primarily of shifting sand that does not provide optimum habitat for benthic invertebrates.

The number of aquatic macroinvertebrates represented by ANSP collections are shown in Figure 2.6-7. There is a dominant pattern evident in the figure, which began in the mid-fifties. The greatest number of species collected in a single sampling year was in the initial year of study (1951-52). Immediately thereafter, the number of species collected at each station declined to less than half that of the initial year. Apparent recovery from this decline did not occur until the early sixties. Complete recovery has not taken place even after 25 years. The reduction in the number of species during the 1950's has been attributed to dredging in the river which had been initiated by 1955. Stabilization of river discharge and elimination of habitat through reduction in flooding of backwater areas may have also contributed to the decline. The groups most affected were Baetid and Heptagenid mayflies, Perlid stoneflies, dragonflies, Hemipterans, Dystiscid and Gyninid beetles, and the Chironomids. The most dramatic reduction among the noninsect fauna occurred in the Crustacea, the Oligochaete worms, and pelecypods. These groups are sensitive to siltation and substrate instability. Pulmonate gastropods were also less abundant, but were able to survive by attachment to areas of riprap placed in the river prior to 1951 for channel stability.⁵⁰

Of the insect fauna, beetles comprised the largest number of species when all ANSP surveys are considered. Mayflies and dragonflies were represented by the largest number of species among the earlier surveys. Following the decline in species in the 1955 through 1960 period, the Diptera (flies) have been represented by the most species, indicating a general decline in environmental quality.⁵⁰

2.6.2.2.2.2 Fish

Streams of the southeastern Atlantic Coastal Plain are noted for their diverse fish fauna. Dahlberg and Scott reported 102 species from the Savannah River drainage basin.⁵¹ The most complete surveys of the Savannah River include those initiated by

FIGURE 2.6-7. Aquatic Macroinvertebrates Represented by ANSP Collections in the Savannah River

the ANSP in 1951 and that of McFarlane and others in 1976-1977 in which they reported 64 species in the environs of the Savannah River near SRP.¹⁰ Numbers of fish species represented in the ANSP collections are shown in Figure 2.6-8.

Looking at the number of species in the ANSP collections for 1951-1976, data from all the Savannah River sampling stations follow a similar pattern. An increase in the number of species collected during the second sampling period (1955-1956) is apparent. The increase can be explained on the basis of revised methodology (i.e., incorporating rotenone toxification) into the collection procedure. Since 1960, the number of species has gradually declined and become more variable from station to station and from one sampling year to the next. The decline in species numbers in collections after 1960 may be attributable to substrate removal and disturbance related to dredging between 1955 and 1960.⁵⁰

2.6.2.2.2.3 Fish Species of Special Concern

McFarlane summarized much of the impact of SRP operations on fishes of the Savannah River.¹⁰ Fish listed as of special concern included the shortnose sturgeon (Acipenser brevirostrum), the American shad (Alosa sapidissima), the blueback herring (A. aestivalis), the striped bass (Morone saxatilis), the channel catfish (Ictalurus punctatus), and the American eel (Anguilla rostrata). Of these, the American shad, the blueback herring, and the striped bass are anadromous; that is, migrating from saltwater to freshwater for spawning. The American eel is catadromous; that is, migrating from freshwater to saltwater for spawning. The only significant commercial species are the American shad and channel catfish (Section 2.2.3.1.2). These are exploited to a limited degree by local fishermen. Sport fishermen are the principal consumers of other river fishes, principally bass, sunfishes, crappie, and catfish. Striped bass are popular in the Augusta area.

- Shortnose Sturgeon

The shortnose sturgeon is the only endangered species of fish known from the Savannah River.⁵² It is restricted to the tide-waters and has not been reported near the SRP.

- American Shad

This anadromous species ascends the Savannah River in early spring spawning above or near the SRP (Table 2.6-4). The semi-buoyant eggs are carried downstream past SRP and can

FIGURE 2.6-8. Fish Species Represented in the ANSP Collections in the Savannah River

TABLE 2.6-4

Fish of Interest to SRP*

Life History	Shad	Blueback Herring	Striped Bass
Spawning			
Location(s)	Savannah River and Steel Creek	Savannah River and Steel Creek	Savannah River - Upper Tidal Reaches
Month(s)	Early January - Late April	March - Late April	Late March - May
Time	Afternoon - Midnight	Afternoon - Night	Late Afternoon
Frequency	Once per year	Once per year	Once per year
Repeat Spawner	Not in South	Yes (17-78%)	Yes
Water temperature	12-20°C	About 20°C	15.5-19.5°C
Water Velocity	Main Channel 0-3 ft/sec	Off Main river Channel and in River Swamps	Main Channel 0-3 ft/sec
Water Type	Tidal Fresh Water	Fresh Water	Tidal Fresh Water
Eggs			
Size	1.27 mm	1.2 mm	1.28-1.36 mm
Fecundity	6x10 ⁴ - 6x10 ⁵	4.6x10 ⁴ - 3.5x10 ⁵	1x10 ⁴ - 5x10 ⁶
Adhesive	No (demersal)	Yes (demersal)	No (demersal)
Movements	By Current	Adhesive	By Current
Incubation	2-3 days (17°C)	2 days (22°C)	2 days (20°C)
Larvae			
Size	9-10 mm	3.5 mm	2.5 mm
Transformation	4-5 weeks	3-4 weeks	3-4 weeks
Juveniles			
First Summer	Natal River	Natal River	Natal River
Migration	To Sea in Autumn	To Sea in Autumn	Remain in River
Size	About 30 mm	About 30 mm	About 10-12 cm
Adults			
Mature	3-6 years	3-6 years	2-6 years
Weight	2-4 pounds	0.5-0.8 pound	Up to 30 pounds
Length	457-483 mm	277-289 mm	15-57 cm

* Sources:

G. Wrich, N. Chipley, J. W. McCord, I. Cupka, J. L. Ensis, Jr., and R. K. Mahood. Development of Fishery Management Plans for Selected Anadromous Fishes in South Carolina and Georgia. Number 14, Marine Resources Department, South Carolina Wildlife and Marine Resources Department, Marine Resources Division, Office of Conservation, Management and Marketing, Charleston, SC; Number 31, Coastal Resources Division, Georgia Department of Natural Resources, Georgia Department of Natural Resources, Coastal Resources Division, Brunswick, GA.

D. H. Bennett and R. W. McFarland. The Fishes of the Savannah River Plant. National Environmental Research Park, Savannah River Ecology Laboratory, E. I. du Pont de Nemours and Co., Aiken, SC (NERP Report, to be published).

C. H. Walburg and P. R. Nichols. Biology and Management of the American Shad and Status of the Fisheries, Atlantic Coasts of the United States. 1960, United States Fish and Wildlife Service, Special Scientific Report -- Fisheries No. 550, Washington, DC (August 1967).

become entrained on intake facilities (Section 5.2.2). Few shad larvae appear to hatch near SRP. Juveniles migrate back up the river and are attracted to the SRP intake canals; however, they are only rarely impinged (Section 5.2.2).¹⁰ A few adults, typically emaciated, are impinged late in the spawning season. Thus, the impact of SRP upon the American shad is limited to entrainment of shad eggs for about a three-month period (Section 5.2.2).¹⁰

- Blueback Herring

This forage fish in the Savannah River has no direct commercial or sport fishing value and is essentially unexploited. It ascends the river to spawn in late spring in adjacent floodplain areas (Table 2.6-4). The eggs are adhesive and are not subject to entrainment, but larval fish, upon hatching, move into the main river channel and can become entrained by SRP intake structures (Section 5.2.2). Juvenile fish are typically not impinged.¹⁰

- Striped Bass

The striped bass has unique spawning habits in the Savannah River.⁵³ Some individuals spend most of the year in upstream waters and migrate downstream for spawning (Table 2.6-4). The Little Back River near the coast is the most important spawning area for striped bass in the Savannah River. Juveniles and adults migrate back upstream and congregate near the dams upstream of SRP as well as potentially use the nonthermal creeks of SRP such as Upper Three Runs Creek during the summer months. Impingement and entrainment have not been reported for this species at SRP (Section 5.2.2).¹⁰

2.6.2.3 Savannah River Swamp Bottomlands

The southwestern boundary of the SRP is formed by the Savannah River and its floodplain which has developed an extensive swamp forest of about 11 to 12 square miles, 7460 acres (Figure 2.6-5). Four of the streams draining SRP flow into this swamp. Production reactors are located on three of these streams, Four Mile Creek, Pen Branch, and Steel Creek. Cooling water is pumped from the Savannah River and discharged into these streams at about 70°C, thereby providing a thermal gradient ranging from temperatures lethal to most organisms to temperatures near ambient. A fourth stream, Beaver Dam Creek, receives heated effluents from a coal-fired power plant. Table 2.6-5 summarizes the approximate maximum possible flow histories of Four Mile Creek, Pen Branch, and Steel Creek from the reactor areas into the Savannah River swamp.

TABLE 2.6-5

Maximum Possible Flow Histories to Savannah River
Swamp Bottomlands from SRP Streams

I. C-Reactor Thermal Discharges to Four Mile Creek

<u>Years</u>	<u>cfs</u>
March 1955 - March 1957	200
April 1957 - Early 1961	330
1961 - Present	400

II. K-Reactor Thermal Discharges to Pen Branch
Via Indian Grove Branch

<u>Years</u>	<u>cfs</u>
October 1954 - July 1957	200
August 1957 - Early 1961	330
1961 - Present	400

III. P-Reactor Thermal Discharges to Steel Creek

<u>Years</u>	<u>cfs</u>
February 1954 - March 1958	200
April 1958 - Early 1961	330
1961	400
Late 1961 - Late 1963	330
Late 1963 - Present	15*

IV. L-Reactor Thermal Discharge to Steel Creek

<u>Years</u>	<u>cfs</u>
July 1954 - November 1957	200
December 1957 - Early 1961	330
1961 - January 1968	400
February 1968	0

* Nonthermal.

The undisturbed areas of the Savannah River swamp forest are dominated by bald cypress (Taxodium distichum) and tupelo gum (Nyssa aquatica) in low areas and along the stream channels and by red maple (Acer rubrum), water ash (Fraxinus caroliniana), water elm (Planera aquatica), and other bottomland hardwoods in higher areas. Upland ridges support water oak (Quercus nigra), willow oak (Q. phellos), and sweet gum (Liquidambar styraciflua).^{35,36,54,55} Such swamp forests are relatively stable systems and are considered to be the climax community for this floodplain environment. The swamps bordering the Savannah River are subjected to seasonal flooding with winter and early spring water levels 10 to 15 feet higher than those of summer and fall. The dominant trees are adapted to periodic short inundations.

In 1951, a closed canopy extended throughout the swamp. Although portions of the forest had been logged, a second-growth forest of bald cypress, tupelo gum, and bottomland hardwoods existed throughout. As heated reactor effluents began to enter the swamp via the three main tributaries especially with increased flow rates in the late 1950's and early 1960's, partial tree kill occurred in about two-thirds of the swamp bottomland (Figure 2.6-5).

Total tree kill in areas of intense effect extended throughout 560 acres of swamp forest (Table 2.6-6), chiefly in the delta areas where the thermal streams enter the swamp. In addition, the floodplain vegetation along each tributary was also killed. Dead trees remain standing throughout much of the area of total kill. Moderate effects have occurred in 650 acres of the swamp forest.⁵⁴ The canopy is open throughout this area, and many of the trees which remain are stunted. An additional 3450 acres show slight effects; i.e., minimal tree kill is detectable, and the canopy is not completely closed. These areas of moderate and slight effect extend throughout a large portion of the swamp below each stream delta. Upland ridges and the Savannah River levee between the river and the swamp bottomland appear unaffected.

The release of reactor cooling water not only elevated the water temperatures but also increased the water level in the tributaries and the swamp. Periods of prolonged flooding are detrimental, especially to the hardwood species.⁵⁴⁻⁵⁶ Even the flood-tolerant bald cypress and tupelo gum are stunted and eventually killed if abnormally high water levels persist throughout several growing seasons. In addition, these two species require a drier period during which the sediments are exposed to achieve seed germination and successful seedling establishment.⁵⁷

TABLE 2.6-6

**Areal Extent of Reactor-Effluent Effects on the Savannah River
Swamp Forest Bordering the Savannah River Plant***

<u>Delta Region</u>	<u>Areal Extent Acres, by Impact Category**</u>				<u>Total Area Affected</u>
	<u>Intense Effect</u>	<u>Moderate Effect</u>	<u>Slight Effect</u>	<u>No Effect</u>	
Beaver Dam Creek	110	60			170
Four Mile Creek	70	45			115
Pen Branch	55	50			105
Steel Creek	245	130			375
Total (Deltas)	480	285			765
Total Swamp	560	650	3450	2800	4660

* Source: R. R. Sharitz, J. W. Gibbons, and S. C. Ganse. "Impact of Production-Reactor Effluents on Vegetation in a Southeastern Swamp Forest." In: Thermal Ecology, AEC Symposium Series, pp 356-362 (CONF-730505) (1974).

** Impact Categories

1. Intense effect: two-thirds to total tree kill.
2. Moderate effect: one-third to two-thirds of trees killed, canopy open.
3. Slight effect: less than one-third of trees killed, same mortality and uneven canopy.
4. No effect: no apparent tree mortality, apparent natural swamp.

Prolonged flooding along the tributaries destroyed the vegetation along the stream floodplains and eroded the banks. Eroded sediments were deposited downstream and in areas near the mouth of the tributaries where they entered the Savannah River floodplain.⁵⁸ Thus, Four Mile Creek, Pen Branch, and Steel Creek have marked delta areas at their entrance into the Savannah River swamp. Portions of the stream deltas in which silt deposition has occurred comprise most of the areas of intense vegetational kill.

In areas of the Savannah River swamp more distal from the delta areas, the occurrence of moderate effects reflects the sensitivity of certain tree species to flooding and siltation.⁵⁴ In areas of moderate effects, many less tolerant hardwood species have died and bald cypress and tupelo gum remain. The establishment of occasional cypress saplings where hardwoods previously grew reflects a mean elevation in the water table in those areas sufficient to eliminate the hardwoods yet allow invasion of more flood-tolerant species. In areas of slight effect, resulting in an uneven canopy, survival results from subtle changes in topography and selective elimination of hardwoods.

Although the hardwood forest has been removed from the deltas and the peripheral of each delta, some vascular plants are found in the thermal deltas.^{54,59} These plants are found typically above the water level on small islands formed by the fallen logs and stumps of trees which were killed when reactor discharges were introduced into the stream. These plants are commonly annual and perennial herbs; the most common species is Ludwigia leptocarpa (Table 2.6-7). Few woody plant seedlings are found on these stump and log islands.^{54,59} On the post-thermal Steel Creek delta area which has not received a prolonged cooling water discharge since 1968, a few seedlings of the original swamp forest species are found. Seedlings, saplings, and small trees of black willow (Salix nigra) are commonly found in the Steel Creek delta area today.

2.6.2.4 Steel Creek and the Steel Creek Floodplain and Delta Area

Steel Creek is located in the southeastern portion of SRP (Figure 2.6-4). The stream length from the L-Area Reactor thermal outfall to the delta is about seven miles. The 100-year floodplain as defined by the USGS along this reach of stream occupies about 725 acres or 1.13 square miles. Water from Steel Creek flows an additional 1.5 miles to its entry into the Savannah River. The Steel Creek delta through which the creek flows occupies another 250 to 300 acres of the Savannah River swamp bottomland (Figures 2.6-5 and 2.6-9).

TABLE 2.6-7

Typical Herbaceous Plants of Savannah River
Swamp Delta Areas of SRP*

<u>Pen Branch (Thermal)</u>	<u>Steel Creek (Post-Thermal)</u>
<u>Ludwigia leptocarpa</u>	<u>Ludwigia leptocarpa</u>
<u>Ludwigia decurrens</u>	
<u>Boehmeria cylindrica</u>	<u>Boehmeria cylindrica</u>
<u>Cyperus strigosus</u>	
<u>Arundinaria gigantea</u>	
<u>Ammannia coccinea</u>	
<u>Fimbristylis</u> sp.	
<u>Ampelopsis arborea</u>	
<u>Panicum</u> sp.	<u>Panicum</u> sp.
<u>Sabal minor</u>	<u>Polygonum punctatum</u>
	<u>Sagittaria latifolia</u>
	<u>Leersia orygoidea</u>
	<u>Bidens</u> spp.
	<u>Hypericum walteri</u>
	<u>Aneilema keisak</u>
	<u>Scirpus cyperinus</u>

* Sources: R. R. Sharitz, J. E. Irwin, E. J. Christy.
"Vegetation in Swamps Receiving Reactor
Effluents." Oikos 25, 7-13 (1974).

C. E. Martin, E. J. Christy, and K. W. McLeod.
"Changes in the Vegetation of a South Carolina
Swamp Following Cessation of Thermal Pollution."
J. Elisha Mitchell Sci. Soc. 93, 173-176 (1977).

FIGURE 2.6-9. March 1979 Aerial View of Steel Creek Delta

Steel Creek has had a varied thermal history (Figure 2.5-2 and Table 2.6-5). From 1954 to 1963, it received thermal effluent from L and P Reactors. After cooling water was diverted to PAR Pond from P Reactor in 1963, Steel Creek continued to receive thermal effluent from L Reactor until early in 1968 when L Area was placed on standby. Since then, Steel Creek has received no thermal cooling water discharge except for a temporary one month diversion in June 1976, of about 30,000-50,000 gpm from P Reactor. The maximum thermal impact to the Steel Creek floodplain occurred in about 1961 with maximum flow from both L and P Reactors (Figure 2.6-10). Cooling water impact to the delta continued until 1968 when L Reactor was placed on standby. The floodplain and delta vegetation has been recovering since 1968. Figures 2.6-11 through 2.6-19 show the extent of vegetational recovery in the delta and floodplain since shutdown in 1968. A wide variety of aquatic and semi-aquatic animals and other wildlife have also reinvaded the floodplain, delta, and creek.

Biological studies and comparisons have been made between Steel Creek and Four Mile Creek, Pen Branch, and Upper Three Runs Creek so that a reasonable body of information exists on the biota of Steel Creek (Table 2.6-8). Field studies have been done on most of the more visible groups of organisms of Steel Creek. Bacteria, fungi, plankton, algae, and most macroinvertebrates have received less study.

More recently extensive ecological surveys of the Steel Creek area were begun in the spring of 1981 by the Savannah River Ecology Laboratory. These studies are concentrating on the flora and fauna of Steel Creek, potential impacts to endangered species, wetland communities, waterfowl, anadromous fish, and cesium-137 distribution in the biota and floodplain (Section 2.7.3).⁸⁸

The species which have been found in Steel Creek today are typical of similar nonthermal streams of SRP. The presence of stoneflies, mayflies, caddisflies, and dragonflies indicate that Steel Creek is recovering from prior cooling water impacts. Collections of species of crustaceans (crayfish) have been similar in both Steel Creek and the nonthermal Upper Three Runs Creek. About 40 species of fish have been collected recently from Steel Creek.⁸⁸ These are of a wide variety ranging from gar and bowfin, to chubs, shiners, suckers, bullheads, sunfish, bass, and darters.⁸⁸ Amphibian, reptilian, and waterfowl use in and along the Steel Creek floodplain and delta is common.⁸⁸ The present diversity of organisms in Steel Creek indicates that post-thermal recovery of the animal community has progressed rapidly in the past 13 years. Likewise, the water quality data of Steel Creek (Table 2.6-9) indicate that Steel Creek has recovered from previous thermal impacts.

FIGURE 2.6-10. 1961 Composite Aerial View of Steel Creek Floodplain

FIGURE 2.6-11. L-Area Cooling Water Canal, June 1981

FIGURE 2.6-12. Steel Creek at Road A-14 (Looking Upstream, 1972)

FIGURE 2.6-13. Steel Creek at Road A-14 (Looking Upstream, June 1981)

FIGURE 2.6-14. Steel Creek at Road A-14 (Looking Downstream, 1972)

FIGURE 2.6-15. Steel Creek at Road A-14 (Looking Downstream, June 1981)

FIGURE 2.6-16. Steel Creek at Road A (Looking Downstream, 1972)

FIGURE 2.6-17. Steel Creek at Road A (Looking Downstream, June 1981)

FIGURE 2.6-18. Steel Creek Delta Area, 1974

FIGURE 2.6-19. Steel Creek Delta Area, 1981 (Same Location as Figure 2.6-18)

TABLE 2.6-8

Major Groups of Organisms Studied on Steel Creek
and the Steel Creek Delta (Prior to 1981)

Subject	Comment	References
Fungi	Thermophilic and thermotolerant fungi	Tansey and Fliermans ⁶⁰
Bryophytes	Effects of thermal flooding	Niesmann ⁶¹
Vegetation	Bottomland forests	Swails et al. ⁶² Porter et al. ⁶³
	Effects of flooding	Welbourne ⁶⁴
	Effects of thermal effluents on swamp bottomlands	Gibbons and Sharitz ³⁵ R. R. Sharitz et al. ^{36,56} Gibbons, et al. ⁶⁵
	Vegetational recovery	Martin et al. ⁵⁹
	Flora of SRP	Batson et al. ⁶⁶
	Bottomland forests	Whipple et al. ⁵⁵
Invertebrates		
Insects	Thermal stress on dragonfly nymphs	Martin and Gentry ⁶⁷
	Thermal effluents and aquatic insect diversity	Howell and Gentry ⁶⁸
	Thermal ecology of dragonfly nymphs	Gentry et al. ⁶⁹
	Thermal tolerance of dragonfly nymphs	Garten, Jr. and Gentry ⁷⁰
Other Invertebrates		
	Crayfish of SRP	Hobbs et al. ⁷¹
	Bivalve Mollusca of SRP	Britton and Fuller ⁷²
	Aquatic snails	Wood and Wiener ⁷³

TABLE 2.6-8 (continued)

<u>Subject</u>	<u>Comment</u>	<u>References</u>
Vertebrates		
Fish	Fish of SRP	Bennett and McFarlane ⁷⁴
	Thermal effluents and mosquito fish	Falke and Smith ⁷⁵
	Effects of thermal effluents on mosquito fish populations	Ferens and Murphy ⁷⁶
	Fish diversity	McFarlane ⁷⁷
	Thermal tolerance of cyprinid minnows	McFarlane et al. ⁷⁸
Amphibians and Reptiles		
	Striped mud turtle in Steel Creek	Duever ⁷⁹
	Turtle parasites	Bourque and Esch ⁸⁰
	Turtle growth	Christy et al. ⁸¹
	Reptiles and amphibians of SRP	Gibbons and Patterson ⁸²
	Alligators of SRP	Murphy ⁸³
Birds	Birds of SRP	Norris ⁸⁴
	Waterfowl	Jenkins and Provost ⁸⁵
	Bird diversity and thermal stress	Straney et al. ⁸⁶
	Wood ducks	Fendley ⁸⁷
Mammals	Mammals of SRP	Jenkins and Provost ⁸⁵

TABLE 2.6-9

Water Quality Monitoring Data for Steel Creek at SRP Road A for 1973-1980

Parameter	Units	January	February	March	April	May	June	July	August	September	October	November	December
Temperature	°C	8.36 (3.0-13)	8.07 (5.0-10)	12.1 (8.0-17)	19.6 (17-24)	21.0 (18-24)	25.1 (23-26)	26.3 (23-30)	24.9 (23-27)	24.4 (23-27)	17.3 (2.4-23)	15.9 (11-19)	10.1 (6.0-17.5)
pH	pH	11.2 (5.9-8.0)	11.1 (6.3-7.4)	10.7 (6.0-7.3)	9.80 (6.1-7.5)	9.21 (6.1-7.3)	8.46 (5.7-7.3)	7.84 (5.3-7.78)	7.54 (5.8-8.0)	7.99 (5.7-7.1)	7.90 (6.5-7.3)	8.70 (6.4-7.6)	9.76 (6.4-9.0)
Dissolved Oxygen	mg/l	19.5-13	(9.8-12.6)	(8.6-13)	(8.2-12.9)	(6.4-12)	(7.0-12.1)	(5.1-12)	(6.8-10.4)	(6.1-9.5)	(5.3-10)	(6.4-10.9)	(6.0-12.7)
Alkalinity (CaCO ₃)	mg/l	14.8 (7.0-20)	14.3 (6.0-18)	14.4 (12-17)	24.6 (17-61)	19.0 (18-20)	20.1 (16-22)	18.1 (6.0-22)	16.7 (0.39-23)	19.6 (9.0-23)	20.6 (13-31)	21.1 (17-24)	17.9 (12-20)
Suspended Solids	mg/l	6.29 (2.0-18)	8.43 (2.0-32)	6.86 (1.0-13)	13.4 (5.0-21)	7.71 (10-12)	3.86 (1.0-9.0)	8.63 (1.0-4.0)	8.44 (3.0-19)	<6.31 (1.0-12)	5.13 (2.0-10)	11.5 (2.0-42)	5.13 (1.0-10)
Volatile Solids	mg/l	18.0 (14-22)	18.3 (11-34)	21.0 (16-25)	23.6 (6.0-61)	<20.3 (1-46)	14.3 (2.0-21)	19.3 (7.0-32)	19.1 (10-31)	21.9 (14-38)	16.4 (12-20)	20.4 (6.0-40)	15.5 (3.0-27)
Total Dissolved Solids	mg/l	44.9 (38-52)	41.0 (24-51)	41.1 (25-50)	45.4 (22-71)	43.9 (18-51)	49.7 (38-59)	50.4 (28-62)	48.7 (39.5-62)	46.8 (39-64)	49.4 (45-56)	48.0 (36-60)	47.8 (37-69)
Total Solids	mg/l	51.3 (42-58)	49.1 (41-56)	52.0 (48-62)	59.0 (34-92)	51.6 (20-72)	53.4 (44-61)	58.5 (28-100)	55.4 (50-65)	55.6 (51-68)	54.0 (48-60)	59.3 (42-86)	54.0 (41-70)
Fined Residue	mg/l	33.6 (26-42)	31.6 (24-42)	32.2 (28-40)	34.0 (27-43)	31.6 (29-38)	37.6 (30-54)	41.4 (20-73)	38.0 (25-49)	35.0 (30-40)	38.2 (34-40)	46.0 (30-69)	38.0 (32-44)
COD	mg/l	<9.17 (<5-19)	9.22 (3.3-24)	9.00 (7.0-13)	12.3 (5.0-22)	11.4 (9.0-15)	<13.0 (<5-24)	<12.0 (<5-20)	<12.0 (7.0-20)	<15.2 (7.0-33)	17.6 (<5-57)	<9.83 (<5-18)	<11.5 (<5-21)
BOD	mg/l	<1.13 (<1-1.4)	<1.10 (<1-1.3)	<1.0 (<1-1.0)	<1.0 (<1-1.0)	<1.0	<1.0	<1.0	<1.33 (<1.0-2.0)	<1.0	<1.0 <2.17	<1.13 (<1.0-1.4)	<1.0 (<1.0-1.0)
Kjeldahl N		<1.0 4.44	<1.0 3.80	<1.0 3.67	<1.0 3.99	<1.0 3.61	<1.0 3.65	<1.0 3.96	<1.0 3.86	<1.0 4.28	<1.0 4.04	<1.0 4.64	<1.0 4.18
Chloride (Cl)	mg/l	(2.7-7.1)	(3.2-4.4)	(2.9-4.8)	(3.2-4.9)	(1.5-5.0)	(2.9-4.2)	(3.0-5.1)	(2.7-5.1)	(3.4-5.2)	(0.001-6.5)	(2.8-5.9)	(3.5-5.6)

TABLE 2.6-9 (continued)

Parameter	Units	January	February	March	April	May	June	July	August	September	October	November	December
Nitrite (NO ₂ -N)	mg/l	<0.02 0.092	<0.02 0.104	<0.02 <0.086	<0.02 <0.083	<0.02 0.144	<0.02 0.141	<0.02	<0.024 (<0.02-0.05)	<0.02	<0.033 (<0.02-0.12)	<0.02	<0.02
Nitrate (NO ₃ -N)	mg/l	(0.031-0.14) 3.46	(0.07-0.16) 2.60	(<0.02-0.12) 2.27	(<0.02-0.14) <2.14	(0.02-0.25) <2.97	(0.03-0.27) <1.95	0.203 (0.01-0.42)	0.099 (0.02-0.22)	<0.080 (<0.02-0.14)	0.649 (0.06-4.45)	0.087 (0.04-0.13)	<0.099 (<0.02-1.16)
Sulfate (SO ₄ -S)	mg/l	(2.0-7.0)	(1.6-3.6)	(2.0-3.6)	(<2-2.9)	(<2-5.0)	(<1-3.0)	<2.23 (<1-3.0)	2.16 (1.9-3.9)	<2.83 (1.9-4.0)	2.11 (1.4-3.4)	<2.39 (<2-4.6)	<1.96 (1.1-2.2)
Sulfide (S)	mg/l	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Orthophosphate (O-PO ₄ -P)	mg/l	<0.02 0.02	<0.02 <0.027	<0.02 <0.029	<0.02 <0.024	<0.02 <0.031	<0.02 <0.026	<0.02 <0.059	<0.02 <0.026	<0.02 <0.025	<0.02 <0.021	<0.02 <0.021	<0.02 <0.02
Total Phosphate (PO ₄ -P)	mg/l	(<0.02-0.02) 0.72	(<0.02-0.05) 0.71	(0.02-0.08) 0.5	(0.02-0.03) 0.71	(0.02-0.07) 0.59	(<0.02-0.06) 0.64	(0.02-0.15) 0.65	(<0.02-0.04) 0.73	(<0.02-0.05) 0.78	(<0.02-0.025) 0.5	(<0.02-0.05) 0.54	(<0.02-0.025) 0.69
Aluminum (Al)	mg/l	(<0.5-<2.02) 0.02	(<0.5-<2) 0.02	0.02	(<0.5-<2) 0.02	(<0.5-<1) 0.20	(0.5-1.0) 0.16	(0.5-<2) 0.02	(<0.5-<2) 0.02	(<0.5-<2) 0.04	(<0.5-<2) 0.03	(<0.5-<2) 0.03	(<0.5-0.02) 0.01
Ammonia (NH ₄)	mg/l	(.002-.04) 6.68	(0.01-0.03) 5.81	(0.01-0.03) 6.13	(0.01-0.05) 6.55	(0.02-<1) 6.83	(<0.01-<1) 9.03	(0.01-<0.04) 7.75	(0.01-0.03) 7.48	(<0.01-<0.1) 7.02	(0.01-<0.1) 7.13	(<0.01-<0.1) 8.78	(.002-0.02) 6.54
Calcium (Ca)	mg/l	(4.4-10.65) 4.10	(4.6-9.0) 3.98	(5.0-8.0) 4.15	(4.7-8.7) 4.20	(5.1-8.0) 3.94	(5.3-15) 4.11	(5.5-11.3) 3.34	(5.0-12) 4.12	(5.0-9.8) 4.55	(0.90-12.4) 4.64	(6.0-13) 5.70	(7.65-8.7) 4.16
Sodium (Na)	mg/l	(2.5-7.8) 0.34	(2.0-8.0) 0.34	(2.5-7.1) 0.41	(2.2-8.2) 0.67	(2.9-5.6) 0.71	(2.7-5.3) 0.42	(1.1-7.6) 0.41	(2.9-6.7) 0.58	(2.9-7.6) 0.48	(3.1-8.6) 0.39	(3.2-10.8) 0.28	(2.4-8.5) 0.38
Total Iron (Fe)	mg/l	(0.1-0.5) 0.69	(0.2-0.6) 0.60	(0.1-1.0) 0.60	(0.20-6.75) 0.69	(<0.2-1.4) 0.60	(<0.1-0.75) 0.60	(<0.1-0.5) 0.60	(<0.1-1.5) 0.60	(<0.1-1.05) 0.60	(<0.1-0.9) 0.60	(<0.1-0.5) 0.60	(0.2-0.67) 0.60
Lead (Pb)	mg/l	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	(<0.5-2.0)	(<0.5-1.3)	<0.5

2.6.2.5 Species of Concern

Table 2.6-10 lists those species of organisms which could or have been found within the Steel Creek area that are on the Federal list of endangered species or various State of South Carolina lists of special concern. Not all of these species will be found in surveys of the Steel Creek area and several are common on SRP.

2.6.2.5.1 Federal Listings of Concern

The nearest colony of red-cockaded woodpecker (Picoides borealis) to Steel Creek is about one-half mile from Steel Creek in an upland loblolly-longleaf pine stand near SRP Road A-19.1 (Figures 2.6-20 and 2.6-21). This colony consists of one male bird and should not be impacted by cooling water discharge from L Area.

American alligators (Alligator mississippiensis) of all age classes have been observed in the Steel Creek floodplain from the L Area outfall through the delta area (Figures 2.6-22 and 2.6-23).⁸⁸ These include adults and one- to two-year old juveniles. One former nest has been located near SRP Road A and a new nest in the Steel Creek delta. Studies are ongoing to determine the distribution, numbers, sizes, reproductive status, and habitat use of the creek area by these reptiles.⁸⁸

The wood stork (Mycteria americana) has been observed at SRP during the summer months.* This bird is migratory at SRP and occurs here in small numbers during the summer. Studies are underway to determine the use of the Steel Creek delta area by these birds during their migratory visits at SRP.⁸⁸

2.6.2.5.2 State of South Carolina Listings of Concern

Several animal species and possibly a few plant species listed by the State of South Carolina occur in the Steel Creek area. Most of these species are found in other wetlands and aquatic habitats of SRP; for example, the red-headed and hairy woodpecker, the bobcat, the longtail weasel, the river otter, the bird-voiced treefrog, and the tiger salamander.

* May be added to the Federal list prior to L-Reactor startup; currently on the State of South Carolina list as "threatened."

TABLE 2.6-10

Species That May Occur in the Steel Creek Floodplain or Delta Area Which Are on the Federal List of Endangered Species or on the South Carolina List of "Endangered," "Threatened," or "Of Special Concern" List*

<u>Species</u>	<u>Federally Endangered**</u>	<u>Threatened, South Carolina</u>	<u>Of Special Concern, South Carolina</u>
Red-cockaded woodpecker† (<u>Picoides borealis</u>)	X		
American alligator (<u>Alligator mississippiensis</u>)	X		
Bald eagle (<u>Haliaeetus leucocephalus</u>)	X		
Cooper's hawk (<u>Accipiter cooperii</u>)		X	
Osprey (<u>Pandion haliaetus</u>)		X	
Wood stork†† (<u>Mycteria americana</u>)		X	
Black bear (<u>Ursus americanus</u>)		X	
Longtail weasel (<u>Mustela frenata</u>)			X
Bobcat (<u>Lynx rufus</u>)			X
River otter (<u>Lutra canadensis</u>)			X
Mississippi kite (<u>Ictinia mississippiensis</u>)			X
Red-headed woodpecker (<u>Melanerpes erythrocephalus</u>)			X
Hairy woodpecker (<u>Picoides villosus</u>)			X

* Sources:

Department of Interior, U.S. Fish and Wildlife Service. "List of Endangered and Threatened Wildlife and Plants." Federal Register, Vol. 44, No. 12, 3636-3654, (1979).

D. M. Forsythe and W. B. Ezell, Jr. (eds). Proceedings of the First South Carolina Endangered Species Symposium. Sponsored by the South Carolina Wildlife and Marine Resources Department and the Citadel, November 11-12, 1976. Charleston, SC. (1979).

D. A. Rayner. "Native Vascular Plants Endangered, Threatened or Otherwise in Jeopardy in South Carolina." South Carolina Museum Commission, Museum Bulletin No. 4, (1979).

** Also state "endangered."

† An upland species of pine stands. Included for completeness of listing.

†† May be added to the Federal list.

TABLE 2.6-10 (continued)

Species	Federally Endangered**	Threatened, South Carolina	Of Special Concern, South Carolina
Swainson's warbler (<u>Limnothlypis swainsonii</u>)			X
Spotted turtle (<u>Clemmys guttata</u>)			X
Carolina swamp snake (<u>Seminatrix pygaea</u>)			X
Bird-voiced treefrog (<u>Hyla avivoca ogehiensis</u>)			X
Pickerel frog (<u>Rana palustris</u>)			X
Tiger salamander (<u>Ambystoma tigrinum tigrinum</u>)			X
American shad (<u>Alosa sapidissima</u>)			X
Blueback herring (<u>Alosa aestwales</u>)			X
Crayfish (<u>Procambarus hirsutus</u>)			X
Spatulate seedbox (<u>Ludwigia spathulata</u>)		X	
Ann-petaled meadow beauty (<u>Rhexia aristosa</u>)		X	
Pink tickseed (<u>Coreopsis rosca</u>)		X	
Little burhead (<u>Echinodorus parvulus</u>)		X	
Green-fringed orchid (<u>Habernaria lacera</u>)		X	

* Sources:

Department of Interior, U.S. Fish and Wildlife Service. "List of Endangered and Threatened Wildlife and Plants." Federal Register, Vol. 44, No. 12, 3636-3654, (1979).

D. M. Forsythe and W. B. Ezell, Jr. (eds). Proceedings of the First South Carolina Endangered Species Symposium. Sponsored by the South Carolina Wildlife and Marine Resources Department and the Citadel, November 11-12, 1976. Charleston, SC. (1979).

D. A. Rayner. "Native Vascular Plants Endangered, Threatened or Otherwise in Jeopardy in South Carolina." South Carolina Museum Commission, Museum Bulletin No. 4, (1979).

** Also state "endangered."

† An upland species of pine stands. Included for completeness of listing.

FIGURE 2.6-20. Red-Cockaded Woodpecker Colony 1/4 Mile from Steel Creek in an Upland Pine Stand

FIGURE 2.6-22. American Alligator in Vicinity of L-Area
Cooling Water Canal

FIGURE 2.6-23. American Alligator Status of SRP

Studies are underway to better define the occurrence of these species in the Steel Creek area.⁸⁸ Investigations are also being conducted on the potential use of Steel Creek and the Steel Creek delta area by anadromous fish, especially American shad and blueback herring.

2.7.1 Radiological Characteristics of the Environment

Natural radiation contributes about 48% of the annual dose of 194 mrem which an average member of the population receives within 50 miles of SRP. Medical exposure accounts for 47% of the annual dose and the combined doses from weapons test fallout, consumer and industrial products, and air travel account for about 5% of the dose. Releases of radioactivity to the environment from SRP accounts for less than 0.1% of the dose.

2.7.1.1 Natural Background Radiation

2.7.1.1.1 Cosmic Radiation

The contribution of cosmic radiation to natural background dose varies with both latitude and altitude. Sea-level dose rates range from 30 mrem per year in Florida to 45 mrem per year in Alaska; the exposure rate increases to 200 mrem per year at an altitude of 8000 feet.⁸⁹ The average unshielded cosmic radiation dose rate in Georgia and South Carolina is 40 mrem per year.⁹⁰ SRP and the surrounding area lie between latitudes 33°N and 34°N and with an altitude variation between sea level and roughly 1000 feet (305 meters). It has been estimated that the total unshielded dose equivalent from cosmic radiation in the vicinity of SRP (50-mile radius) is 35 mrem per year, of which 29 mrem per year is from the ionizing component and 6 mrem per year is from neutrons.⁸ Shielding by buildings and the body reduces cosmic radiation dose to about 32 mrem per year, a 10% reduction.

2.7.1.1.2 Terrestrial Gamma Radiation

Terrestrial gamma radiation (external to the human body) is attributed primarily to gamma-emitting radionuclides in the natural radioactive series derived from uranium and thorium, with some additional contribution from potassium-40. Variation in the distribution of these natural radioactive materials with geologic formations and their inclusion in materials of construction commonly used in urban areas leads to a wide variation with location. The average unshielded external dose rates from this source of exposure are 60 mrem per year and 70 mrem per year in Georgia

and South Carolina, respectively. Within 50 miles of SRP, measured external gamma dose rates range from 6 to 385 mrem per year.⁸ A value of 55 mrem per year represents the average unshielded external terrestrial background in the vicinity of SRP. Shielding by buildings and the body reduces this terrestrial radiation dose to about 33 mrem per year, a 40% reduction.

2.7.1.1.3 Natural Radioactivity in the Human Body

Internal radiation from natural sources arises primarily from potassium-40, daughters of radium-226, carbon-14, and rubidium-87. No estimate of variation with location is made because the widespread distribution of fertilizers and food and population mobility has an averaging effect for these long-lived radionuclides that produce the internal dose. It is estimated that the average internal radiation exposure in the United States from natural radioactivity is 28 mrem per year.⁹¹

2.7.1.2 Medical Radiation

Medical radiation exposure is the largest source of population exposure to man-made radiation in the United States. Based on a nationwide survey⁹² made in 1970, the Bureau of Radiological Health of the Food and Drug Administration estimated that 65% of the people in the United States were exposed to medical and dental x-rays that year. Based on this survey, the average dose to an individual when prorated* over the total population was 77.3 mrem per year. In addition, radio-pharmaceuticals administered to patients for diagnostic and therapeutic purposes account for an average annual dose of 13.6 mrem when prorated over the population. To these patient doses must be added the radiation dose to medical and dental personnel (occupational exposure), which amounts to 0.36 mrem per year when prorated over the total population. Thus, the average medical radiation dose in the U.S. population is about 91 mrem per year.

* Prorating of the dose over the population, as used here and in following parts of this section, is a means of arriving at an average dose, which when multiplied by the population size, produces an estimate of population exposure. It does not mean that every member of the population receives a radiation exposure from these sources.

2.7.1.3 Weapons Test Fallout

Fallout from nuclear weapons tests is a source of radioactivity in the environment. The large-scale atmospheric tests conducted by the United States and the Soviet Union in 1961 and 1962 introduced radioactive materials into the stratosphere which were later distributed worldwide. A small amount of radioactivity from these tests continues to be deposited. The more recent Chinese and French tests have been sufficient to maintain a relatively constant rate of fallout deposition. The current and past fallout contributes to human exposure through:

- External radiation from radioactive material on the earth's surface
- Internal radiation from inhalation of airborne fallout
- Internal radiation from ingestion of food and water contaminated by fallout

Cesium-137 deposited from past nuclear weapons tests is the major source of long-lived external gamma radiation from fallout. Short-lived radionuclides also contribute significantly to external radiation within a few years of major tests but currently contribute little to the dose. The current dose rate from external gamma radiation is estimated to be about 0.9 mrem per year.⁹⁰

Most doses from inhalation of fallout are received in the year after exposure. However, doses from strontium-90 and plutonium-239 will be received over a lifetime because of the long residence time of these radionuclides in the body. The annual dose from inhaled fallout radioactivity was estimated to be only 0.04 mrem in 1969⁹⁰ and is currently even lower.

Ingestion of radioactivity of fallout origin in food and water is the largest source of radiation exposure. It is estimated that this source of exposure was 3.7 mrem per year in 1980, consisting of 0.6 mrem from carbon-14, 0.4 mrem from cesium-137, and 2.7 mrem from strontium-90.

The average annual total body dose in 1980 from fallout from nuclear weapons tests is estimated to be 4.6 mrem (0.9 from external gamma and 3.7 from ingested radioactivity).

2.7.1.4 Consumer and Industrial Products

A variety of consumer and industrial products yield ionizing radiation or certain radioactive materials and therefore cause radiation exposure to the general population. Some of these sources are television sets, luminous dial watches, airport x-ray inspection systems, dental prosthesis, smoke detectors, cardiac pacemakers, tobacco products, fossil fuels, and building materials. The estimated whole body dose for the U.S. population from these sources is four to five mrem per year.⁹¹ About 3/4 of this is from external exposure to naturally occurring radionuclides in building materials.

2.7.1.5 Cosmic Radiation Dose to Airline Passengers

Persons who travel by aircraft receive additional exposure from cosmic radiation because at high altitude the atmosphere provides less shielding from this source of radiation. The average annual airline passenger dose is 2.8 mrem, which when prorated over the entire U.S. population amounts to an average dose rate of 0.5 mrem per year.⁹¹

2.7.1.6 Nuclear Facilities Other Than SRP

The growth of nuclear industry and facilities in the southern United States has been rapid, most of it occurring in the 1970's. Figure 2.7-1 shows the location of facilities either operating or licensed to operate in 1981. The low-level burial site shown at Maxey Flats, Kentucky was shut down in 1977. Figure 2.7-1 shows 24 power reactors. Not shown are 34 power reactors under construction and 4 reactors being planned. When all of these are operating, there will be 61 power reactors in the southern U.S. Typically, the average radiation dose to individuals within 50 miles of a nuclear facility is quite low as shown in Table 2.7-1.⁹³ The radiation doses shown in this table are population-weighted averages for the entire 50-mile radius around the nuclear facilities.

The only nuclear facility operating within 50 miles of the Savannah River Plant (during the operating history of SRP) is a low-level waste burial site operated by Chem-Nuclear Systems, Inc., near the east SRP boundary. This facility, which started operation in 1971, releases essentially no radioactivity to the environment⁹⁴ and population dose from normal operations is nil. The 50-mile radius population receives an immeasurable external radiation dose from transportation of low-level radioactive waste to the burial site.

FIGURE 2.7-1. Nuclear Facilities in the Southern United States - October 1980

TABLE 2.7-1

Average Dose Rates to 50-Mile-Radius Population
from Nuclear Facilities⁹³

<u>Facility</u>	<u>Dose to Average Individual, mrem/yr</u>
Power reactors	
boiling water reactor (BWR)	0.0033
pressurized water reactor (PWR)	0.0021
Nonpower reactors	
test reactors	0.00044
research reactors	0.00021
university reactors	0.00097
Reactor fuel fabrication	0.000036
Low-level burial	0.012
DOE facilities - Oak Ridge, TN	0.0068

2.7.1.7 Savannah River Plant

Construction of the Savannah River Plant started in February 1951, with completion of most of the major facilities by July 1955.²³ Releases of radioactive material to the environment from current operations (1978-1980) cause an average dose of about 0.2 mrem per year of operation to the 50-mile radius population and to downstream consumers of Savannah River water.⁹⁵⁻⁹⁸

2.7.1.8 Summary of Major Sources of Population Exposure

A summary of the major sources of exposure for the population within 50 miles of SRP and to the river water consuming population in Beaufort and Jasper Counties, South Carolina, and in Port Wentworth, Georgia, is presented in Table 2.7-2. Natural background radiation and medical exposure account for about 48% and 47%, respectively, of the annual average dose of 194 mrem. Weapons test fallout, consumer and industrial products, and air travel combine to account for about 5% of the dose. Releases of radioactivity to the environment from SRP accounts for only about 0.1% of the dose.

TABLE 2.7-2

Major Sources of Radiation Exposure in the Vicinity of SRP

<u>Source of Exposure</u>	<u>Dose to Average Individual, mrem per year of exposure</u>	<u>Percent of Exposure</u>
Natural Background Radiation		
Cosmic Radiation	32	
External Terrestrial Gamma	33.0	
Internal	<u>28.0</u>	
Natural Background Total	93	47.9
Medical Radiation		
Diagnostic X-Rays	77.3	
Radiopharmaceuticals	13.6	
Medical and Dental Personnel	<u>0.4</u>	
Medical Total	91.3	47.1
Weapons Test Fallout	4.6	2.4
Consumer and Industrial Products	4.5	2.4
Air Travel	0.5	0.3
Nuclear Facilities (other than SRP)	nil	-
Savannah River Plant - Environmental Radioactivity (1980)	<u>0.2</u>	0.1
Grand Total	194	

2.7.2 Cesium-137 in Steel Creek and the Savannah River Swamp

2.7.2.1 Source of Cesium-137

The cesium-137* in SRP streams and swamp bottomlands originated primarily from discharge to onsite streams from reactor fuel storage facilities during the 1960's (Figure 2.7-2 and Table 2.7-3).⁹⁹ An additional 39 curies of cesium-137 was discharged from the 200 Separations Areas to Four Mile Creek.⁹⁹ Thus, a total of about 500 curies of cesium-137 has been discharged to all SRP streams since 1955 (Figure 2.7-3). Of this total, approximately 16 curies were discharged between 1955 and 1961 and 267 to 268 curies were discharged to Steel Creek between 1961 and 1973 (Table 2.7-4). The discharges to Steel Creek were substantially reduced in 1970 after modifications to P Reactor and shutdown of L-Reactör.

Of the 500 curies of cesium-137 released to streams, 290 curies have been measured in transport at SRP Road A (SC 125). Of the total released, only 90 curies, or 18%, has been measured in transport in the Savannah River, downstream of SRP at the U.S. Highway 301 bridge.⁹⁹ Much of the cesium-137 becomes sorbed or bound to the sediments of the streams and swamps of SRP. However, in addition to transport of cesium-137 to the Savannah River some cesium-137, about 25 curies, has been deposited offsite of SRP onto the Creek Plantation Swamp.⁹⁹

As described in Section 2.5.1 the Savannah River floods about 23% of the year primarily from January through April (Table 2.5-5). When this flooding occurs, Beaver Dam Creek, Four Mile Creek, and the combined Pen Branch-Steel Creek flow do not discharge to the Savannah River through their normal breaches in the levee along the river. Instead, the water from these streams flows parallel to the river along with the flood waters, past the southeast corner of the SRP boundary, and across approximately four miles of privately owned swamp, known locally as Creek Plantation Swamp. The flood water enters the Savannah River at Little Hell Landing, an oxbow in the river which is no longer part of the main channel. Figure 2.5-4 shows the apparent flow path of SRP streams offsite through Creek Plantation Swamp during flood stage.

* It is assumed that all of the radioactive cesium was Cs-137. Cs-134, half-life of 2.1 years, was also present but represented less than 10 percent of the amount of Cs-137.

FIGURE 2.7-2. Reactor Releases of Cesium-137 During Years of Principal Release, 1961-1973.

TABLE 2.7-3

Cesium Releases by Reactor Areas During Years of Principal Release, 1961-1973

	<u>R</u>	<u>P</u>	<u>L</u>	<u>K</u>	<u>C</u>	<u>Total</u>
1961	10.3	4.2	1.0	1.8	1.7	19.0
1962	13.2	13.7	1.3	4.6	4.8	37.6
1963	83.4	9.0	0.9	3.3	0.7	97.3
1964	47.1	45.6	7.7	5.6	0.7	106.7
1965	-	29.8	1.3	2.5	0.3	33.9
1966	-	35.7	0.9	<0.1	-	36.6
1967	-	45.1	0.7	0.5	0.7	47.0
1968	-	40.9	0.2	0.1	0.1	41.3
1969	-	13.1	3.4	-	3.5	20.0
1970	-	7.7	3.2	-	9.7	20.6
1971	-	1.3	-	-	0.2	1.5
1972	-	0.2	-	<0.1	-	0.2
1973	<u>-</u>	<u>0.4</u>	<u>0.4</u>	<u><0.1</u>	<u>0.1</u>	<u>0.5</u>
Total	154.0	246.7	20.6	18.4	22.5	462.2

FIGURE 2.7-3. SRP Map Showing Cesium Releases to Each Effluent Stream, 1961-1973

TABLE 2.7-4

Cesium-137 Release, Transport and Accumulation in the Steel Creek System
1955-1980

Year	P Release Ci/Yr	L Release, Ci/Yr	Cs-137 Discharge Corrected for Decay, Ci	Cs-137 Transported Past Road A in Steel Creek, Ci/yr	Inventory above Road A Corrected for Decay, Ci
1955	0.2	0.2	0.4	(-)	0.4
1956	0.4	0.3	1.1	(-)	1.1
1957	1.1	0.7	2.9	(-)	2.9
1958	0.5	0.6	3.9	(-)	3.9
1959	0.7	1.6	6.1	(-)	6.1
1960	4.8	5.2	16.0	4.5	11.5
1961	4.2	1.0	20.8	6.1	10.3
1962	13.7	1.3	35.3	11.8	13.3
1963	9.0	0.9	44.4	9.2	13.7
1964	45.6	7.7	96.7	23.0	42.9
1965	29.8	1.3	125.6	20.0	53.0
1966	35.7	0.9	159.4	25.2	63.2
1967	45.1	0.7	201.5	20.3	87.2
1968	40.9	0.2	238.0	22.2	104.2
1969	13.1	0.2	249.1	14.7	103.6
1970	7.7	3.4	254.4	9.2	102.9
1971	1.3	3.2	244.9	1.6	100.3
1972	0.2	0	244.4	0.8	97.4
1973	0.2	0	239.0	0.8	94.6
1974	0.07	0	233.6	0.6	91.9
1975	0.04	0	228.4	0.5	89.4
1976	0.07	0	223.2	0.8	86.6
1977	0.09	0	218.2	0.3	84.4
1978	0.02	0	213.3	0.3	82.2
1979	0.02	0	208.5	0.4	80.0
1980	0.02	0	203.7	0.7	77.5

(-) Not measured, assumed to be 0.

When the swamp is flooded, the velocity of water flow is lower than that in the main river channel because of the width (2000 to 3000 feet) and because of flow restrictions caused by the dense understory and hardwood forest. At the margin of the floodplain, there is a depressed channel in the swamp through which most of the SRP effluents flow during flood stage.

As the SRP streams enter the onsite SRP swamp, coarser sediments have been deposited, and deltas have formed in the swamp. Finer sediments, consisting mainly of silts and clays (especially kaolin) are deposited further downstream in the Savannah River swamp during flood stage, both on the SRP site and in the Creek Plantation Swamp. The radioactivity in the swamp is sorbed or bound on these sediments by natural ion-exchange processes. From these sediments a small percentage (<1%) is taken up and passed into the food chains and the biota of the floodplain area. The sediments, once deposited, especially in the Creek Plantation Swamp, are relatively immobile and not subject to erosion because of the low water velocity in the swamp during periods of flooding and overlayering of later sediment deposits. In addition the Steel Creek floodplain and delta are now well stabilized with vegetational cover (Figures 2.6-11 through 2.6-19). Increased cesium movement from Steel Creek to the Savannah River and onto Creek Plantation Swamp would not be expected unless the vegetational cover decrease and flow rates increase significantly, as will occur following L-Reactor startup with cooling water discharge to Steel Creek.

2.7.2.2 Cesium-137 Distribution in Steel Creek and the Steel Creek Delta

2.7.2.2.1 Distribution in the Soils of the Steel Creek Area

The distribution of radiocesium in Steel Creek and the Steel Creek Delta is primarily the result of erosional processes. Sediments were eroded and deposited repeatedly in Steel Creek by cooling water discharges from P and L Reactors (Figures 2.5-3 and 2.7-4) during much of the period of cesium release to Steel Creek resulting in a complex mosaic of radiocesium distribution. Surveys indicate that apparently over 95% of the cesium is contained within the soil profile and that this value is probably closer to 98 to 99% for most locations in Steel Creek. Within the soil profiles of Steel Creek and its delta about 70% of the total cesium is located in the upper 20 cm with nearly all of the cesium confined to the upper first meter (Table 2.7-5).^{88,100}

The cesium is also primarily associated with the smaller sized soil particles and the soils can be classified as fine or coarse.^{88,100} This classification accounts for the large

FIGURE 2.7-4. Annual Flow and Cesium-137 Release and Transport in Steel Creek and the Savannah River

TABLE 2.7-5

Distribution of Average Radiocesium Concentration
(pCi/g dry wt) at Various Depths in 21 Soil Cores Taken
Along Two Transects in Steel Creek, 1974.*

<u>Depth Interval, cm</u>	<u>Mean</u>	<u>Standard Error</u>	<u>Range</u>
0-10	93.5	32.3	5.6-516.4
11-20	24.5	6.8	3.1-137.5
21-30	15.1	4.1	2.3-75.1
31-40	13.0	3.8	1.4-60.6
41-50	7.1	2.1	1.0-42.8
51-60	3.8	0.6	0.5-10.9
61-70	3.4	0.4	0.8-7.2
71-80	4.0	0.9	0.2-15.5
81-90	3.3	0.7	0.1-14.0
91-100	2.1	0.4	0.0-6.9

* Reference 100.

variation in cesium concentration between soil samples in the Steel Creek area. Near the delta, fine soils ranged from means of 145.8 to 189.5 pCi of cesium-137 per gram dry weight. Also, the spatial distribution of the cesium can be quite variable on a micro-geographic basis. Soil samples taken near the delta can differ by more than 190% of their mean even when they come from sites only 1 meter apart.^{100,101} Thus, large variation in survey data from permanent transect samples from year to year may be explained by slight differences in sampling sites rather than necessarily temporal shifts in cesium in the stream and swamp areas.

There is no unambiguous data to support major shifts in the distribution of cesium in the Steel Creek area and Creek Plantation Swamp since L Reactor was shut down. The present distribution is probably due primarily to high flow conditions that prevailed in Steel Creek during operation of L Reactor (Figure 2.7-4). The cesium was already distributed along Steel Creek and its floodplain, into the delta, and offsite onto Creek Plantation Swamp to Little Hell Landing when surveys first detected its presence offsite.⁹⁹

2.7.2.2.2 Cesium-137 Concentrations in the Biota

The amount of radiocesium in some typical plants and animals of the Steel Creek delta are given in Tables 2.7-6 through 2.7-9.

The mean concentrations are generally higher for the delta than those reported elsewhere for the biota of the Creek Plantation Swamp.^{95,96,99,102-104} The amount of cesium in the vegetation is higher than from studies elsewhere in North America. The concentration factor for radiocesium in plants (concentration in plant/concentration in soil) is generally higher for the southeastern United States than other parts of the country.¹⁰⁵ The concentration factor for plants in the Steel Creek area is almost two orders of magnitude higher than in White Oak Lake in Tennessee. Similarly, higher concentration factors are observed in Lower Three Runs Creek of SRP.^{106,107}

The concentration of radiocesium in the smaller terrestrial animals is higher than that for the larger ones. For example, cotton rats averaged 607.9 pCi per gram of dry weight (Table 2.7-6), while deer and other larger fur bearing animals typically do not exceed 20 pCi per gram of dry weight.⁹⁹ These larger animals probably forage over larger areas, and thus reduce their exposure and body burdens due to lower average dietary intake of radiocesium.

The concentration of radiocesium in wildlife species is generally not high in Steel Creek. Typical values for the Steel

TABLE 2.7-6

Radiocesium Concentrations (pCi/g dry wt) in Selected Components of the Steel Creek Floodplain Ecosystem. Time and Place of Sample Collection is Variable

<u>Component with Species or Type</u>	<u>n</u>	<u>$\bar{X}$ Conc. or Range of $\bar{X}$ Concentrations</u>	<u>Reference</u>
Soil - Fine Clay	182	145.8-189.5	100
Coarse Sand	114	13.1-23.5	100
Producers			
Herbaceous Leaves			
<u>Sagittaria latifolia</u>	194	347.6-514.8	108
" "	280	257.9-961.5	109
<u>Scirpus cyperinus</u>	272	35.2-190.2	109
" "	130	509.9	110
<u>Polygonum punctatum</u>	138	265.4-323.4	108
" "	294	115.8-635.5	109
<u>Andropogon spp.</u>	102	494.4	110
" "	20	470.0-2300	111
Woody Leaves			
<u>Salix nigra</u>	280	178.8-595.2	109
" "	20	510-1600	111
<u>Myrica cerifera</u>	59	134.3	110
" "	18	540-1500	111
<u>Alnus serrulata</u>	45	215.6	110
" "	18	370-1000	111
Consumers			
Invertebrates			
Coleoptera	50	440-990	111
Orthoptera	50	400-1500	111
Homoptera	50	150-600	111
Araneae	50	260-970	111
Amphibians and Reptiles			
<u>Hyla cinerea</u>	141	189.2	112
<u>Natrix spp.*</u>	13	122.2	113
Birds			
Herbivores*	**	32	114
Omnivores*	**	25	114
Carnivores	**	12	114
Mammals			
<u>Sigmodon hispidus</u>	91	607.9	†
<u>Oryzomys palustris</u>	47	214.2	†

* pCi/g wet weight; to approximate pCi/g dry wt, multiply by 4.

** Sample sizes not reported.

† M. Smith, Savannah River Ecology Laboratory, Aiken, SC, Personal Communication.

TABLE 2.7-7

Cesium-137 in Steel Creek Vegetation, pCi/g (dry wt)

Sample Point	<u>1970</u> <u>Avg</u>	<u>1971</u> <u>Avg</u>	<u>1972</u> <u>Avg</u>	<u>1973</u> <u>Avg</u>	<u>1974</u> <u>Avg</u>	<u>1975</u> <u>Avg</u>	<u>1976</u> <u>Avg</u>	<u>1977</u> <u>Avg</u>	<u>1978</u> <u>Avg</u>	<u>1979</u> <u>Avg</u>
0	600	310	150	210	380	240	420	1000	160	110
1	2200	360	20	340	280	220	250	1300	520	270
2	1000	890	150	120	160	240	400	1800	770	310
3	1300	660	450	360	210	380	360	420	270	250
4	220	1100	340	280	310	180	230	410	250	200
5	1960	510	360	210	210	200	100	420	220	200
6	1100	1100	770	220	260	160	390	220	150	130
7	1600	660	290	240	220	220	180	250	210	83
8	1100	570	460	190	130	110	170	220	160	110
9	260	160	380	210	190	190	190	210	170	140
Average	1300	630	340	240	235	214	270	625	290	190

* The higher values for 1977 and 1978 may have resulted from the 1976 hot water discharge to Steel Creek from P Area.

TABLE 2.7-8

Cesium-137 in Wildlife in the Steel Creek Vicinity

<u>Organism</u>	<u>Number</u>	<u>Concentration in Muscle, pCi/g Wet Wt Unless Noted</u>		<u>Year</u>
		<u>Maximum</u>	<u>Average</u>	
Deer	11	15*	8*	1973
Bobcat	3		10*	1974
Fox	1		6*	1974
Raccoon	1		8*	1974
	4	0.9	0.5	1977
	1	0.6	0.6	1978
Opossum	4		10*	1974
Beaver				
Road A.14.1			21.6	1977
Road A.14			22.5	1977
Duck	2	0.1	0.1	1977
	19	36.1	5.7	1978
Road B	2	30	25	1974
Road A	5	105	67	1974
Fish				
Bream - Road A	1	3.9	3.9	1977
Bream - Mouth of Steel Creek	5	1.0	0.4	1977
Bream - Road A	8	29	20	1978
Bream - Mouth of Steel Creek	4	6	2	1978
Bass - Mouth of Steel Creek	4	3	1	1978
Catfish - Road A	1	2.8	2.8	1977

* pCi/g dry wt

TABLE 2.7-9

Cesium-137 Inventory in the Steel Creek System

Above Road A		
Mass Balance Basis (1980)		77.5 Ci
Below Road A		
Mass Balance Basis (1980)		82 Ci
Contaminated Area Basis		
Road A to ACL Bridge ($8.41\text{E}6\text{ft}^2$)	22.3*	
ACL Bridge to Delta ($7.49\text{E}6\text{ft}^2$)	19.9	
Delta ($12.36\text{E}6\text{ft}^2$)	32.8*	
Total (1972)	75	
(1980)	62 Ci	
Total**		<u>159.5 Ci</u>

*. Estimated using data from ACL Bridge-Delta and the assumption the cesium-137 depth distribution was the same.

** The higher cesium-137 inventory estimate below Road A was used for the total inventory.

Creek area are given in Table 2.7-8.⁹⁹ The maximum concentration in ducks was slightly over 105 pCi per gram of dry weight during the 1974 Steel Creek survey,⁹⁹ but the mean concentration in the delta in wood ducks during the winter of 1973-1974 was 82.9 pCi per gram of dry weight.⁸⁷ The concentration in the biota seems to be declining in Steel Creek although the reason(s) for the decline are not known. Typical values for fish from Steel Creek are also given in Table 2.7-8.

The concentration in the biota is not sufficient, considering the amount of mass which they represent for there to be a substantial fraction (<1%) of the total inventory of cesium-137 in the Steel Creek system.

2.7.2.2.3 Estimate of Present Inventory in Steel Creek and Steel Creek Delta

Most of the cesium-137 was discharged to Steel Creek in the middle 1960's (Table 2.7-4), and the discharge decreased steadily until 1972 at which time discharges to the creek were stopped. From aerial radiological surveys, the cesium-137 contamination is spread in the floodplain area of the Steel Creek system from P Area to the Savannah River (Figure 2.7-5).¹¹⁵ The largest area of contamination is the Steel Creek delta. The delta occurs at the mouth of Steel Creek in the Savannah River floodplain and has accumulated sediment since reactor startup.

The cesium-137 inventory in the Steel Creek system was estimated by using mass balance and contaminated area approaches. The mass balance approach accounts for the amount released by measuring the amount in transport at downstream locations. An accumulation is assumed if less is transported at a location than was supplied to it from upstream. The contaminated area approach uses radiological measurements of sediment and integrates over the area and depth of contamination. Aerial radiologic inventories require assumptions about the depth distribution and averages over large measured areas. Ground surveys give good information on a small scale and on the depth distribution but are restricted in the amount of area actually surveyed. Both approaches are useful in determining the amount of cesium-137 in the Steel Creek system.

Measurements of cesium-137 transport in Steel Creek (Road A) and the Savannah River (Highway 301) showed that most of the cesium-137 discharged was still in the Steel Creek system. An estimate based on an aerial cesium-137 survey indicated that an inventory of about 13 curies was present in Steel Creek below Road A (Figure 2.7-6).⁹⁹ A ground survey, covering about the middle 30% of aerial survey, estimated that about 20 curies were present in this smaller region.¹⁰⁰ The discrepancy between these two

FIGURE 2.7-5. Gamma Exposure Rate Isopleths for Cesium-137 Derived from an Aerial Radiological Survey of the Savannah River Plant on June 2 Through June 25, 1974¹¹⁵

FIGURE 2.7-6. Sampling Locations for Cesium-137

estimates probably lies in the fact that the aerial inventory was calculated by using the assumption that the cesium-137 was distributed similar to nuclear weapons fallout cesium-137 (i.e., most of the cesium-137 was in the upper 7 cm). Whereas the Steel Creek system is an eroding-depositing system that distributes the cesium-137 to greater depths than in the fallout assumption. The Savannah River Ecology Laboratory (SREL) is conducting a ground survey to estimate the cesium-137 inventory in the Steel Creek system.⁸⁸ Preliminary results indicate that distribution of cesium-137 to greater depths is common along the creek.

The mass balance and contaminated area approaches were used to update and extend the cesium-137 inventories made in 1974. The on site cesium-137 inventory was divided into two areas: above Road A and below Road A. The overall biomass cesium-137 inventory was also estimated. The cesium-137 inventory was adjusted to 1980 to reflect the amount of radioactive decay that has occurred since the measurements were made.

A total inventory of about 160 Ci of cesium-137 has been estimated as still remaining in the Steel Creek system (Table 2.7-9). This is probably a conservative estimate in that preliminary results from the SREL survey program currently in progress indicate an inventory of 60 to 100 Ci of cesium-137.⁸⁸

- Cesium Inventory Above Road A

A cesium-137 inventory above Road A was made by using the mass balance approach. The accumulated cesium-137 inventory above Road A was made by subtracting the yearly transport of cesium-137 past Road A from the yearly releases to Steel Creek and accumulating the remainder with correction for radioactive decay (Table 2.7-4 and Figure 2.7-7). The resulting cesium-137 inventory was rapidly accumulating in the mid 1960's and peaked in 1968 with little change since that time. About 90% of the inventory decrease since 1971 is due to the radioactive decay of the cesium-137 and the other 10% is due to transport past Road A. This result shows that the cesium-137 has changed very little since discharges to the creek stopped in 1972. The current inventory is about 77.5 curies (Table 2.7-9).

- Cesium Inventory Between Road A and the Savannah River

The amount of cesium-137 below Road A was estimated by using the mass balance sediment analyses and integrating over the area of contamination.

FIGURE 2.7-7. Cesium-137 Inventory Above Road A

An estimate of the amount left in the Steel Creek system below Road A can be made using the cesium-137 transport data at Highway 301 and Road A. The amount of cesium-137 that has been transported past Highway 301 is 90 curies, and this represents all SRP contributions (Figure 2.7-3). If it is assumed that the Highway 301 transport is in direct proportion to cesium-137 transported past Road A, then about 60% of the cesium-137 at Highway 301 comes from Steel Creek. Of the 290 curies in transport at Road A, about 173 curies are from Steel Creek ($173/290 = 0.6$). About 54 curies of cesium-137 has left the Steel Creek system via discharge to the river ($90 \times 0.6 = 54$ curies).

Correcting for the amount of cesium-137 going past Highway 301, the amount of cesium-137 below Road A in 1974 is about 119 curies (173 curies past Road A minus 54 curies past Highway 301 = 119 curies). The amount in the onsite Steel Creek system must be corrected for the amount offsite on Steel Creek Plantation (25 curies) leaving about 94 curies in the Steel Creek system below Road A in 1974, and this would have decayed to 82 curies by the end of 1980 (Table 2.7-9).

Another estimate of the amount of cesium-137 left between Road A and the Savannah River can be made using the available data on cesium-137 concentrations in the sediment, vegetation, and the areas of contamination. Of the area below Road A, about 30% was surveyed in 1972 for the sediment cesium-137 distribution. This area extended from the ACL Railroad Bridge to the mouth of Steel Creek (Figure 2.7-6) where it empties into the Savannah River wetlands. Sediment cesium-137 analyses of other areas of this region have not been completed. However, extensive vegetation surveys have been made in this general region. Even though there are different concentration ratios for different species, the vegetation reflects the cesium-137 concentration in the sediment.^{105,110} Little variation in ¹³⁷Cs concentration of vegetation was found from the primary release point from P Area to the Steel creek delta.¹¹⁰ This same result is shown by using the cesium-137 vegetation analyses from the SRP Environmental Monitoring Program. The vegetation is sampled at 10 marked locations (0-9) along Steel Creek (Figure 2.7-6) biweekly from April to October and the results pooled from each location.^{96,102-104} A plot of the five-year averages and their standard deviations are shown in Figure 2.7-8. A slight decrease in the cesium-137 may be suspected, but it is not statistically different from a straight line of zero slope through the data. From this data, it would appear that the sediments are probably uniform in cesium-137 concentration below Road A (Figures 2.7-6 and 2.7-8, Locations 7, 8, and 9).

FIGURE 2.7-8. Cesium-137 Concentration in Vegetation in the Steel Creek System. For Sampling Locations, see Figure 2.7-6.

The cesium-137 inventory below Road A was calculated by assuming that the cesium-137 was distributed throughout this region as it was in the middle section (ACL Bridge to Steel Creek mouth) and that the inventory is proportional to the area of the floodplain. The area of the floodplain between Road A and the delta was measured by using a U.S. Geological Survey (USGS) floodplain map for SRP. The delta area was determined from aerial photos and by integrating only the areas devoid of trees. The delta area of cesium-137 contamination was probably underestimated by this method. The results from Table 2.7-9 yield an inventory estimate of about 75 curies which would have decayed to 62 Ci in 1980. This estimate is less than that arrived at by the mass balance estimate. The higher estimate of 82 Ci from the mass balance method will be used as the inventory below Road A.

- Inventory of Cesium-137 in the Vegetation

The cesium-137 inventory in the Steel Creek biotic community is very small. The inventory of cesium-137 in the plant community of the Steel Creek system was made by using floodplain areas integrated from USGS floodplain maps, estimates of the biomass inventory (304 grams per square meter)⁵⁹ and vegetation analyses from various reaches of Steel Creek.^{95,102-104} Approximately 0.4 curie of the cesium-137 is in the plant community, Table 2.7-10. The cesium-137 inventory in the animal community would be insignificant (much lower biomass) compared to plant community. By difference, the remaining 160 curies would be in the sediment. This conclusion is not surprising, because other studies have shown the sediments as the major repository of cesium-137.^{89,100,105}

2.7.2.3 Cesium-137 Distribution in Creek Plantation Swamp

In 1958, an aerial survey by the U.S. Geologic Survey revealed no unusual radioactivity in the Savannah River swamp, either onsite or offsite.¹¹⁶ In 1961, the SRP cooling water effluent flows were thermally mapped during a period of swamp flooding and confirmed the general flow path shown in Figure 2.5-3. An initial EG&G, Inc., aerial radiological survey was made in 1969 and followed by more extensive EG&G aerial radiological surveys in 1971 and 1972. Radiation exposure levels in the offsite Creek Plantation Swamp up to 370 mR per year were detected. Ground surveys by Health Protection (HP) of SRP in 1971 and 1972 confirmed the aerial survey by EG&G. In 1974, EG&G made another aerial survey.¹¹⁵ This survey revealed exposure rates ranging from 30 to about 460 mR per year above background. Figure 2.7-9 shows isodose contours for cesium-137, the predominant radionuclide found in the swamp. Also in 1974, HP established ten

TABLE 2.7-10

Inventory of Cesium-137 in the Steel Creek Plant Community

<u>Distance from P Area, Feet</u>	<u>Area Square Feet (Millions)</u>	<u>Cs-137, pCi/gm</u>	<u>Amount, mCi</u>
13119	3.50	257	25.4
16892	2.04	230	15.
23118	3.58	297	30.
28590	3.88	297	32.5
30571	1.54	257	11.2
31515	0.54	215	3.2
36609	3.65	322	33.2
38307	1.06	322	9.6
40195	1.39	206	8.1
42035	1.32	200	7.5
48370	7.08	195	39.0
50721	3.08	198	17.2
53583	4.41	200	24.9
55423	9.73	200	55.0
56547	2.63	200	14.9
			<u>326.7</u> mCi

FIGURE 2.7-9. Isodose Contours for Cesium-137 from 1974 EG&G Aeroradiographic Survey⁹⁹

transects (Figure 2.7-10) across the river swamp for sampling soil, vegetation, terrestrial animals, and fish, and for taking radiation measurements with TLD's (thermoluminescent dosimeters). Annual survey samples were taken from 1974 to 1977 by HP. Because results of these surveys have shown no significant change in radiological conditions, the 1978 and 1979 HP surveys included only TLD measurements.^{96,97} Plans call for a comprehensive survey every five years unless the TLD measurements show substantial changes.

The monitoring data for the ten transects across the Creek Plantation Swamp has shown little change since 1974. Gamma radiation measurements in 1979 ranged from 0.18 to 1.38 mR per day compared to similar values in previous years (Table 2.7-11). Part of the variation seen from year to year is due to water level fluctuations in the swamp. This is evidenced by the lower radiation measurements observed in 1975 when high water levels were observed in the swamp. In 1976, 1977, and 1978, when water levels were lower, radiation measurements were similar to levels recorded in 1974. Any significant increase or decrease in radiation in the swamp would be indicated by a trend over several years.

2.7.2.3.1 Distribution in the Soils of Creek Plantation Swamp

In the Creek Plantation Swamp, most of the cesium is present in the upper few inches near the surface. Sampling in 1974 along the transects showed that 70% of the radioactivity was in the upper 2.5 inches (6-7 centimeters), but was detectable at depths up to ten inches (25 centimeters). Summaries of soil samples for 1974 to 1977 are given in Table 2.7-12.

2.7.2.3.2 Cesium-137 Concentrations in the Biota

Vegetation samples from three locations along each transect (generally locations with the higher TLD measurements) showed cesium-137 concentrations in similar ranges from 1974 to 1977 (Table 2.7-13).

Wildlife samples from Creek Plantation Swamp have not been extensive. Two small creeks drain across the Creek Plantation into the Creek Plantation Swamp. Fish obtained from sloughs into which these creeks drain were analyzed for cesium content (Table 2.7-14). Cesium concentrations ranged from 0.5 to 6 pCi per gram with an average of 3.9 pCi per gram of dry weight.⁹⁹ In comparison, over 300 fish obtained from the Savannah River ranged up to 4 pCi per gram of dry weight with an average of about 0.3 pCi per gram of dry weight. Concentration values for typical terrestrial animals for Creek Plantation Swamp are given in Table 2.7-15.

FIGURE 2.7-10. Radioactivity Deposition in the Savannah River Swamp

TABLE 2.7-11

Savannah River Swamp — Steel Creek to Little Hell Landing
Radiation Measurements (TLD, 1 Meter Above Ground)

Location			mR/Day								
River Mile	Trail Number	Distance From River Meters	1972	Aug 1974	June July 1975	Oct ^a Nov 1975	Aug. Sept 1976	June July 1977	June July 1978	Sept Oct 1979	
141.5	1	0	0.27	0.30	0.23	0.21	0.26	0.30 ± 0.03	0.28 ± 0.03	0.27 ± 0.03	
		178	0.35	0.35	0.29	0.17	.36	.36 ± .04	.39 ± .03	.35 ± .03	
		358	0.58	0.51	0.44	0.31	.60	.54 ± .05	0.54 ± .04	.54 ± .04	
		550	-	-	-	0.76	-	1.23 ± .09	1.26 ± .09	1.06 ± .09	
		656	1.47	1.60	1.56	0.94	1.85	1.51 ± .11	1.56 ± .10	1.38 ± .10	
		805	0.17	0.18	0.15	0.20	0.20	0.19 ± .02	0.16 ± .02	0.20 ± .02	
140.8	2	0	0.19	0.22	0.20	0.22	.28	-----	.19 ± .02	-----	
		207	0.21	0.26	0.20	0.24	.28	.27 ± .03	.25 ± .02	0.24 ± 0.02	
		406	0.19	0.24	0.22	0.22	.27	.28 ± .03	.23 ± .02	.27 ± .02	
		598	0.23	0.28	0.22	0.24	.26	-----	.24 ± .02	.24 ± .02	
		798	0.29	0.37	0.28	0.27	.35	-----	.34 ± .03	.34 ± .03	
		945	-	0.59	0.63	0.54	.58	.62 ± .06	.57 ± .04	.55 ± .04	
		975	0.14	0.19	0.20	0.15	.20	.20 ± .02	-----	.18 ± .02	
139.5 to 140.8	3	0		0.22		0.19	.23	.23 ± .02	.21 ± .02	0.24 ± .02	
		281		0.23		0.17	-	.32 ± .03	.24 ± .02	.24 ± .02	
		627		0.23		0.23	.23	.25 ± .03	-----	.23 ± .03	
139	4	0		0.30		0.27	.31	.30 ± .03	.24 ± .02	0.29 ± 0.02	
		293		0.31		0.25	.33	-----	.26 ± .02	.26 ± .02	
		380		0.49		0.32	.46	-----	.37 ± .03	.36 ± .03	
		515		0.45		0.26	.40	.46 ± .04	.35 ± .03	.36 ± .03	
		580		0.99		0.79	.91	.83 ± .07	.78 ± .06	.72 ± .04	
		729		0.22		0.20	.25	.25 ± .03	.19 ± .02	.73 ± .02	
138.5	5	0		0.19		0.20	.22	.24 ± .02	.19 ± .02	0.25 ± .02	
		534		0.36		0.30	.35	.34 ± .03	.28 ± .03	.31 ± .03	
		573		0.61		0.55	.62	.58 ± .05	.51 ± .04	.54 ± .04	
		640		1.09		1.03	1.22	1.00 ± .08	.91 ± .07	.87 ± .07	
		773		0.24		0.21	0.24	0.26 ± .03	.21 ± .02	.26 ± .02	
137	6	0		0.22		0.18	.30	.25 ± .03	.25 ± .02	0.23 ± .02	
		549		0.30		0.29	.33	.38 ± .04	.31 ± .03	.32 ± .03	
		701		0.84		0.43	.65	.74 ± .06	.68 ± .05	.61 ± .05	
		772		0.85		0.62	.77	.94 ± .08	.85 ± .06	.73 ± .06	
		817		0.26		0.21	.29	.28 ± .03	.24 ± .02	.23 ± .02	
136.3	7	0		0.20		0.19	.21	.25 ± .03	.25 ± .02	0.26 ± .02	
		579		0.19		0.16	.21	.24 ± .02	.24 ± .02	.24 ± .02	
		793		0.90		0.91	.96	1.08 ± .08	.33 ± .03 ^b	.36 ± .03	
		823		0.24		0.24	.23	0.27 ± .03	.26 ± .02	.25 ± .02	
135.7	8	0	0.20	0.22	0.19	0.19	.20	.27 ± .03	.24 ± .02	0.20 ± .02	
		168	0.21	0.25	0.22	0.21	.26	.29 ± .03	.26 ± .02	.26 ± .02	
		279	0.23	0.24	0.20	0.15	.21	.28 ± .03	.25 ± .02	.22 ± .02	
		445	0.21	0.24	0.22	0.22	.28	.26 ± .03	.25 ± .02	.26 ± .02	
		612	0.23	0.24	0.22	0.20	.24	.28 ± .03	.25 ± .02	.27 ± .02	
		814	0.34	0.36	0.35	0.28	.39	.44 ± .04	.39 ± .03	.36 ± .03	
		884	-	0.64	0.63	0.57	.62	.64 ± .06	.58 ± .04	.57 ± .04	
		915	0.22	0.22	0.23	0.22	.23	.27 ± .03	.25 ± .02	.25 ± .02	
135.5	9	0		0.22		0.20	.23	.28 ± .03	.25 ± .02	0.24 ± 0.02	
		512		0.46		0.36	.44	.50 ± .04	.35 ± .03	.42 ± .03	
		621		0.54		0.29	.57	.63 ± .06	.60 ± .05	.56 ± .05	
		671		-		0.47	.75	.72 ± .06	.68 ± .05	.66 ± .05	
		769		0.18		0.18	.20	.24 ± .02	.21 ± .02	.22 ± .02	
134.4	10	0		-		0.18	-	-----	.28 ± .03	0.38 ± 0.03	
		30		-		0.28	-	.26 ± .03	.39 ± .03	-----	
		73		0.20		0.18	-	.45 ± .04	.20 ± .02	.20 ± .02	
Green Pond, near 700 Area (Control)				0.16		0.18	0.17	.16 ± .02	0.17 ± 0.02	.20 ± .02	

- No Measurement.

^a Lower results are attributed to shielding from higher water levels observed in swamp.^b Reason for decrease has not been determined.

± Error associated with the precision observed from known exposures of the same magnitude under similar conditions.

TABLE 2.7-12

Savannah River Swamp — Steel Creek to Little Hell Landing
Radioactivity in Soil

Location		Distance From River Meters	pCi/g (dry weight)				⁹⁰ Sr ^a
			¹³⁷ Cs				
			1974	1975	1976	1977	
River Mile	Trail Number		0-6 cm	0-8 cm	0-8 cm	0-8 cm	0-8 cm
141.5	1	0	31	41			
		178	23	14	21	18	0.7
		358	126	46			
		550	345	261	174	100	0.6
		656	194	75			
805	3	1	1	1	0.1		
140.8	2	0	1	1			
		207	2	3	2	3	
		406	4	3			
		598	9	4			
		798	47	18			
		945	122	73	5	38	
		975	3	1	1	9	
139.5 to 140.8	3	0	<1	2	<1	1	
		281	5	2	2	2	
		627	4	1	1	1	
139	4	0	1	2			
		293	13	19	18	19	
		380	86	61			
		515	72	55			
		580	187	98		171	
		729	2	2	44	2	
138.5	5	0	1	1			
		534	34	13	<1	27	
		573	140	86			
		640	260	141	<1	99	
		773	1	2	<1	1	
137	6	0	1	2			
		549	50	29	27	23	
		701	160	124			
		772	300	123	93	196	
		817	4	1	3	3	
136.3	7	0	2	1			
		579	6	3	3	6	
		793	527	26	159	173	
		823	3	2	2	3	
135.7	8	0	12	1			
		168	4	1	2	2	
		279	1	2			
		445	5	2			
		612	6	2			
		814	63	37	32	35	
		884	114	5			
		915	5	2	4	3	
135.5	9	0	2	1			
		512	120	57			
		621	134	111	74	92	
		671	1	92	117	105	
		762		1	2	2	
134.4	10	0		24	28	30	
		30	51	36	34	27	
		73	5	2	4	4	
Control (100 mi. from plant)			0.8	0.3	1	1	0.3

Blank data space indicates no analysis

^a Analyzed for trail 1 only.

TABLE 2.7-13

Savannah River Swamp — Steel Creek to Little Hell Landing
Radioactivity in Vegetation

Location		Distance From River, Meters	Vegetation, pCi/g (Dry Wt)						pCi/ml (Free Water) Tritium
River Mile	Trail Number		¹³⁷ Cs				Alpha		
			1974	1975	1976	1977	1976	1977	
141.5	1	0	2	<1					
		178	20	13	52	2	0.3	0.0 ± 0.2	9 ± 3
		358	3	2					
		550	122	103	100	132	0.4	0.2 ± 0.3	32 ± 5
		656	22	189					
		805	2	<1	<1	2	<0.1	0.2 ± 0.2	3 ± 2
140.8	2	0	<1	<1		<1		0.1 ± 0.2	
		207	3	<1	<1		<0.1		
		406	1	<1					
		598	<1	<1					
		798	2	<1					
		945	144	54	3	10	<0.2	0.1 ± 0.2	
		975	1	<1	<1	<1	<0.1	0.3 ± 0.3	
139.5	3	0	<1	<1	<1	3	<0.2	0.4 ± 0.3	
to		281	<1	<1	<1	<1	0.2	0.3, ± 0.3	
140.8		627	<1	<1	<1	<1	<0.2	<0.1 ± 0.2	
139	4	0	2	<1					
		293	2	<1	7	2	<0.2	0.5 ± 0.3	
		380	15	2					
		515	19	30					
		580	98	15	<1	29	<0.1	0.2 ± 0.3	
		729	1	<1	1	<1	0.3	0.5 ± 0.3	
138.5	5	0	1	<1					
		534	1	<1	<1	2	0.2	0.3 ± 0.3	
		573	15	3					
		640	36	6	<1	12	<0.1	0.8 ± 0.4	
		773	<1	<1	<1	2	0.3	0.1 ± 0.2	
137	6	0	1	<1					
		549	47	15	9	4	0.3	0.2 ± 0.3	
		701	18	26					
		772	235	2	119	13	0.4	0.1 ± 0.2	
		817	1	<1	1	<1	0.2	0.2 ± 0.2	
136.3	7	0	1	2					
		579	1	<1	1	7	0.3	<0.1 ± 0.2	
		793	79	24	35	8	0.3	0.2 ± 0.3	
		823	<1	<1	<1	<1	0.3	0.2 ± 0.3	
135.7	8	0	4	1					
		168	1	<1	<1		<0.2	0.8 ± 0.4	
		279	<1	<1					
		445	1	2					
		612	1	<1	<1	6			
		814	11	6	8	2	<0.1	0.6 ± 0.3	
		884	43	19					
		915	1	3	<1	<1	<0.1	0.1 ± 0.2	
135.5	9	0	<1	<1		<1			
		512	3	1					
		621	1	1		<1	<0.1	0.1 ± 0.2	
		671	1	6	2	1	<0.1	0.3 ± 0.3	
		769		1	<1		<0.1	0.3 ± 0.3	
134.4	10	0		3	11	9	0.2	0.3 ± 0.3	
		30	1	2	<1	2	0.2	0.1 ± 0.2	
		73	<1	<1	1	<1	0.3	0.3 ± 0.3	
Plant perimeter and 100 mile radius vegetation (Control)			1	1	<1	<1	0.1	0.1 ± 0.2	1-37 ^a

^a Blank data space indicates no analysis
Range, plant perimeter

TABLE 2.7-14

Cesium in Fish (1974)

	<u>Number</u>	<u>Concentration,</u> <u>pCi/g, Dry wt</u>	
		Max	Avg
Creek Plantation Swamp			
Bream	23	6.1	2.7
Jack	2	3.5	3.5
Catfish	3	6.1	<u>5.5</u>
		Average 3.9	
Savannah River*			
Upstream	114	1.6	<0.3
Adjacent to SRP	82	2.5	<0.3
Downstream	137	4.0	<0.3

* Savannah River fish were predominantly bream and catfish.

TABLE 2.7-15

Cesium-137 Concentrations in Wildlife from
Creek Plantation Swamp (1978)

<u>Species</u>	<u>Number</u>	<u>¹³⁷Cs in Muscle,</u> <u>pCi/g Wet wt</u>	
		<u>Max</u>	<u>Avg</u>
Fox	4	0.4	0.3
Raccoon	2	0.5	0.3
Opossum	12	1.0	0.4
Rabbit	3	0.1	0.05
Rat	-	3.8	1.9

2.7.2.3.3 Estimate of Present Inventory of Cesium in Creek Plantation Swamp

Since the 1974 estimate of the 25 curies of cesium-137 inventory in Creek Plantation Swamp, little change has occurred to alter this estimate except radioactive decay. Cesium-137 transport in the Savannah River at Highway 301 has changed little since 1971 (Figure 2.7-4), indicating little if any movement to the Savannah River. Environmental Monitoring made measurements of cesium-137 over 10 established transects, Figure 2.7-10, to determine if cesium-137 was moving from SRP to the Creek Plantation Swamp or was moving from Creek Plantation Swamp to the Savannah River. The yearly averages of all transects have shown little change from 1974 to 1977. In 1977, the sampling was changed to a five-year cycle because no yearly change could be detected. The 25 curies on Creek Plantation Swamp would have decayed to 22 curies in 1980 assuming no net movement of the cesium-137.

2.7.2.4 Other Radionuclides in the OffSite Swamp

During the time that the cesium-137 was released from the reactor areas, about 58 curies of cobalt-60 (5.3 year half-life) was also released. Transport of the cobalt-60 in the Savannah River was not measurable except during years of higher release. As much as 60% of the cobalt-60 may have been transported in the river and as much as 23 curies may have initially been retained in onsite streams and the off-site swamp.⁹⁹ On the basis of HP surveys and the 1974 EG&G flyover, it was estimated that less than one curie of cobalt-60 resides in the Creek Plantation Swamp.^{99,115}

Approximately 63 curies of strontium-89-90 was released to SRP streams. Of this, 52 curies have been measured in transport at the U.S. Highway 301 bridge. Kaolin clay particles have little sorptive capacity for strontium; thus, this radionuclide has not been detected above background in Creek Plantation Swamp sediments. However, strontium-90 concentrations of a few pCi per gram has been detected in composited samples of vegetation from the Creek Plantation Swamp.⁹⁹

2.7.2.5 Cesium-137 in Savannah River Sediments

Fine particles are kept in suspension by the turbulence of normal river flow. Exceptions are in locations where the water velocity is low such as inside river meanderings, dead oxbows, and the downstream side of pilings. Sediments from such locations upstream of SRP normally have about one pCi per gram of cesium-137

or less. In 1974, sediments from downstream of SRP contained values from about two pCi per gram at U.S. Highway 301 to 6.5 pCi per gram at S.C. Highway 119 (Clyo, Georgia). More recent monitoring data for sediments near SRP are given in Table 2.7-16 .102,103

2.7.2.6 Cesium-137 in Savannah River Fish

Fish are trapped in the Savannah River upstream, adjacent to, and downstream from SRP effluents. Summaries of monitoring results are given in Table 2.7-17 for cesium and other radionuclides.^{95,96}

TABLE 2.7-16

Radioactivity in Savannah River Sediments, pCi/g (dry wt)

Year	Location	River Mile	^{60}Co	^{90}Sr	^{137}Cs
1977	Control Above SRP	160.5	<0.6	<0.1	0.3
	Below Four Mile Creek	150.2	<0.7	0.1	0.7
	Above Little Hell Landing	136.6	<0.5	0.1	0.6
	Below Little Hell Landing	134.0	<0.8	0.2	9.3
	Above Lower Three Runs Creek	129.5	<0.7	0.1	1.0
	Highway 301	118.7	<0.7	0.1	1.2
1978	Control Above SRP	160.5	<0.6	0.06	0.4
	Below Four Mile Creek	150.2	<0.7	0.03	0.1
	Above Little Hell Landing	136.6	<0.5	0.02	0.2
	Below Little Hell Landing	134.0	<0.8	0.04	0.7
	Above Lower Three Runs Creek	129.5	<0.8	0.02	0.1
	Highway 301	118.7	<0.7	0.07	0.3

TABLE 2.7-17

Radioactivity in Fish, pCi/g (wet wt)

Year	Location	Species	Number of Fish	$^{89,90}\text{Sr}$		^{137}Cs		^3H , pCi/mL	
				Bone		Whole Fish		Individual Fish	
				Max	Avg	Max	Avg	Max	Avg
1977	2R (1 mi upstream of SRP)	Bream	9	6.1	2.3	<0.2	<0.2	26	9
		Catfish	11	-	-	<0.1	<0.1	15	6
	8R (Below Steel Creek)	Bream	1	-	-	<0.2	<0.2	12	-
		Catfish	5	-	-	0.2	<0.1	24	11
		Bass	1	-	-	<0.2	<0.1	12	-
	10R (Highway 301)	Bream	2	-	-	<0.2	<0.2	2	1
		Catfish	7	-	-	<0.1	<0.1	20	13
		Bass	1	-	-	<0.1	<0.1	-	-
1978	2R (1 mi upstream of SRP)	Bream	1	-	-	<0.2	<0.2	-	-
	8R (Below Steel Creek)	Bream	2	-	-	<0.2	<0.2	-	-
		Catfish	3	9.1	8	<0.1	<0.1	-	4
	10R (Highway 301)	Catfish	5	17	<10			7	4
		Bass				<0.1	<0.1		

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3. FACILITY DESCRIPTION

3.1 REACTOR FACILITIES

3.1.1 L-Area Reactor Building

The L-Area Reactor building (Figures 3.1-1 and 3.1-2) is a large concrete structure. It contains the following major process areas: Reactor Area, Assembly Area, Disassembly Area, and Purification Area. An online activity confinement system is used to limit radioactive releases. Seismic stabilization for the stack, actuator tower, and cooling systems will be added before reactor startup.

3.1.2 Reactor Area

The Reactor Area occupies the central portion of the building. It houses the reactor, control and safety rod actuator systems, heat exchangers, process pumps and piping, pump motors, crane and reactor control rooms, crane wash and maintenance areas, and auxiliary equipment and service facilities (Figure 3.1-3). The top of the reactor is about 2 feet above the 0-foot elevation floor. The main heat exchangers are located at the -20-foot elevation; the primary D_2O pumps and motors are at -40-foot elevation. The reactor room from +2-foot to +66-foot elevation is occupied by the control actuator system (control and safety rod guide tubes and latches) during normal operation and by the charge and discharge machines during reloading shutdowns. The area above the +66-foot elevation is occupied by the control rod and safety rod drive systems. The reactor control room is located at the +15-foot elevation. The reactor room, pump rooms, and heat exchanger bays are inaccessible during reactor operation but may be viewed through observation windows and periscopes.

A general diagram of air and water flow and fuel transfer through the reactor system is shown in Figure 3.1-4.

3.1.3 Assembly Area

Material to be charged to the reactor is received in the Assembly Area. Items handled on a routine basis include fuel components, targets, housings, orificing components, and control rods. Equipment for the transport, loading, cleaning, and testing of assembled components is provided. A final storage area large

FIGURE 3.1-1. L-Area Reactor Building

FIGURE 3.1-2a. Perspective of L-Area 105 Building, West Side

FIGURE 3.1-2b. Perspective of L-Area 105 Building, East Side

FIGURE 3.1-3. Schematic Cross Section of Reactor Process Area

FIGURE 3.1-4. General Diagram of Air, Water, and Fuel Flow Through the L Reactor System.

enough to store one and one-half full charges of assembled components is located in the Assembly Area. When the reactor is being charged, material is transferred from this area to a transfer station located in the reactor room.

3.1.4 Disassembly Area

The Disassembly Area contains equipment for the transfer, storage, disassembly, and examination of irradiated material. The basin is a large concrete-lined pool of water. The top is at 0-foot elevation. The storage sections are about 30 feet deep. Irradiated components are transferred from the reactor to a conveyor that carries them under the wall that separates the reactor room from the Disassembly Area. The irradiated components are then transferred to a hanger and monorail system which is used to transport components to the basin to await disassembly, storage, and subsequent shipment by rail to separation facilities in the 200 Areas.

3.1.5 Purification Area

This section of the reactor building contains purification equipment for the heavy water and the helium gas systems. The heavy water purification facilities include shielded cells for resin beds, filters, a surge tank, a temporary storage tank and an evaporator, and includes a partially shielded area that contains isotopic distillation columns and a control room. A crane traveling above the shielded cells removes exhausted resin beds and used filters by remote control.

The helium purification system contains condensers, heaters, a blower, and a catalytic recombiner. The system removes the deuterium and oxygen evolved from the heavy water during reactor irradiation by recombining them in a recombiner. The resulting D_2O is returned to the heavy water system by the moderator purification system.

3.2 SUPPORTING FACILITIES AND PROCESSES

3.2.1 Water Systems

Water from the Savannah River is supplied to the reactor to cool D_2O from the reactor coolant system. River water is pumped into a 25-million-gallon cooling water basin at the reactor area and pumped from the basin to the reactor building where it extracts heat from the D_2O circulating through primary heat exchangers. Effluent cooling water flows from the heat exchangers

back to the river via Steel Creek and the Savannah River swamps. A simplified schematic of the cooling water system is shown in Figure 3.2-1.

The river water is pumped to the reactor area cooling water basins through concrete lined steel pipes by two pumping stations located on the Savannah River. Individual lines supply each reactor area, and alternative tie lines provide for emergency supply of cooling water should the primary line fail (Figure 3.2-2).

A pump house adjacent to the 25-million-gallon basin contains ten pumps that distribute water to the reactor building through two 42-inch headers. The eight smaller pumps have flywheels, which allow the pumps to continue pumping for a short time after a power failure. Even if all the pumps fail, gravity flow will deliver sufficient water from the basin to the reactor building to remove reactor shutdown heat.

Nominal flow from the river of up to 400 cfs is established prior to reactor startup and is maintained during reactor operation.

Additional water from two deep wells and a water treatment plant provide domestic and fire protection services. This water eventually reaches the process sewer and is discharged to Steel Creek.

3.2.2 Electric Power

Electrical power is supplied to L Area through two 115 kV power transmission lines. Underground power feeder cables (13.8 kV) are used to furnish power to all buildings in L Area.

3.2.3 Steam

Steam is supplied to the reactor facility for process services and to provide heat for the building ventilation system. Steam requirements range from an average of 8,000 pounds per hour during summer months to approximately 22,000 pounds per hour during winter. Maximum steam consumption is 30,000 pounds per hour. Steam pressure ranges from 25 psig for heating and ventilation to 175 psig for process.

An interarea steam pipeline will supply steam to L Area from the K-Area Powerhouse. The 6-inch steam line will be installed above ground along 2-1/4 miles of existing river water line between K and L Areas. To provide the necessary additional export capacity from the K-Area powerhouse, a new crosstie between boiler

FIGURE 3.2-1. L-Area Reactor Cooling Water System (Schematic)

Note: R and L Reactors are not currently operating.

FIGURE 3.2-2. Reactor Area Cooling Water System

discharge headers, a new hydrogen water softening unit, and a silica absorbing unit will be installed. Existing facilities are adequate to neutralize demineralizer regeneration waste streams to meet National Pollution Discharge Elimination Systems (NPDES) requirements in K Area.

3.2.4 Sewage and Miscellaneous Process Discharges

The L-Area sanitary sewage plant is a commercial secondary treatment plant with a capacity of about 35,000 gallons per day. This capacity is adequate for the approximately 350 people to be employed at the reactor area doing operation. The secondary treatment plant output will be chlorinated and discharged to the process sewer and Steel Creek.

L Area contains process sewers which collect water from various parts of the area. Process sewers combine and discharge to Steel Creek.

Drainage ditches are provided throughout the area to collect surface water runoff. The water is conveyed to various outfalls which flow to Steel Creek or Pen Branch.

3.3 REACTOR PROCESSES

3.3.1 Reactor Systems

3.3.1.1 Reactor Tank and Lattice

The reactor tank is a cylinder with a height of 15 feet and a diameter of 16-1/4 feet. The tank is 1/2-inch Type 304 stainless steel plate and contains six effluent nozzles uniformly spaced around the circumference at the tank bottom (Figure 3.3-1). Six tapered inlet nozzles are uniformly spaced around the circumference of the water plenum at the top of the tank. Top and bottom shields are located above and below the tank. Each of these shields is a hollow-disk tube and tube-sheet weldment. Above the top shield and 12-inch-thick gas plenum is the D₂O plenum, which is a hollow-disk weldment about 17 feet in diameter and 8-2/3 inch high. Tubes welded to both top and bottom surfaces of the water plenum align with similar tubes in the top and bottom shields to locate components inserted into the reactor. The bottom shield contains 600 monitor pins (Figure 3.3-2) which provide flow (pressure impulse tube) and temperature (thermocouple) monitoring for each fuel position. The reactor tank is surrounded by a segmented annular thermal shield 20 inches thick containing Duriron™ (Duriron Co., Dayton, Ohio) grids and H₂O and by a 5-foot-thick concrete biological shield.

FIGURE 3.3-1. Reactor Structure (Schematic)

FIGURE 3.3-2. Schematic of Bottom Shield of L-Area Reactor

The reactor contains positions for 600 principal fuel and target assemblies, which are suspended vertically in the reactor tank on 7-inch centers in a triangular array. The full weight of the reactor charge bears on the top of the water plenum and top shield. Other principal lattice positions are used for control rod housings, spargers,* gas ports, and pressure relief tubes. Interspersed among the principal lattice positions are 162 secondary positions for 1-inch-diameter components. The secondary positions are occupied by safety rods, tie bolts connecting the water plenum to the top shield, instrument rods,** and special components. The reactor lattice is shown in Figure 3.3-3.

3.3.1.2 Reactor Control System

Neutron flux in the reactor is controlled by neutron-absorbing rods in 61 control positions. Each position contains seven individually-motor-driven control rods. Full-length rods are used for reactor criticality control and radial flux shaping; partial length rods are used for axial and radial flux shaping. Rods can be moved in gangs for simultaneous positioning or sequentially moved on an individual basis. Normally, three gangs of 19, 18, and 24 control positions are used. The control rods can contain a discardable poison such as cadmium or can be made of target material for isotope production (e.g., lithium or cobalt). No soluble burnable neutron poison is used in the D₂O moderator/coolant during normal operation.

The control rod drive motors are located approximately 120 feet above the top of the reactor. The motors are connected to the rods by long extensions and latches inside hollow guide tubes and can move the rods about 15 feet vertically. The guide tubes are shown in normal operating position in Figure 3.3-4. This equipment is raised in a telescoping manner during reloading shutdowns to allow the charge and discharge machines to service the reactor.

* Sparger assemblies are dual purpose, providing jet flow to promote circulation of the D₂O moderator and injection ports for the supplementary safety system neutron poison.

** Instrument rods include gamma flux, neutron flux, and moderator temperature sensors.

FIGURE 3.3-3. Lattice Arrangement for L-Area Reactor

FIGURE 3.3-4. Actuator Guide Tube Arrangement for an SRP Reactor

3.3.1.3 Control Room and Instrumentation

Process monitoring and control of the reactor are accomplished in the central control room located at the +15 foot elevation. Nuclear instruments, nuclear controls, and assembly flow and temperature monitoring are grouped together at one end of the control room; similar equipment for the hydraulic and auxiliary systems is located at the opposite end of the room.

Reactor power can be controlled manually from the control console or automatically by an online computer. A reactor operator is stationed at the control console at all times. Under manual control, the operator can move the control rod gangs to change or maintain reactor power. Individual control rods may be moved by another operator from a nearby panel. The operator can also introduce a manual scram (rapid insertion of control and safety rods) from the control console. Neutron flux monitors, period monitors, a reactor power monitor, a level galvanometer and an axial power monitor are readily observable from the control console.

The D₂O temperature and flow for each principal fuel and target position are monitored in the control room. Flow is monitored by comparing the pressure inside the bottom of the assembly with the reactor tank bottom pressure. The assembly pressure is sensed by an impulse tube running through the monitor pin in the bottom shield. The monitor pin also contains four thermocouples which measure the assembly effluent D₂O temperatures from individual channels or quadrants.

Flows and pressures at various points in the D₂O circulating system and the H₂O cooling water system are displayed on a graphic panel in the control room. This panel also indicates the status of pumps (running/not running) and the position of control valves. Adjacent panels provide graphic information on the status of the building ventilation and electrical distribution systems.

A digital process control computer is used extensively for data logging and monitoring of process variables. If a variable deviates from the normal operating range, an alarm is typed out for investigation by operating personnel. The computer is also used to monitor the approach to reactor power limits under both manual and computer control of the reactor.

3.3.1.4 Core Reloading Equipment

Equipment provided for core reloading includes a charge machine, a discharge machine, and an irradiated component conveyor. The charge and discharge machines are shown in

Figure 3.3-5, and a picture of one machine servicing the reactor is shown in Figure 3.3-6.

The charge and discharge machines are similar in design and external appearance. Either can perform most of the required functions of the other. Each machine contains three basic sections called masts. Each mast is designed to handle several different components. One of the three masts (on the discharge machine only) is equipped with facilities to provide water cooling to irradiated assemblies and is used to handle fuel and target assemblies. The discharge machine is equipped to collect and store D_2O drained or flushed from components removed from the reactor.

As shown in Figure 3.3-5, the machines are supported and travel on tracks on two parallel ledges, which are a part of the reactor room wall. Normal and emergency electrical power for operation is fed through cables traveling the length of the ledge. A sliding contact provides another power source for the discharge machine. Chain drives for the machines are also located on the ledges.

Reloading operations are conducted from the crane control room, which is adjacent to the reactor control room. The charge and discharge machines can be operated from the machine control console either manually or by an automatic tape control system. A graphic display is provided on the control console to track the location and operation of the machines. Controls and interlocks are provided to prevent the machines from colliding during operation.

The underwater conveyor, called the deposit and exit conveyor, is located in an H_2O -filled canal connecting the reactor room with the irradiated assembly storage basin. The conveyor receives an irradiated assembly from the discharge machine and carries it in a slightly inclined position under the reactor room wall to the storage basin.

3.3.1.5 Reactor Reloading

Reactor reloading shutdowns are scheduled several times a year as required by the demands of the production programs. A reloading shutdown can involve replacement of up to all of the fuel (drivers) and/or up to all of the target assemblies. A given charge of fuel or targets can use the outer housings from the previous cycle, or new housings can be installed. In addition to fuel and targets, all other reactor-core components can be replaced if required, including:

FIGURE 3.3-5. Charge and Discharge Machines in Reactor Room

FIGURE 3.3-6. Charge and Discharge Machine Over Reactor

- Inner housings
- Control rods and/or housings
- Safety rods and/or thimbles
- Instrument rods and/or thimbles
- Sparjet housings
- Sparjet target inserts
- Flow orifices
- Monitoring inserts
- No-flow assemblies for vacant position
- Source rods

The large number of components handled (e.g., up to several thousand) requires detailed controls so that the right component is charged to the correct position in the correct sequence.

All components are moved by either the charge machine or the discharge machine. Normally, all irradiated components are removed by the discharge machine, and all unirradiated components are charged with the charge machine. Components, such as shield plugs, can be handled by either machine to improve the efficiency of charge and discharge operations.

Reloading a typical fuel (driver) or target position requires the following steps:

- Removal of the upper plenum plug
- Removal of a flow orifice (if present)
- Removal of the irradiated assembly by using the discharge machine
- Insertion of the unirradiated assembly by using the charge machine
- Insertion of a flow orifice (if required)
- Reinsertion of the plenum plug

These operations are generally done with automatic sequence control by using a prepunched control tape, but they can be done

with manual control by operating personnel. After each position is reloaded, appropriate steps are checked off in written procedures.

To maintain the reactor subcritical by the maximum amount, components are replaced in a specified order. For example, for a given type of charge, control rods are replaced first, followed by targets, and then fuel (drivers). The neutron flux is monitored during these replacements to detect any unexpected approach to criticality.

3.3.1.6 Assembly Cooling During Discharge

During the interval between removal from the reactor and insertion in the irradiated fuel storage basin, irradiated components are cooled by water (D_2O or H_2O) or by natural convection with air.

Fuel and target assemblies are discharged with the part of the discharge machine which has facilities for water cooling of the assemblies. There are four sources of water available on the discharge machine; primary D_2O , primary H_2O , secondary D_2O , and secondary H_2O . The primary and secondary sources discharge at different points on the machine. Except at the point of final discharge, each of the sources has independent hoses, pipes, and actuation valves. The D_2O source is required to be available when the discharge machine is over the reactor. Primary H_2O cooling is started automatically when an irradiated assembly is withdrawn from the reactor and the water pan* swings under the assembly. H_2O cooling serves the function of rinsing D_2O from the assembly surface to prevent carryover of tritiated D_2O to the disassembly basin; the rinse water is saved, and secondary D_2O is recovered. If primary H_2O flow stops, switching to the emergency source is automatic. The supply hoses for the water cooling systems are festooned on monorails under the crane ledges on both sides of the reactor room. This hose arrangement allows movement of the discharge machine crane over the full length of the reactor room. There are hose festoons on the crane itself to allow motion vertically as well as side to side. The hoses for the primary water systems are on one side of the reactor room, and those for the secondary water systems are on the other side to reduce the potential of common mode failure for the water sources.

* The water pan catches the H_2O rinse water and funnels it to a storage tank.

For each type of assembly, an upper limit on heat generation at discharge is specified; discharge is not permitted until the heat generation rate has decayed to this upper limit. For fuel and target assemblies, the specified upper limit is the lower of the following:

- Maximum heat generation for adequate cooling by the discharge machine cooling system
- Maximum heat generation for adequate cooling if the assembly should be dropped accidentally to a horizontal position on the discharge basin floor.

The time that each assembly may be held in air without water cooling is specified for each fuel and target assembly. The time is based on the maximum allowable heat generation at discharge, and the maximum allowable surface temperature that will permit complete wetting of the hot surfaces when water flow is initiated (typically 200°C). In addition, the maximum allowable stress that may be applied to any fuel or target assembly component is specified. The maximum stress is limited to a value safely below the ultimate strength of the stressed component; typically, a factor of three lower for current assemblies.

Diesel generators provide backup power for the charge and discharge machines. If the discharge machine stalls while it contains an irradiated assembly, the charge machine can be used to push the discharge machine over the canal. The component can then be released into the canal.

3.3.1.7 Storage of Unirradiated Components

Before fuel is transferred to the reactor, it is received and stored in the reactor assembly area. Racks and hangers are used to maintain a specified distance between assemblies to prevent criticality. For assemblies containing a large quantity of fuel, an extra margin of safety is provided by the addition of poison to the racks, (e.g., borated concrete). The quantity and type of material in process at any time is limited by procedural controls. The presence of materials which could serve as a moderator is not allowed in the final storage area or in storage racks in the assembly area.

3.3.1.8 Storage of Irradiated Components

After discharge from the reactor, irradiated assemblies are initially stored in a vertical position in a deep, water-filled

storage basin until the nuclear decay heat is low-enough to permit shipment. The storage time depends upon the type of assembly and its irradiation history. Cooling of assemblies during storage is by natural convection of the basin water through the assemblies.

Hangers for vertical storage of components are designed to maintain a specific distance between assemblies to minimize the possibility of criticality in the storage basin and to permit adequate cooling of the components. In addition to cooling, the basin water provides radiation shielding. A specified minimum depth of water is maintained over the stored components. Auxiliary systems and piping for the basin are designed such that even if a malfunction occurs, the basin water level will not be reduced to the level where radiation shielding and/or component cooling becomes inadequate. Makeup water sources are provided to automatically maintain the basin water level.

3.3.1.9 Control and Safety Computer System

The process control and safety computer systems consist of four digital computers and peripheral instrumentation for monitoring and controlling the reactor and for communicating with reactor operators. The control computer system serves as an aid to operating personnel and has three primary functions:

- Operator guidance
- Limits and systems monitoring
- Closed-loop control

These functions are an extension of those for an earlier type of control computer which was used in the SRP reactors for approximately ten years.

The safety computer system monitors temperature and flow in all of the fuel and target assemblies in the reactor and initiates a reactor shutdown if these variables exceed predetermined setpoints.

Many aspects of the control and safety computer systems are similar, and limited communication between them is provided while maintaining functional independence. Redundancy is provided for both the control and safety functions so that a single failure

will not compromise either normal reactor control or protection system functions. The use of dual computers permits a continuation of essential functions with some reduction in the rate of data processing should a failure of one computer occur.

Separate power sources are provided for each half of the control and safety systems to eliminate a potential common mode failure. Peripheral equipment shared by both computers is operated automatically by either power supply in the event the other power supply fails.

3.3.2 Reactor Hydraulic Systems

The reactor hydraulic system is divided into: 1) the D_2O primary recirculating system and 2) the once-through H_2O secondary cooling water system. The once-through H_2O system was discussed in Section 3.2.1.

The D_2O primary recirculating system consists of six parallel pumping systems. In each system, about 25,000 gpm is pumped from one of the six outlet nozzles at the bottom of the reactor through two parallel heat exchangers into one of the six inlet nozzles in the water plenum. All components of the D_2O system in contact with the D_2O , except pump seals, are made of stainless steel.

From the plenum, D_2O enters the fuel and target assemblies through slots in the plenum tubes and slots or holes in the assembly sleeve-housings. The flow rate in the assembly is determined by the size of orifices at the top of the assembly or by hydraulic resistance of the assembly itself. The D_2O passes through the assembly and leaves through metering holes in the bottom end fitting; it then enters the bulk moderator in the reactor tank and flows through the outlet nozzles back to the pump, completing the closed loop. A schematic of one of the six circulating systems is shown in Figure 3.3-7.

Normally, about 6000 to 7000 gpm of D_2O from the heat exchangers is diverted to supply upflow headers for cooling the control rods. Most of this D_2O flows through perforations in the control rod housings to cool and agitate the moderator.

Auxiliary D_2O systems provide for overflow to and from the purification area.

Each of the six circulating systems contains a centrifugal pump rated at 25,000 gpm at a total head of 420 feet of water. Each main circulating pump is driven by a 3400-hp motor drawing 125 amperes at full load (1785 rpm) from a 13.8 kV line. Pumps and motors are separated in groups of three in each of two pump

FIGURE 3.3-7. Schematic of Reactor Cooling System

rooms and two motor rooms 40 feet below ground level (-40-foot elevation, Figure 3.1-3). The motor drives the pump with a shaft extending through the 4-foot concrete wall separating the pump room and the motor room. The AC motor speed is reduced to the 1000-rpm pump speed by a gear reduction unit. Each AC motor also drives a 3-ton flywheel which stores sufficient kinetic energy to continue pumping D_2O for about 4 minutes after a complete power failure. Power supplies for the AC motors are divided between two substations.

Backup pumping capacity for D_2O circulation is provided by six DC motors coupled through gear reduction units to the AC motor drive shafts. All DC motors are normally online whenever the AC motors are operating. Each DC motor is equipped with a nonreversing clutch to prevent reverse rotation. In the event of an AC power failure, each DC motor will drive the pump at reduced speed to deliver about 25% of normal full flow to the reactor. Power to drive the six DC motors is supplied from eight diesel engine-generator sets located in two engine rooms at -20-foot elevation. Each DC motor is directly connected to its own diesel engine-generator set with two engine-generator sets as spares. Two of the operating diesel generators are connected to large fuel tanks, which will permit unattended operation of two DC motors for several months with adequate core cooling.

Each of the six D_2O coolant systems contains two parallel single-pass heat exchangers to transfer heat from the primary D_2O coolant to the cooling water (H_2O). The heat exchangers are located in the heat exchanger bay at -20-foot elevation (Figure 3.1-3). Each heat exchanger is about 33-1/2 feet long and 7-1/2 feet in diameter and contains about 9000, 1/2-inch-OD stainless steel tubes with a total heat transfer surface area of about 33,000 feet. Leakage between the process water and cooling water systems is minimized by double tube sheet construction.

3.3.3 Reactor Blanket Gas System

The reactor blanket gas system serves three primary functions: 1) to dilute deuterium gas evolved from the moderator to a nonflammable concentration, 2) to recombine the deuterium gas to heavy water, and 3) to pressurize the gas plenum to five psig to increase the saturation temperature of the D_2O . Helium is used as the blanket gas because it does not react with moderator decomposition products, nor does it absorb neutrons to produce radioactive gases.

A schematic diagram of the blanket gas system is shown in Figure 3.3-8. The blanket gas system contains two catalytic recombiners, one of which is online at all times. Spray separators are provided to remove most of the entrained D₂O moisture from the helium.

3.3.4 Reactor Heat Dissipation Systems

The reactor waste heat is carried away by the H₂O cooling water system.

Effluent cooling water leaves the reactor building in two 42-inch headers and is delivered to an effluent sump. The water overflows a weir in this sump and flows back to the Savannah River via Steel Creek.

In addition to forced flow from the cooling water pumps, four other sources of water can provide heat exchanger cooling:

- Gravity flow from the 25-million-gallon basin through the pump house. A 24-inch bypass line connects each 42-inch supply header to the area basin. The bypass flow and gravity flow will supply about 20,000 gpm to each header.
- Three emergency pumps in the reactor building can supply water directly from the 25-million-gallon basin through a 36-inch line that bypasses the pump house. These pumps can supply 7000 gpm to either supply header. Cooling water can be conserved by using the effluent sump pump to return 11,000 gpm to the area basin.
- Recirculating water from the 25-million-gallon basin with the emergency pumps. If cooling water supply to an area is lost and the effluent sump pump is inoperable, cooling water can be recirculated through the basin by the emergency pumps.
- Recirculating irradiated fuel storage basin water (disassembly basin water) with the emergency pumps. If no water can be supplied from outside the reactor building, the emergency pumps can recirculate water from the irradiated fuel storage basin in the reactor building.

3.3.5 Safety and Confinement Systems

3.3.5.1 Protective Instrument and Shutdown Systems

The Savannah River reactors are equipped with an extensive protective instrument system for response to abnormal conditions. Four types of instrument responses are provided.

FIGURE 3.3-8. Schematic of the Reactor Blanket Gas System

- Scram (inserts safety and control rods)
- Control Rod Reversal (inserts control rods)
- Alarm (requires procedural action)
- Automatic Backup Shutdown (injects liquid neutron poison into the moderator space)

3.3.5.2 Safety Rods

The L-Area Reactor is equipped with a set of 66 safety rods that operate independently of the control rod system. During normal operation, the safety rods are held above the core by magnetic clutches. Upon receipt of a scram signal, the safety rods drop into the core by gravity in approximately one second, and control rods are driven into the reactor.

Safety rods are removed before control rods during reactor startup and inserted during scheduled reactor shutdowns. Each safety rod is equipped with a drive motor for removal and insertion.

When in the reactor, safety rods are located in interstitial positions among the principal fuel and target positions. The rods are about one inch in diameter and are normally about the same length or slightly longer than the reactor core. The neutron-absorbing material is normally cadmium.

3.3.5.3 Control Rod Reversal

Control rods are inserted a small increment (rod reversal), or continuously for some cases, if a monitored signal is outside preset limits. If the reversal signal continues, the rods will again be driven in a step increment. Although rod reversals serve only as operating aids, several successive rod reversals can result in a reactor scram from low blanket gas pressure, because density changes cause the moderator to contract and thus reduce gas pressure. Reactor conditions presently monitored as signals for rod reversal are:

- Neutron flux (High-Level Flux Monitor)
- Count rate meter
- Rate of change of neutron flux (period)
- Safety rod in reactor

- Axial power (flux profile)
- Assembly effluent temperature (control computer)
- Low flow in top shield, bottom shield, and thermal shield.

3.3.5.4 Alarms

Most scram and rod reversal instruments are equipped with an alarm which is set to actuate before the scram. This alarm alerts operating personnel to a change in the monitored variable and may provide a margin for manual correction of the abnormality before the scram occurs.

3.3.5.5 Supplementary Safety System

Each SRP reactor is equipped with a supplementary safety system (SSS). When actuated, the SSS injects a solution of gadolinium nitrate into the reactor moderator through six sparger housings near the center of the reactor. Moderator circulation and diffusion distribute the nuclear poison through the reactor core.

The poison is stored in two separate pressurized tanks, each of which supplies three sparger housings. Each tank is equipped with three parallel discharge valves (two explosive and one pneumatic). The poison is forced into the reactor by gas pressure maintained in each storage tank. Each half of the SSS contains sufficient poison to shut down the reactor from full power. The gadolinium nitrate can be removed from the moderator by deionization.

The SSS can be actuated manually from two locations in the reactor control room. The SSS can also be actuated automatically as discussed in Section 3.3.5.6.

3.3.5.6 Automatic Backup Shutdown-Safety Computer (ABS-S/C)

The ABS-S/C is a backup shutdown system that will actuate the SSS if a requested scram is ineffective, e.g., if the safety rods fail to drop. It will terminate all anticipated reactivity transients.

3.3.5.7 Emergency Cooling System

An emergency cooling system (ECS) is provided to protect against the consequences of two postulated accidents: 1) loss of D_2O coolant and 2) loss of D_2O circulation. A loss of D_2O coolant could be caused by a rupture in the primary system. The most credible mechanism for a loss-of-circulation accident is a large rupture of the secondary (H_2O) cooling system which floods the D_2O circulating pump motors.

Emergency cooling of the Savannah River reactors is accomplished by the addition of H_2O directly to the reactor plenum. Core cooling following a loss-of-coolant accident is enhanced by recirculation of the emergency H_2O by the primary D_2O circulating pumps.

The ECS systems in all reactor areas contain storage capacity for about 20,000 gallons of H_2O containing boron for nuclear poisoning. The poison is required, because some reactor charges are calculated to experience a large positive reactivity increase with H_2O in the assembly coolant channels and D_2O in the reactor tank. When the ECS is activated, the poison solution is forced through the assembly coolant channels and into the moderator. By the time unpoisoned H_2O reaches the coolant channels, sufficient D_2O moderator is displaced with poisoned H_2O to prevent criticality.

Three primary sources and a secondary source of H_2O for the emergency cooling system are provided:

- A diesel-driven booster pump draws from the 25-million-gallon basin. This header is one of two normally supplying secondary coolant to half of the main heat exchangers.
- Another 42-inch header is pressurized by five addition pumps. This header normally supplies secondary coolant to the remaining heat exchangers.
- The secondary source is a line pressurized by the river station pumps. This line is the normal supply for the 25-million-gallon basin of cooling water. The water from the river can contain debris which could plug flow channels and orifices in the reactor components. Therefore, this source of water is valved off from the ECS and would only be used after all other sources had failed. Furthermore, the pressure in this line is not high enough to qualify it as a primary source, but the pressure in the system would be adequate to supply enough water after the reactor core decay heat has diminished.

All ECS water flows through the large poison-storage pipe. There is a strainer in this pipe that will trap debris. The strainer can accumulate up to 20 ft³ of debris without a significant increase in the pressure drop or decrease in the flow.

3.3.5.8 Confinement Heat Removal System

A confinement heat removal system (CHRS) is provided to prevent failure of the confinement system in a postulated total meltdown of a reactor core. Such a meltdown could occur from just the nuclear decay heat if both normal cooling and emergency cooling fail. The CHRS provides limited water flooding in the -40-foot level floor to cool any molten core material that may penetrate the reactor tank or process pipes.

The source of water for the CHRS is the disassembly basin. Only the top 4.5 feet of disassembly basin water can be drained onto the -40-foot level floor. The remaining basin water still maintains adequate shielding and cooling for fuel elements stored in the basin. There is a system to provide makeup water to the disassembly basin from two sources.

3.3.5.9 Activity Confinement System

L-Reactor is equipped with an activity confinement system. In the event of an accident, airborne fission product release would be expected to occur in the reactor room, with the possibility of some release in the heat exchanger bay or pump room. As shown in Figure 3.3-9, the air from these areas is exhausted through a set of confinement filters before release to the stack. During normal operation, the process areas are sealed and maintained at a negative pressure with respect to atmosphere.

Air is exhausted from the process areas by using large centrifugal fans driven by electric motors. There are three fans in parallel, two of which are normally online, although only one fan is necessary to maintain negative pressures in the process areas. The rated air flow capability of two fans is 128,000 cfm at about six inches of H₂O pressure drop. The fan motors can be powered from three sources:

- Normal building power
- Emergency building power
- Special containment substation

Each online fan has a backup motor powered by diesel generators.

FIGURE 3.3-9. Flow Diagram of Reactor Ventilation System

Exhaust filters are provided to remove moisture, particulate activity, and halogen activity. The filter banks are enclosed in five separate compartments, three to five of which are normally online. A vertical cross section of a filter compartment is shown in Figure 3.3-10. Each compartment can be isolated for maintenance and testing. The three separate filter banks in order of air flow treatment are:

- Moisture separators. The moisture separators Demisters™ (Otto H. York Co., Inc., Parsippany, New Jersey) are designed to remove about 99% of entrained water particles of 1-to 5- μ m diameter to protect against significant blinding of the water-repellent particulate filters. The separators consist of mats woven from Teflon™ (Du Pont) yarn (individual fibers about 0.001 inch in diameter) and stainless steel wire forming a pad 24 x 24 x 2 inches thick. The case, mat, and support mechanism are designed and tested to withstand flows equivalent to about 10 times the rated air flow through the separator.
- Particulate filters. The particulate filters are designed to retain 99+% of all particles of 0.3 μ m or larger diameter. The filter medium is made of 18-mil-thick glass felt sheet, which is fire resistant and water repellent and has high wet strength characteristics. Under accident conditions, the filters could be exposed to hot air, wet steam at 100°C, or fog mixture of steam and air.
- Carbon beds. Activated carbon beds were designed to retain halogen activity that might be released if a reactor accident should occur. Each carbon unit is packed with 57 pounds of activated coconut-shell carbon that is relatively dustfree. Twelve separate pleats maintain a rigid one-inch-thick bed, retard settling, and expose about 15 ft² of perforated face area for air flow. Retention of iodine on the carbon beds is shown in Figure 3.3-11.

3.3.5.10 Reactor Room Spray System

A system is provided in the reactor room to spray water on an irradiated assembly if one is accidentally dropped during unloading operations. This system consists of a header with twelve groups of fixed spray nozzles mounted on the reactor room wall. The spray pattern from these nozzles covers the area traversed by the discharge machine. There also are two remotely controllable spray nozzles. One is mounted on each side of the reactor room approximately halfway between the reactor tank and the discharge canal. These nozzles provide a concentrated stream of water to any specific location within their range. These two spray nozzles greatly enhance the capability of the system to cool assemblies that are suspended in the discharge machine. Each spray nozzle group has its own actuation valve.

FIGURE 3.3-10. Filter Compartment (Elevation Cross Section)

FIGURE 3.3-11. Iodine Retention Tests in Radiation Field of 15 Million rads $^{60}\text{Co/hr}$

3.3.6 L-Reactor Source Terms and Radwaste Systems

3.3.6.1 Source Terms

3.3.6.1.1 Atmospheric Releases

Radionuclides will be released to the atmosphere as a result of routine operation of L Reactor from three atmospheric release points:

- at the 200-foot high stack (Figures 3.1-4 and 3.3-9)
- at ground level from evaporation of disassembly basin water (Figure 3.1-4)
- and at ground level from evaporation of water purged from the disassembly basin to a seepage basin.

Stack Release

Tritium, in the form of DTO, is released to the ventilation system (Figure 3.3-9) and, therefore, to the stack by evaporation of process water exposed to air flowing through the process area. During reactor operation, D_2O containing DTO is evaporated from small leaks in pipe flanges, valves, and from the D_2O process water exposed in the control rod guide tubes. During reactor shutdown, DTO is evaporated when pipes or valves are opened for inspection and maintenance work, and when wet fuel, target, and control rods are discharged from the reactor.

Disassembly Basin

Although the discharged fuel and target assemblies are rinsed with H_2O before being placed in the disassembly basin, some tritium is transferred to the disassembly basin with process water that adheres to the assemblies and from DTO contained as water of hydration in the aluminum oxide on the assemblies. Water vapor containing DTO evaporates at ground level from the disassembly basin and from the seepage basin to which the disassembly basin water is occasionally purged (Figure 3.1-4).

Seepage Basin

Disassembly basin water is normally recirculated through filters and deionizers to clarify the water and to remove radionuclides. Tritium is not removed in the process. When the tritium content of the disassembly basin water has built up

through several reactor discharges to a procedural control range — 0.2 to 0.4 microcuries/mL — the water is purged to a seepage basin through filters and deionizers. Based on average atmospheric conditions, 30% of the tritium purged evaporates each year.

Other Radionuclides

Fission product noble gases (isotopes of xenon and krypton) are released to the reactor coolant from small defects in fuel and target assemblies and occasionally, but rarely, from failures in the depleted uranium target assemblies. The gases diffuse to the helium blanket gas system, and, because of leaks in the pressurized gas system, can enter the process ventilation system, where they are released from the 200-foot stack.

Argon-41 is produced by neutron irradiation of natural argon in the air space that exists between the reactor tank wall and the thermal side shield. The radioactive argon (1.83 hour half-life) diffuses to the process area ventilation system and is released from the 200-foot stack. The confinement system filters, consisting of moisture separators, particulate filters, and carbon beds, do not prevent the release of tritium and noble gases to the atmosphere.

Carbon-14 is produced in the moderator in three ways: from (n, alpha) reactions with naturally occurring O^{17} in the D₂O process water, from (n,p) reactions with N^{14} present as dissolved gas in the moderator or as nitric acid used to control the moderator pH, and from irradiation of O^{17} present in the air around the reactor tank wall. Most of the carbon in the moderator is removed as carbonates by the moderator ion-exchange purification system. Some of it, as CO₂, escapes to the pressurized blanket gas system, leaks out, and is exhausted through the stack. The calculated total annual releases from the three reactors operating at SRP for the last three years have been 34, 33, and 39 curies.

Iodine-131, a fission product, is released to the process room air by the same pathways as xenon and krypton. The fraction of iodine released through the carbon filters is 5×10^{-5} .

Estimated Atmospheric Releases

The expected annual atmospheric releases from operation of L Reactor are given in Table 3.3-1. The values listed are based on the average annual releases from P, K, and C Reactors for 1978, 1979, and 1980. The P, K, and C values of estimated tritium and

TABLE 3.3-1

Expected Annual Atmospheric Releases for L-Area Reactor (3% ^{240}Pu Operation)

Radionuclide	Half-Life	L Reactor			Maximum Observed (P, K, C)*		
		Stack Release	Ground Level Release		Stack Release	Ground Level Release	
			Disassembly Basin	Seepage Basin		Disassembly Basin	Seepage Basin
^3H , Curies	12.3 y	48,500	3200	3200	62,800	3450	3000
^{14}C , Curies	5730 y	12			13		
^{41}Ar , Curies	1.83 h	19,500			31,700		
$^{85\text{m}}\text{Kr}$, Curies	4.5 h	600			1,690		
^{87}Kr , Curies	76 m	540			1,700		
^{88}Kr , Curies	2.8 h	790			2,390		
^{131}I , mCi	8.04 d	0.84	3.3		2.24	6.01	
^{133}Xe , Curies	5.3 d	1,700			3,880		
^{135}Xe , Curies	9.2 h	1,390			3,550		
Unidentified Beta-Gamma, mCi	-	0.20			0.95		
Unidentified Alpha, μCi	-	1.0			2.63		

* Per reactor for years 1978, 1979, and 1980.

iodine evaporated from the disassembly basin and tritium evaporated from the seepage basin have been adjusted for the more frequent target discharges expected for forecast 3% plutonium-240 operation of L-Reactor. Under present operation, three sets of targets are discharged for each fuel cycle; with 3% plutonium-240 operation, five sets of targets are discharged during each fuel cycle.

The maximum observed annual releases from P, K, and C Reactors are also listed in Table 3.3-1.

3.3.6.1.2 Liquid Releases

Radionuclides are released to liquid pathways from L Area to a low level seepage basin and from water used to flush heat exchangers at the heat exchanger repair facility in Central Shops and/or C-Area. Radionuclides are also released to Steel Creek as a result of leaks of process water into the cooling water in the twelve reactor heat exchangers and by leaks to the process sewer.

Tritium and other radionuclides are transferred to the reactor disassembly basin during reactor discharge by methods described in the previous section (3.3.6.1.1). The average annual amount of tritium released to the seepage basin is expected to be 10,500 curies, of which 3200 curies would be released to the atmosphere at ground level by evaporation (Table 3.3-1). About 3600 curies of tritium in the cooling water would be released to streams. Expected and maximum observed annual releases for all radionuclides are given in Table 3.3-2.

One basin has a common usage for all reactors. Basin 690-G receives liquid waste from the heat exchanger repair facility. The L Reactor contribution to this basin is listed in Table 3.3-3.

The liquid release values listed in Tables 3.3-2 and 3.3-3 have been adjusted for the more frequent target discharges expected for L-Reactor operation.

3.3.6.1.3 Solid Waste Generation

Operation of one SRP reactor results in the generation of about 20,000 cubic feet of solid waste annually from the reactor itself and about 200,000 cubic feet, containing 86,000 curies of radioactivity, prorated from the fuel fabrication and fuel reprocessing areas.

TABLE 3.3-2

Expected Annual Liquid Releases from L-Area Reactor (3% ^{240}Pu Operation)

Radionuclide	Half-Life	L Reactor		Maximum Observed (P, K, C)*	
		To Seepage Basin	To Streams	To Seepage Basin	To Streams
^3H , Curies	12.3 y	10,500	3600	10,100	5250
^{32}P , mCi	14.3 d	1.2		2.75	
^{35}S , mCi	87.2 d	9.5		16.8	
^{51}Cr , mCi	27.7 d	180		221	
$^{58,60}\text{Co}$, mCi	57.2 d, 5.3 y	0.37	45	1.7	406
^{89}Sr , mCi	50.5 d	0.07		0.32	
^{90}Sr , mCi	29 y	0.20	0.16	0.87	1.41
^{91}Y , mCi	58.6 d	5.1		17.2	
^{95}Zr , mCi	65.5 d	11		48	
^{106}Ru , mCi	1.01 y	0.34		0.73	
^{125}Sb , mCi	2.73 y	8.0		21	
^{131}I , mCi	8.04 d	6.9		18.8	
^{134}Cs , mCi	2.06 y	5.1		9.6	
^{137}Cs , mCi	30.1 y	44	0.41	73	
^{144}Ce , mCi	284 d	19		46	
^{147}Pm , mCi	2.62 y	2.8		7.4	
Unidentified Beta-Gamma, mCi	-	89	111	250	650
Unidentified Alpha, mCi	-	0.32	0.02	0.37	0.12

* Per reactor for years 1978, 1979, and 1980.

TABLE 3.3-3

Expected Annual Release to the 690-G Seepage Basin from L-Area Reactor

Radionuclide	690-G Seepage Basin	
	Expected	Maximum*
^3H , Curies	0.2	1.2
^{60}Co , mCi	0.003	0.05
^{90}Sr , mCi	0.001	0.004
^{137}Cs , mCi	0.001	0.003
Beta-Gamma** mCi	0.005	0.029
Alpha** mCi	0.0003	0.002

* Maximum annual release from P, K, and C Reactors.

** Unidentified.

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

Work clothing, plastic suits, and other items of a similar nature are packaged in boxes and sealed prior to disposal in the SRP Burial Ground. The highly radioactive stainless steel and aluminum parts are placed in a shielded cask prior to transport. The SRP Burial Ground is a 195-acre area located near the center of the plant between the F- and H- fuel reprocessing areas. The solid waste from the cask is placed in trenches — 20 feet wide and 20 feet deep — designated for low- and high-level beta-gamma contaminated solid waste. Waste placed in trenches is covered with soil at the end of each working day. When the waste-soil mixture fills the trench to within four feet of the top, clean soil is placed in the trench to make the trench surface level, and a shallow-rooted grass is planted.

The SRP Burial Ground has been in operation since 1953. Since the start of operation, 12 million cubic feet of solid waste have been emplaced in the Burial Ground. This waste contained 9.7 million curies of radioactivity when emplaced; as of December 1981, the radioactivity had decayed to 4 million curies. At present, about 600,000 cubic feet of solid waste containing 260,000 curies of activity is added to the Burial Ground each year. After L-Area Reactor restart the expected solid waste input to the Burial Ground will gradually increase to about 800,000 cubic feet and 350,000 curies of radioactivity per year.

3.3.6.2 Source Terms from Other Areas Impacted by L-Reactor Operation

The restart and operation of L-Area Reactor will increase the release of radionuclides from the separation areas, the fuel fabrication area, and the heavy water rework area. The expected contribution from operation of L-Area Reactor is estimated by using the average area releases for 1978, 1979, and 1980 and adjusting these releases for the expected 3% plutonium-240 operation of L-Area Reactor.

Expected annual releases to the atmosphere and release of isotopes to streams from the two separation areas are listed in Table 3.3-4. Releases to the seepage basins in both areas are listed in Table 3.3-5. About 30% of the tritium released to seepage basins evaporates to the atmosphere at ground level.

The fuel and target fabrication area will increase the output of fuel, target, and control rod components to supply L-Area Reactor and to support the 3% plutonium-240 production schedule. Average releases from the fabrication area for the last three years are used to estimate the L-Area Reactor contribution. Results are listed in Table 3.3-6.

Rework of heavy water used in L-Area Reactor will increase the throughput in the SRP heavy water area. The L-Area Reactor contribution, based on the last three-year SRP average, is given in Table 3.3-6. It is assumed that the tritium content of the water charged to L-Area Reactor is the same as in the operating P, K, and C reactors.

3.3.6.3 Description of the Gaseous Radwaste Systems

The air exhaust filters used to filter air from the reactor process area contain activated carbon beds (Section 3.3.5.9). These beds contain an impregnated Type GX-176 (coconut shell) carbon. The impregnants in Type GX-176 carbon are potassium iodide (KI) and triethylene diamine (TEDA). Typical radiolytic iodine desorption data are plotted in Figure 3.3-11.

Studies of aging effects in carbon performance show that Type GX-176 carbon can be used up to 30 months in the confinement system (Table 3.3-7).

3.3.6.4 Description of Liquid Radwaste Systems

Facilities are provided for routine removal of radioactive nuclides from the reactor moderator and the irradiated assembly storage basin (disassembly basin) water. Radioactivity in the moderator can arise from neutron activation of the moderator, impurities, and from fuel failures. Radioactivity in the storage basin is carried over by discharged irradiated assemblies with a minor amount caused by miscellaneous operations in the basin.

A side stream of D_2O from one of the six circulating systems is pumped to the building purification area for removal of particulate and water soluble activity and nonradioactive ionic impurities. Normally, a flow rate of about 25 to 50 gpm is maintained. This can be increased to as high as 150 gpm if special conditions warrant.

TABLE 3.3-4

Expected Annual Releases from Separations Areas --
L-Area Reactor Contribution (3% ^{240}Pu Operation)

Atmospheric Releases

^3H from stack, Ci	6900
^3H -evaporation from seepage basins; Ci	1700
^{14}C , Ci, stack	8
^{85}Kr , Ci, stack	201,800
$^{89},^{90}\text{Sr}$, mCi, stack	1.5
^{95}Zn , mCi, stack	6.0
^{95}Nb , mCi, stack	12
^{103}Ru , mCi, stack	1.2
^{106}Ru , mCi, stack	28
^{129}I , Ci, stack	0.07
^{131}I , mCi, stack	17
^{131}Xe , Ci, stack	1.9
^{133}Xe , Ci, stack	0.10
^{134}Cs , mCi, stack	0.11
^{137}Cs , mCi, stack	1.2
^{141}Ce , mCi, stack	0.08
^{144}Ce , mCi, stack	8.0
Other β - γ , mCi, stack	0.22
$^{241},^{243}\text{Am}$, mCi, stack	0.39
$^{242},^{244}\text{Cm}$, mCi, stack	0.35
$^{235},^{238}\text{U}$, mCi, stack	1.7
^{238}Pu , mCi, stack	1.9
^{239}Pu , mCi, stack	0.27

Liquid Release to Streams

^3H , Ci	39
$^{89},^{90}\text{Sr}$, mCi	4.9
$^{134},^{137}\text{Cs}$, mCi	19
Other β - γ , mCi	53
Alpha, mCi	2.9

TABLE 3.3-5

Expected Annual Release to Seepage Basins from the Separations Areas,
L-Area Reactor Contribution (3% ^{240}Pu Operation)

<u>Radionuclide</u>	<u>Curies Released</u>
^3H	5700*
^{51}Cr	0.36
^{58}Co	0.0003
^{60}Co	0.054
^{65}Zr	0.030
^{89}Sr	0.053
^{90}Sr	0.54
^{95}Zr	1.3
^{95}Nb	0.82
^{103}Ru	0.65
^{106}Ru	9.2
$^{124}, ^{125}\text{Sb}$	0.011
^{131}I	0.013
^{134}Cs	0.22
^{137}Cs	2.2
^{141}Ce	0.007
^{144}Ce	3.0
^{147}Pm	0.12
Other β - γ	0.093
$^{241}, ^{243}\text{Am}$	0.033
$^{242}, ^{244}\text{Cm}$	0.001
U	0.073
^{238}Pu	0.013
^{239}Pu	0.009

* 30% of ^3H evaporates and is released to the atmosphere at ground level (see Table 3.3-4).

TABLE 3.3-6

Expected Annual Release from the Fuel Fabrication and
Heavy Water Areas -- L-Area Reactor Contribution

<u>Atmospheric Releases</u>	<u>Fuel Fab. Area</u>	<u>Heavy Water Area</u>
^3H , Ci	-	790
^{238}U , μCi	0.86	-
Alpha, μCi	2.6	-
<u>Liquid Releases</u>		
<u>To Streams</u>		
^3H , Ci	-	520
$^{89,90}\text{Sr}$, mCi	-	0.04
$^{134,137}\text{Cs}$, mCi	-	0.08
Other β - γ , mCi	-	3.5
$^{235,238}\text{U}$, mCi	50	-
Alpha, mCi	-	0.007
<u>To Seepage Basin</u>		
$^{235,238}\text{U}$, mCi	35	-

TABLE 3.3-7

Effect of Service Aging on Impregnated (Type GX-176) Carbon

<u>Service Age Months</u>	<u>Radiolytic Iodine Penetration, %*</u>
0	0.028
14	0.121
19	0.338
25	0.270
30	0.577

* Penetration during a 5-hour test at 80°C,
95% relative humidity and absorbed dose rate
of $>1.5 \times 10^7$ rad/hr.

The moderator purification facility is located in a shielded cell serviced by an overhead crane to facilitate removal of spent resin beds and used filters. The purification train consists of prefilters, deionizers, afterfilters, and evaporators. Two deionizer units are connected in parallel (with prefilters and afterfilters). When the ion exchange resin is depleted in one unit, it can be replaced while the remaining unit remains in operation. Spent resin is buried in the SRP Burial Ground.

The L-Area Reactor purification facility contains a D_2O evaporator for concentrating particulate activity into a sludge. When full of sludge, the evaporator is removed for burial and replaced with a new unit.

L-Area Reactor also contains a pair of distillation columns for removing H_2O from the D_2O purification stream. Although not designed for radionuclide control, the reboiler section of the distillation facility aids in concentrating particulate activity. There are no facilities provided for the removal of tritium from the reactor moderator.

Activity is transferred to the irradiated assembly storage basin (disassembly basin) when assemblies are removed from the reactor. Activity concentrations in the basin are significantly lower than those in the reactor moderator. Each basin has piping connections for a portable deionizer which can be used intermittently as required to reduce the basin water activity level. The flow rate to the deionizer is about 150 gpm. Resin is regenerated in the separations area when needed, and high-level activity is concentrated and stored in tanks.

Periodic purging of the disassembly basin water is necessary to minimize operating personnel exposure to tritium inhalation hazards. During the purging operation, water from the basin is passed through two deionizer beds in series. The water is then discharged to a seepage basin. The effluent from the first resin bed is monitored during the purge, and pumping is stopped when there is indication of column breakthrough. The resin bed is replaced before purging is resumed to minimize the release of any radioactivity other than tritium to the seepage basin. Spent resin in the deionizer beds is regenerated in the separations areas, and the activity is concentrated and stored.

Each basin has two sand filters ($\sim 100 \text{ ft}^3$ each) to maintain basin visibility. The filters remove most particulate matter, including that which contains trace amounts of adsorbed radioactive material. These filters can also be used to remove sludge accumulated on the basin floor. The flow rate to the filters is about 500 to 1500 gpm. When required, the sand filters are back-flushed, and the activity is collected and transferred to the separations area for concentration and storage.

3.3.6.5 Process and Effluent Monitoring

Air and water samples are monitored routinely to detect routine and abnormal activity releases. If activity levels above normal are detected, they are investigated to locate the source and correct the condition. Samples routinely analyzed include:

- Moderator
- Stack exhaust air
- Effluent heat exchanger cooling water
- Disassembly basin effluent purge water

In addition, air monitoring at local sections of the reactor building is frequently used to protect working personnel.

As described in Chapter 6, samples of water from plant streams and the Savannah River are analyzed periodically. Stations located at various points onsite and offsite sample air for laboratory analysis. Specimens of plant life, crops, animals, fish, and birds from SRP and nearby areas are collected and analyzed periodically for radionuclide uptake.

Monitoring points are listed for atmospheric releases in Table 3.3-8 and for liquid releases to streams and seepage basins in Table 3.3-9.

3.4 NONRADIOACTIVE WASTES

3.4.1 Chemical and Biocide Wastes

The normal usage of chemicals in L Area is expected to be similar to that of the other reactor areas. The expected usage and discharges from L Area are summarized in Table 3.4-1. The normal discharges to the environment are sodium hypochlorite, Polybor® (Pacific Coast Borax Co., New York, NY), and Drewgard™ (Drew Chemical Corp., Boonton, NY). These are discharged to process sewers and Steel Creek.

3.4.2 Sanitary and Other Waste Systems

The sanitary waste system is described in Section 3.2.4. There are no other routine nonradioactive waste disposal systems in L Area. Overflows of both the 25-million-gallon basin and the water plant clearwell may routinely occur and are discharged to Steel Creek at L-Area outfalls (Section 5.4).

TABLE 3.3-8

Reactor Area Monitoring for Radioactivity Released to Atmosphere

<u>Emission Point</u>	<u>Type of Release</u>	<u>Current Monitoring</u>
200-ft Stack	Tritium	Continuous sampling for tritium using dehumidifier to collect moisture sample. Sample taken daily for lab analysis.
	Noble gases	Continuously monitored with Ge(Li) system.
	Activation Products and Fission Products Alpha	A continuous filter paper sample taken for lab analysis.
	Radioiodine	A continuous charcoal filter sample taken for lab analysis.
Disassembly Bay (Exhaust Vent in 105-P)	Tritium Iodine	Once a week grab sample taken for lab analysis. Continuous sampling.
Heat Exchanger Decontamination Facility (105-C)	Activation Products and Fission Products	Continuous sampling.
Heat Exchanger Repair Facility	Activation Products and Fission Products Alpha	Grab sampling during operation.
Contaminated Equipment Workshop	Activation Products and Fission Products Alpha	Grab sampling.

TABLE 3.3-9

Reactor Area Monitoring for Radioactivity Released to Streams
and Seepage Basins

<u>Emission Point</u>	<u>Type of Release</u>	<u>Current Monitoring</u>
Disassembly Basin Water	Activation Products Fission Products Alpha	Grab sample daily when not purging; continuous sampling during basin purge with lab analysis for radionuclides.
	Tritium	Once per day a portion of of sample sent to lab for analysis.
Thermal Shield and Top and Bottom Shield System	Activation Products Fission Products Tritium	Grab sample sent to lab for complete isotopic analyses before pumping.
Dry Cave Floor Drain	Activation Products Fission Products Tritium	Grab sample.
Heat Exchanger Cooling	Activation Products Fission Products	Continuously monitored by in-line cooling water gamma monitor.
	Tritium	Grab sample once per week during normal operations and once per day during startup.
Moderator Spillage	Activation Products Fission Products Alpha Tritium	Sumps sampled before pump out; analyzed in lab.

TABLE 3.3-9 (Continued)

<u>Emission Point</u>	<u>Type of Release</u>	<u>Current Monitoring</u>
Deuterization Waste Water (K only)	Activation Products Fission Products Alpha	Grab sample of each drum; analysis before release.
Heat Exchanger Repair Facility	Activation Products Fission Products Alpha	Grab sample of tank prior to dumping.
Miscellaneous Contaminated Drains (including tool, mask, and personnel decontamination and H.P. Lab waste)	Activation Products Fission Products	Grab sample daily.
Disassembly Deionizer Leaks and Heat Exchanger Leak- through	Activation Products Fission Products Alpha	Grab sample daily when not pumping. Continuous sampling during basin purge.
	Tritium	Portion of daily grab sample sent to lab for analysis.
Process Area Floor Decontamination Water and Inhibitor Waste Water	Activation Products Fission Products Alpha Tritium	Grab sample sent to lab for analysis before release.
Distillation Cooling Water	Activation Products Fission Products Alpha Tritium	Grab sample daily. Analyzed for nonvolatile beta and alpha by HP.
Cask Decontamination Water and Drainage from Scrap Casks	Activation Products Fission Products	Grab sample daily when not purging disassembly basins. Continuous sampling during basin purge.

TABLE 3.4-1

Normal Chemical and Biocide Usage and Storage

<u>Chemical</u>	<u>Approximate Annual Usage</u>	<u>Storage Capacity</u>	<u>L-Area Discharge</u>
Diesel Fuel	390,000 gal	70,000 gal	None
Kleerall™* 3574 (20% Methylene chloride)	35 gal	50 gal	None
Gasohol	110,000 gal	5,000 gal	None
Alum	700 lbs	100 lbs	None
Nitric Acid (1 normal)	100 liters	1.5 liters	None
Sodium Hydroxide (12% solution)	100 gals (in water)	100 gal	Seepage basin
Malathion/Kerosene, 5%	1 gal	0	None
Sodium Hypochlorite, 15%	80,000 gal (in water)	5,000 gal	Process sewer
Sodium Phosphate	500 lbs	30 lbs	None
Sodium Sulfite	50 lbs	10 lbs	None
Clean & Waste Oil	35 drums	13 drums	None
Drewgard™ (Corrosion Inhibitor)	60 gal (in water)	80 gal	Leakage to Process sewer
Polybor® (2% sodium Poly-borate)	3600 gal	23,000 gal	Process sewer
Solvents, Misc.	150 gal	50 gal	None

* Octagon Process Inc., States Island, NY

3.5 TRANSPORTATION OF MATERIALS

The materials transported from 100-L Area after startup will be packaged in casks, steel boxes and drums, dumpster pans, tank trailers, and cardboard boxes typical of those being used in other reactor areas. The volumes of materials and, therefore, the number of shipments will be typical of the other three operating reactor areas.

Shipments on the SRP rail system will include:

- Empty casks to transport reactor fuel elements
- Intact irradiated fuel in 70-ton casks (CD casks) on flat bed rail cars to 200-F or 200-H Areas
- Any irradiated fuel with cladding defects in a special containment device ("harp") within a 55-ton failed fuel element cask to a 200 Area
- Occasionally containers of helium or Polybor or other nonradioactive materials

Onsite truck shipments for L Area will include:

- Unirradiated fuel in steel shipping boxes and lithium-aluminum targets from the 300-M Area
- Irradiated lithium-aluminum targets in a 45-ton cask on a flat bed trailer from the L-Area disassembly basin to 200-H Area
- Irradiated scrap metal in a 15-ton cask or replacement cask from the L-Area Disassembly Basin to the SRP Burial Ground (about 80 shipments annually)
- Moderator (D_2O) in stainless steel 55-gallon drums to and from other reactor areas and the 400-D Area where contaminant removal and purification facilities are located (about 700 drums annually)
- D_2O purification deionizers from 100-L Area. After the resin is depleted, the deionizer is shipped to 100-K Area in a cask on a special flat bed trailer for dedeuterization before being shipped to the Burial Ground (about three annually). A replacement D_2O equilibrated purification deionizer is concurrently shipped from 100-K to 100-L Area.
- Basin water deionizers mounted in casks on a special trailer to Building 245-H Area for regeneration and return to L-Area service (about five annually)

- Liquid and gas samples on a pickup truck to laboratories in Buildings 772-D or 772-F on each shift
- Dry wastes in collection pans on a daily basis and intermittently boxes of wastes generated during jobs such as replacing containment filters to the SRP Burial Ground
- Infrequently, liquid light water wastes may be transported to the underground storage tank in 100-C Area or, when volumes are large, may be transported to Building 211-F Area, in an unshielded tank trailer
- Nonradioactive materials to L Area on SRP or vendor trucks

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4. ENVIRONMENTAL EFFECTS OF SITE RENOVATION AND UPGRADING

4.1 STARTUP PROGRAM AND SCHEDULE

Renovation, restoration, and upgrading of the L-Area facilities will be covered by two projects. One project will cover capital improvements, and the other project will cover the repair aspects of the work. The major portion of the work will be accomplished by Engineering Department — Construction Division forces with minor restoration functions carried out by SRP maintenance forces. The work is expected to take about three years with the reactor scheduled to go critical in October 1983. The major activities in the renovations and their sequence and duration are shown in Figure 4.1-1.

4.1.1 Area Entry Activities

Preparations for L-Area re-entry began on October 16, 1980. Office areas in 704-L were cleaned and furnished; electrical power was restored; and a temporary telephone system was installed. Portable toilet facilities, electric heaters, and drinking water containers were used until restoration of necessary facilities was completed.

Trees and brush were removed from the area; weeds were mowed inside the area fence; and sidewalks and roadways were cleared of overgrowth. Some overhead steam lines and supports were removed because of deteriorated support poles.

Cleaning of Buildings 105-L and 190-L began on November 1, 1980. Safety inspections were begun and Health Protection (HP) coverage was established.

4.1.2 Work Forces

Construction forces will reach a peak of about 1040 people in mid-1982 (Figure 4.1-2); the permanent operating group will gradually increase to about 415 employees in mid-1983 and then level off to about 350 employees after reactor restartup (Figure 4.1-2).

4.1.3 Construction Facilities

Accommodations for the construction forces consist of temporary modular office units, skid shacks, and temporary building units located to the east of the 105-L Building (Figure 4.1-3). Utilities will be provided to the temporary construction (TC) facilities via the existing domestic water system that has been

FIGURE 4.1-1. L Reactor Startup Schedule

FIGURE 4.1-2. L-Area Manpower Forecast

FIGURE 4.1-3. L-Area Construction Activities

upgraded to supply the required flow from two existing wells located just outside the perimeter fence. Waste treatment for the construction period will be by an existing septic tank system with the drain to the process sewer blocked off. The septic tank will be pumped out as required. A new packaged waste treatment plant will be installed by mid-1982 and will handle both the permanent system and the TC facilities (Section 4.2.1.3).

Temporary parking lots have been constructed for use by construction forces (Figure 4.1-3). These parking lots were completed and in use by July 1981 and will continue in use until after L-Area restartup.

4.2 PROJECT ACTIVITIES

4.2.1 Inside Area

4.2.1.1 Water Plant and Wells

The existing water plant has been dismantled and will be replaced. The new system will include two additional deep wells of 500 gpm each with the necessary facilities for degasification and chlorination (Figure 4.1-3). Storage will be provided by modifying and upgrading the existing filter compartment and the clearwell. These facilities are expected to be completed and in service by May 1982.

4.2.1.2 186 Basin - Cleaning

The 186 basin (25-million gallon basin) was drained and cleaned in March 1981 (Figure 4.1-3). Flows to Steel Creek through the discharge canal ranged from 12,000-15,000 gpm during the draining period. The residue in the bottom of the basin was flushed to Steel Creek. The basin will be refilled after the underwater equipment has been restored.

4.2.1.3 Sanitary Waste Treatment Plant

During the initial stages of site renovation of L Area, an existing 16,000-gallon septic tank and 16 portable chemical toilets will be used to accommodate sanitary waste. The overflow drain from the septic tank was plugged, so there is no discharge to SRP streams. The waste is trucked offsite to the Augusta Waste Treatment Plant, Augusta, Georgia.

Upon installation, a new package treatment plant will handle domestic sewage from L-Area construction and normal operation work forces (Figure 4.1-3). The new system will include a lift station

to intercept the flow in the existing sewers. The unit is designed for a 35,000 gallon-per-day flow and will include an aeration chamber, a clarifier chamber, and a sludge holding tank. The existing septic tank will be available for additional sludge storage. The effluent will be chlorinated prior to discharge through the L-Area cooling water outfall to Steel Creek. Periodically, the treated sludge will be pumped from the sludge holding tank to a mobile tank and transported to the sludge pit near Central Shops at SRP.

4.2.1.4 Electric Power

The two existing 115 kV power lines which supply electrical power to L Area will remain in service. Two new 115 kV lines will be installed within the area (Figure 4.1-3). One tie line will be connected to the existing line south of the L-Area outer perimeter fence and will run to a new transformer yard close to the former location of the L-Area power house. The other new line will connect the new transformer yard to the existing transformer yard. No new land clearing will be required for these power lines.

4.2.1.5 Backup Boiler

An oil-fired steam boiler will be installed north of Building 105-L to provide steam until the steam line from K Area is operational (Figure 4.2-1). The boiler has a rated output of 12,000 pounds of steam per hour at 358°F and consumes 35 gallons per hour of No. 2 fuel oil.

4.2.1.6 Seismic Bracing

Additional bracing will be provided on critical process water equipment in the reactor building and to the vent stack and the actuator tower to prevent failure in case of an earthquake with an acceleration of 0.2 g. Bracing was completed on the actuator tower in late 1981. Bracing on the stack will be completed by May 1982 and on the process water equipment in early 1983.

4.2.2 Outside Area

4.2.2.1 Steam Lines

The L-Area powerhouse was dismantled and removed shortly after the area was placed on standby in 1968. Instead of constructing a new powerhouse, a steam line will be installed between K and L Areas to supply the L-Area steam needs.

FIGURE 4.2-1. K- to L-Area Steam Line

Construction of the steam line will primarily use the existing right-of-way for a river water line between K and L Areas (Figure 4.2-1). Less than twenty acres of land will require clearing. The steam line, which will be aboveground on concrete and steel supports, will not interfere with wildlife. Road crossings will be structural steel and protected from vehicle collision. Right-of-ways will be maintained by mowing. No significant temporary roadwork for construction forces is expected. The steam line is expected to be completed and in operation by April 1983.

4.2.2.2 Rubble Pit

A new rubble pit will be established near L Area (Figure 4.1-3). The pit will be 10 feet deep, 60 feet wide and 114 feet long and will accommodate about 68,400 ft³ of waste. The rubble pit will be used for disposal of concrete and other miscellaneous noncombustible material generated during construction. Location near L Area will minimize hauling distance. When construction activities cease or when the pit is full, it will be covered with earth, and the surface will be revegetated.

4.2.2.3 Meteorological Tower

Currently, instrumented meteorological towers are located in all production areas to provide wind data for emergency response conditions and for routine assessments. The data are telemetered from each of the seven towers to the Weather Information and Display (WIND) minicomputer system every 1.7 seconds for processing and archiving. A 61-meter meteorological tower will be located in the vicinity of L Area. The tower and its equipment will be similar to the other seven towers of SRP. However, the processors and telemetry transmitters will be located in a weatherproof enclosure at the tower site because there will not be a heated building nearby.

The extent of activity at the tower and its effect upon the environment will be minimal. The access road and the trench for the transmission lines will be located to minimize tree removal. The tower installation will require a clear area of about 200-300 ft², including the concrete pad and the work area around the pad. No activity other than routine salvage of timber is permitted in the 250-foot radius zone to protect the tower and guy wires. Forest areas within 2,000 foot of the tower will be maintained according to normal forestry practices.

4.2.2.4 Cooling Canal Renovation

Renovation of the L-Area outfall canal (Figures 2.6-11 and 4.1-3) consisted of cleaning out the brush that had grown up within the canal and reinforcing the earthen banks and canal bed with riprap to prevent future erosion. This project was completed in February 1982.

4.2.2.5 50-Million-Gallon Basin

The 50-million-gallon basin (Figure 4.1-3) designed to receive radioactive water in the event of a major accident was renovated in November 1981. Trees were removed, and the earthen floor was repaired. A 500,000-gallon tank will be placed in the basin to contain the initial discharge of water in case of an accident. The 3000 feet of piping from the reactor area to the basin will be replaced.

4.2.2.6 Railroad Track Spur to L Area

During construction, large, heavy equipment will be transported to L Area by railroad. However, before shipments are made, the track spur to L Area will be reworked because it has not been maintained since L Area shutdown. Grade crossings will be reworked where rails were covered with asphalt when roads were repaved. Signal gear will be refurbished, and rail ties will be replaced where needed.

4.2.2.7 River Pumphouses

SRP operates two pumping stations (1G and 3G) to distribute cooling water to the reactor areas. There are 20 pumps, each with a 3,600 HP motor, located in Buildings 681-1G and 681-3G (10 pumps in each building). At present, only 18 pumps are operable. Pumps 6 and 8 at station 1G are out of service. Approximately 11 river water pumps are required to supply the necessary water for P, K, and C Areas when all three reactors are operating. When P, K, C, and L Reactors are operating, 15 to 18 pumps will be required. The two retired pumps in station 1G will be placed back in service in the summer 1983 before L Reactor is restarted.

4.2.2.8 Low-Level Liquid Seepage Basin

An existing seepage basin located south of L Area will be returned to service (Figure 4.1-3). The basin will receive purge water from the disassembly basin. The purge water will contain

trace quantities of radionuclides (Section 3.3.6). Reconditioning of the basin will consist of clearing the basin area of vegetation, grading, and repairing the exclusion fence. Soil sample surveys of the basin in 1978 gave radiation measurements of about 20,000 counts per minute beta-gamma with most of the radioactivity in the top 30 cm of soil (Table 4.2-1).

4.3 IMPACTS — NONRADIOLOGICAL

4.3.1 Terrestrial Ecology

Most of the renovation activities associated with L-Reactor restart will take place within the existing 82 acres used in previous L Area operations. However, about 20 acres of 20 to 30-year old pine plantations will be cleared for construction of the K to L steamline, power transmission lines, and the meteorological tower. The biota will shift from that characteristic of young pine forest to open fields and "edge" habitat. Open upland habitat is limited on SRP, since most of SRP is managed for timber production.

4.3.2 Aquatic Ecology

The average flow of Steel Creek will increase by about 5 to 20 cfs from discharges to Steel Creek from L Area. Periodically flows will increase by 200 and 400 cfs for 2 to 3 day periods. These high flows will cause local flooding along Steel Creek and in the Steel Creek delta similar to large storm events (i.e., 50 or 100 year flood events). Impacts associated with these high flows would be temporary, but could include increased turbidity and sediment transport, increased invertebrate drift, disruption of fish nesting and spawning, and amphibian and reptilian breeding along the floodplain.

4.3.3 Species of Special Concern

4.3.3.1 Red-cockaded Woodpecker (Picoides borealis)

The vicinity of L Area and the proposed K to L steam line were surveyed for red-cockaded woodpecker colonies on March 15-17, 1981, by Dr. Jackson (Figure 2.6-3 and Appendix A). No evidence of past or present activity was found. No colonies of red-cockaded woodpecker are within typical foraging distances of L Area. The renovation and construction activities at L Area or the steam line should not affect this species.

TABLE 4.2-1

Radioactivity in L-Area Seepage Basin Soil

Core at Site	Depth, cm	pCi/g (Dry)		
		⁶⁰ Co	¹³⁷ Cs	⁹⁰ Sr
1	0-15	80	5	NA
	15-30	5,930	400	NA
	285-300	20	1	NA
2	0-15	12,800	300	112
	15-30	30	3	2
	30-45	6	2	1
	45-60	15	1	1
	285-300	3	1	1
	585-600	30	2	1
3	0-15	2,160	70	31
	15-30	35	1	6
	30-45	24	1	1
	45-60	25	1	1
	285-300	1	1	1
	585-600	1	1	1
4	0-15	7	1	NA
	15-30	1,150	1	NA
	30-45	40	1	NA
	45-60	3	1	NA
	285-300	5	1	NA

NA -- No analysis

4.3.3.2 American Alligator (Alligator mississippiensis)

The American alligator should be little affected by renovation activities, since L Area and any proposed construction near L Area are located in upland areas not suitable for alligator habitat. Periodic discharges of cooling water in the spring of 1982 from L Area to Steel Creek will be of short duration (typically less than 2 days), at low volumes (90,000 gpm), and at ambient temperatures; therefore, no adverse effects should occur on alligators in the Steel Creek floodplain or the Savannah River swamp bottomland. Further full-flow testing in the late spring or summer of 1983 of 180,000 gpm for 2 to 3 days could flood potential nests or nesting sites in the Steel Creek area.

4.3.3.3 Other Species of Concern

Table 2.6-10 lists other species of concern which could occur in the vicinity of L Area, Steel Creek, the Steel Creek floodplain, or the Steel Creek delta area. A few species such as the bald eagle, Cooper's hawk, and the wood stork are migrating visitors on SRP and should be unaffected by renovation or by release of ambient river water to Steel Creek. Other species such as the hairy woodpecker, the red-headed woodpecker and the bobcat are common on SRP and are found along thermal and ambient streams of SRP. Adult turtle, frog, and amphibian species would be relatively unaffected by periodic ambient cooling water flow from L Area provided that increased flows to 90,000 gpm and 180,000 are of short duration. Periodic ambient low flow also would have little impact on resident fish and macroinvertebrates of "special concern."

The presence of any plant species of "special concern" in the Steel Creek area is unknown. Five species known to occur at SRP or nearby are listed in Table 2.6-10. All occur in moist to semi-aquatic habitats and would probably survive temporary flooding.

4.3.4 Hydrology

4.3.4.1 Surface Hydrology

During March 1981 water was pumped from the Savannah River to flush the 25-million-gallon basin (Section 4.2.1.2). In addition, treated waste water from the sanitary facilities and other process sewer discharges from L Area will be released to Steel Creek. These flows will range from 5 to 20 cfs. The average flow of Steel Creek at Road A prior to L-Area activities was about 50 cfs. Flushing and testing of the cooling water system will begin in the Spring 1982, with flows to 90,000 gpm (200 cfs). In 1983, test

flows of up to 180,000 gpm (400 cfs) will be released to Steel Creek. Elevated flows of 200 and 400 cfs for a few days from L Area will cause temporary flooding along Steel Creek and elevated water levels in the Steel Creek delta area. No long term impacts are expected from these temporary increased flows.

Concurrent with the increased cold water flows in the Spring 1982, cesium-137 transport will be monitored in Steel Creek. The results of the cesium monitoring will be used to further predict cesium-137 transport when L Reactor is restarted (Section 5.1.1.3).

4.3.4.2 Subsurface Hydrology

In L Area the water table is found at depths ranging generally from 10 to 40 feet below the ground surface. Shallow ground water beneath the site moves generally either to the south-southeast in the direction of Steel Creek or to the west-southwest in the direction of Pen Branch. For example, contaminants entering the low-level seepage basin in L Area would probably flow to an outcrop point along Steel Creek. The hydraulic heads in the area are such as to prevent movement of contamination to the Tuscaloosa Formation (Section 2.5.2).

During the renovation of L Area, water from two existing deep wells (600 feet, Tuscaloosa Formation) will be used for domestic consumption, sanitary facilities, fire protection, and other construction activities. Two new wells (600 feet) will be drilled to later supply water for operational needs. Wells from the Tuscaloosa can produce about 1000 gpm. Monitoring of ground water use from the Tuscaloosa by SRP (4000 to 5000 gpm over the last 28 years) has not shown any progressive decline in water levels in the Tuscaloosa. Water use by L Area of about 300 gpm should have no significant effect on this aquifer.

4.3.5 Historic Resources

Renovation and upgrading in L Area prior to startup will have no significant effect on historic or prehistoric resources.

4.3.6 Sanitary and Solid Wastes

4.3.6.1 Sanitary Wastes

During the initial stages of site renovation of L Area, an existing 16,000-gallon septic tank and 16 portable chemical toilets are being used to accommodate sanitary waste. The overflow drain from the septic tank has been plugged, so there is no

discharge to SRP streams. The waste is trucked offsite to the Augusta Waste Treatment Plant.

Upon installation, a new package treatment unit will handle domestic sewage from L Area construction and normal operation work forces (Section 4.2.1.3).

4.3.6.2 Solid Wastes

Other wastes which will require disposal during the renovation of L Area are

- Asbestos
- Rubble
- Conventional Garbage
- Salvageable Waste

All asbestos waste removed from L Area will be sealed in plastic and transported to C Area for burial in the asbestos burial pit. The largest quantity of asbestos removed to date was that used to insulate steam lines which were removed. This quantity of asbestos covered about 8000 linear feet of steam lines that varied in diameter from three to sixteen inches. Smaller quantities will be removed from time to time as renovation proceeds.

Rubble such as broken concrete, asphalt, wood trash (not lumber), insulation (except asbestos), and other miscellaneous trash will be buried in a new rubble pit (Section 4.2.2.2). Conventional garbage generated during renovation will be collected routinely and transported to a permitted, existing landfill onsite. Salvageable waste will be monitored for contamination and transported to the SRP salvage yard. This salvaged material will be sorted and stored with other material until it is sold.

4.3.6.3 Low-Level Waste

During the renovation and construction phase of L-Area startup, low-level radioactive solid waste will be generated (Table 4.3-1). The waste consists mainly of contaminated clothing, equipment, piping, cleanup materials, and miscellaneous items. Waste generated prior to 1980 represented clothing and material used during routine inspection of the area before renovation began.

TABLE 4.3-1

L-Area Low-Level Radioactive Waste Generation

<u>Year</u>	<u>Low-Level Waste</u>	
	<u>Cubic Feet</u>	<u>Curies</u>
1978	60	0.000
1979	286	0.010
1980	1435	0.181
1981	24,886	42.438
1982 (Jan)	2726	20.4

4.4 RESOURCES COMMITTED

4.4.1 Transmission Lines

New piping and electrical lines will be installed as part of the refurbishment and capital improvement work in L Area. In addition, a new K- to L-Area insulated steam line will be required (Figure 5.3-1). A summary of the materials required for the new transmission lines (i.e., mechanical piping and electrical wiring) is as follows:

Piping (all steel)

- New steam line (insulated) — 6 inches ~2.25 miles
- Other (not insulated) — 6 inches and under ~1.5 miles
8 inches to 18 inches ~0.5 miles
20 inches and greater ~0.7 miles

Electrical Wiring

- #4/0 Al-Bare ~3 miles
- #12 Cu-"Kapton" Insulated ~75 miles
- #2 Cu-"THWN" Insulated ~7 miles

4.4.2 Construction Materials

Several major capital improvement items will be installed in L Area. These items include new process water heat exchangers, a new 500,000-gallon contaminated water storage tank, a new settler tank for the disassembly basin filtering system, a new water plant for domestic and clarified water, a new sanitary treatment facility, and seismic reinforcement. A summary of the construction materials required is as follows:

- Concrete

Actuator tower	~280 yd ³ yds.
Contaminated water storage tank	~210 yd ³ yds.
Exhaust stack	~60 yd ³ yds.
Water plant	~50 yd ³ yds.
Settler tank	~15 yd ³ yds.
Total	<u>~615 yd³ yds.</u>

- Earth Fill

Contaminated water storage tank	~2,100 yd ³ yds.
---------------------------------	-----------------------------

④ Stone

Contaminated water storage tank ~2,000 yd³ yds.

⑤ Steel (other than piping)

Process water heat exchangers (SS)	~1,140 tons
Contaminated water storage tank	~80 tons
Actuator tower rebars	~24 tons
Exhaust stack rebars	~6 tons
Settler tank	~6 tons
Total	<u>~1,256 tons</u>

4.4.3 Fuel Commitments

During construction, fuel requirements (primarily electrical demand) will vary depending upon testing requirements and work being performed. The electrical demand in L Area could range from 6 megawatt hours to 28 megawatt hours for short periods of time. Anticipated gasoline (gasohol) and diesel fuel oil demands for vehicles, and construction equipment during the peak construction period could be as high as 250,000 gallons per year gasoline (gasohol) and 100,000 gallons per year diesel fuel oil. The K- to L-Area steam line is scheduled to be completed during 1983. After completion, steam will be supplied by the coal-fired power plant in K Area.

4.5 RADIATION DOSE ASSESSMENT TO CONSTRUCTION/RENOVATION FORCE.

As low as reasonably achievable, (ALARA) principles will be vigorously applied to all radiation work. These principles include judicious use of lead shielding and decontamination of equipment, where practicable, before renovation. Monitoring for all radiation work will be performed by personnel from the Health Protection Department of SRP. The radiation dose commitment is estimated as shown in Table 4.5-1.

TABLE 4.5-1

Estimated Radiation Dose to L-Area Work Force

<u>Work Group</u>	<u>Total Dose in man-rems/year</u>			<u>Maximum Individual Dose in millirems/year</u>		
	<u>1981</u>	<u>1982</u>	<u>1983</u>	<u>1981</u>	<u>1982</u>	<u>1983</u>
Construction Workers	22	83.8	26.5	1000	2000	2000
SRP Workers	<u>8</u>	<u>31.2</u>	<u>12.2</u>	<u>1000</u>	<u>1500</u>	<u>1500</u>
Totals	30	115.0	38.7			

5. ENVIRONMENTAL EFFECTS OF FACILITY OPERATION

This chapter discusses the environmental effects from routine operation of L Area. These effects arise from releases of radioactive and nonradioactive effluents and consumption of resources.

5.1 RADIOLOGICAL IMPACTS

5.1.1 Radiological Impact From Routine Operations

5.1.1.1 Atmospheric Releases

This section presents an assessment of the potential doses to people living in the vicinity of SRP from routine atmospheric releases due to restartup of L Reactor. Average annual doses to maximum exposure individuals and the population within 50 miles are evaluated from the estimated average and maximum annual releases during an assumed 30-year operating period (CY 1985-2015).

The gaseous radwaste systems and the assumptions regarding operating performance and associated releases have been described in Section 3.3. Table 5.1-1 recapitulates the estimated average and maximum annual release rates of radionuclides to the atmosphere.

5.1.1.1.1 Exposure Pathways

Radioactive materials released to the atmosphere reach man through a variety of pathways, involving both internal and external exposure. The importance of these pathways depends upon the particular radionuclides released and the environmental factors which determine the extent of man's exposure. In this assessment, the following pathways were considered:

- Inhalation of airborne radionuclides
- Ingestion of contaminated foodstuff
- External exposure to radiation from radioactive noble gases
- External exposure to radiation from radionuclides deposited on the ground.

With respect to man's exposure due to L-Reactor restartup, the most important radionuclide is tritium (hydrogen-3), which will contribute about 80% of whole-body dose to the 50-mile population.

TABLE 5.1-1

Estimated Routine Operating Releases of Radionuclides to Atmosphere
from Restartup of L Reactor

	Annual Release Rates, Ci/yr*			
	L-Area		Separation Areas	D & M Areas
Radionuclides	Average	Maximum		
Gaseous:				
H-3	5.54x10 ⁴	6.95x10 ⁴	8.6x10 ⁴	7.9x10 ² (D)
C-14	1.2x10 ¹	1.3x10 ¹	8.0x10 ⁰	-
Ar-41	2.0x10 ⁴	3.2x10 ⁴	-	-
Kr-85m	6.0x10 ²	11.7x10 ³	-	-
Kr-85	-	-	2.0x10 ⁵	-
Kr-87	5.4x10 ²	1.7x10 ³	-	-
Kr-88	7.9x10 ²	2.4x10 ³	-	-
Xe-131m	-	-	1.9x10 ⁰	-
Xe-133	1.7x10 ³	3.9x10 ³	1.0x10 ⁻¹	-
Xe-135	1.4x10 ³	3.6x10 ³	-	-
I-129**	-	-	7.0x10 ⁻²	-
I-131**	8.73x10 ⁻⁴	8.2x10 ⁻³	1.7x10 ⁻²	-
Particulate:				
Sr-89,90***	-	-	1.5x10 ⁻³	-
Zr-95	-	-	6.0x10 ⁻³	-
Nb-95	-	-	1.2x10 ⁻²	-
Ru-103	-	-	1.2x10 ⁻³	-
Ru-106	-	-	2.8x10 ⁻²	-
Cs-134	-	-	1.1x10 ⁻⁴	-
Cs-137	-	-	1.2x10 ⁻³	-
Ce-141	-	-	8.0x10 ⁻⁵	-
Ce-144	-	-	8.0x10 ⁻³	-
Uranium†	-	-	1.7x10 ⁻³	8.6x10 ⁻⁷ (M)
Pu-238	-	-	1.9x10 ⁻³	-
Pu-239	-	-	2.7x10 ⁻⁴	-
Am-241,243††	-	-	3.9x10 ⁻⁴	-
Cm-242,244†††	-	-	3.5x10 ⁻⁴	-
Beta-Gamma¶	2.0x10 ⁻⁴	9.5x10 ⁻⁴	2.2x10 ⁻⁴	-
Alpha¶¶	1.0x10 ⁻⁶	2.6x10 ⁻⁶	-	2.0x10 ⁻⁶ (M)

* Combined 200-ft stack and ground-level releases from Tables 3.3-1, 3.3-4 and 3.3-6.

** Half gaseous and half particulate (Reg. Guide 1.109)¹

*** Assumed to be Sr-90.

† Assumed to be U-235.

†† Assumed to be Am-241.

††† Assumed to be Cm-244.

¶ Assumed to be Sr-90.

¶¶ Assumed to be Pu-239.

The two most important pathways are inhalation and ingestion; inhalation will account for about 46% of the whole-body dose to the population and ingestion, for about 38%.

5.1.1.1.2 Assessment Methodology

The average annual doses have been calculated from the estimated release rates (Table 5.1-1) and the site-specific data of Chapter 2, by using the methodology of USNRC Regulatory Guides 1.111 (meteorological models) and 1.109 (dose models).^{1,2} These methods, together with the associated computer codes, are described in more detail in Appendices B and C, respectively.

Appendix B also presents the annual-average atmospheric relative dispersion (χ/Q) and deposition (D/Q) factors for various distances out to 50 miles in each of 16 compass sectors, which were used in the dose computations. These factors have been determined under the conservative (i.e., overestimative) assumption of ground-level releases on flat terrain. Appendix C also indicates the dose conversion factors used in the computations; age-specific, 50-year dose commitment factors have been utilized for internal exposure (inhalation and ingestion).

Table 5.1-2 lists the human parameters used in calculating the doses to the maximally exposed individuals. Table 5.1-3 shows the average individual parameters and demographic data for calculating the doses to the 50-mile population. Footnotes in the tables specify the associated agricultural production data.

5.1.1.1.3 Average Annual Doses to Maximally Exposed Individuals

These individuals (infant, child, teen, and adult) are presumably members of a nearby farm family producing their own foodstuff and consuming more food than counterparts in the general population (Table 5.1-2 vs. Table 5.1-3). The doses to these hypothetical residents are based upon highest whole-body exposure to the air-released radionuclides on the SRP buffer-zone boundary, the nearest approach of the residential population (Appendix C).

Tables 5.1-4 and 5.1-5 show the estimated average-annual doses to these individuals by pathway and body organ for the cases of average and maximum annual release, respectively. As emphasized by underlining in these tables, the child tends to receive the highest organ doses. For this individual, Tables 5.1-6 and 5.1-7 show the percentage contributions to the organ doses by radionuclide for the two cases.

TABLE 5.1-2

Human Parameters Used in Calculating Doses to Maximally Exposed Individuals*

<u>Parameter</u>	<u>Infant</u>	<u>Child</u>	<u>Teen</u>	<u>Adult</u>
Inhalation, m ³ /yr	1,400	3,700	8,000	8,000
Ingestion**				
Cow's milk, L/yr	330	330	400	310
Meat, kg/yr	0	41	65	110
Leafy vegetables, kg/yr†	0	26	42	64
Fruits, vegetables, and grains, kg/yr††	0	520	630	520
External Exposure				
Transmission factor for shielding from buildings	0.7	0.7	0.7	0.7

* Data are recommended values from USNRC Regulatory Guide 1.109.¹

** Foodstuff produced at the reference family's location, except as noted, where exposure to the air-released radionuclides is at a maximum. Crop yield and animal feeding parameters have been presented in Reference 3.

† Seventy-five percent from reference family's garden (March-November growing season); remainder imported (uncontaminated).

†† Seventy-six percent from reference family's crops (Reg. Guide 1.109 recommended value)¹; remainder imported (uncontaminated).

TABLE 5.1-3

Human Parameters and Demographic Data Used in Calculating Doses to the 50-Mile Population

<u>Average Individual Parameters*</u>	<u>Children</u>	<u>Teen</u>	<u>Adults</u>
Inhalation, m ³ /yr	3,700	8,000	8,000
Ingestion**			
Milk, L/yr	170	200	110
Meat, kg/yr	37	59	95
Fruits, vegetables, grain kg/hr	200	240	190
External Exposure			
Transmission factor accounting for shielding by residential structures	0.5	0.5	0.5
Demographic Data, CY-2000†			
50-mile Residential Population	(679,000)		
Age-group distribution, % ††	20.8	11.8	67.4
Geographical distribution	Table 2.2-2		

* Data are recommended values from USNRC Regulatory Guide 1.109.¹

** Foodstuff obtained at large from the 50-mile agricultural production of man's foods; any insufficiency is assumed to be imported (uncontaminated). Crop yield and animal feeding data for the 50-mile vicinity are presented in Reference 3.

† 1970-Census data projected to the assumed midpoint of operations (Section 2.2.1, Table 2.2-5.)

†† From Table 2.2-8

TABLE 5.1-4

**Average Annual Doses to Maximally Exposed Individuals by Pathway from L-Reactor
Restartup — Average Annual Routine Atmospheric Releases of Radioactivity***

<u>Pathways/Individual</u>	<u>Organ Doses</u>							
	<u>Whole Body</u>	<u>GI-Tract</u>	<u>Bone</u>	<u>Liver</u>	<u>Kidney</u>	<u>Thyroid</u>	<u>Lung</u>	<u>Skin</u>
Total, mrem/yr								
Adult	0.37	0.38	0.14	0.37	0.37	1.3	0.37	0.62
Teen	0.40	0.41	0.16	0.40	0.40	1.1	0.40	0.65
Child	0.51	0.52	0.22	0.51	0.51	1.2	0.51	0.76
Infant	0.28	0.28	0.15	0.28	0.28	0.53	0.28	0.53
Inhalation, %								
Adult	27.6	26.4	18.4	28.5	28.2	8.2	27.7	16.3
Teen	25.8	25.1	17.1	26.6	26.4	9.5	26.4	15.8
Child	17.7	17.5	9.6	18.3	18.1	7.8	18.2	11.9
Infant	18.8	18.8	5.8	19.3	19.1	9.9	19.3	9.8
Ingestion, %								
Adult	51.3	52.7	25.7	50.2	50.6	85.5	50.2	30.2
Teen	54.5	55.7	33.8	53.5	54.0	82.9	53.2	33.1
Child	66.8	67.2	55.4	66.3	66.5	85.1	65.9	44.5
Infant	52.5	52.4	41.1	52.3	52.3	75.4	51.4	27.3
External-Noble Gases, %								
Adult	21.3	20.6	55.9	21.2	21.2	6.3	22.0	53.6
Teen	19.7	19.4	49.2	19.6	19.7	7.3	20.3	51.2
Child	15.4	15.3	35.0	15.4	15.4	6.8	15.9	43.6
Infant	28.6	28.7	53.2	28.4	28.4	14.8	29.2	62.8
External-Ground, %								
Adult	0.06	0.06	0.16	0.06	0.06	0.02	0.06	0.05
Teen	0.06	0.06	0.14	0.06	0.06	0.02	0.06	0.05
Child	0.04	0.04	0.10	0.04	0.04	0.02	0.04	0.04
Infant	0.08	0.08	0.15	0.08	0.08	0.04	0.08	0.06

* At the location of maximum whole-body doses on the SRP buffer-zone boundary (7.8 miles W of L-Area) from the average-annual L-Area releases and the other annual releases (Table 5.1-1).

TABLE 5.1-5

Average Annual Doses to Maximally Exposed Individuals by Pathway from L-Reactor
Restartup — Maximum Annual Routine Atmospheric Releases of Radioactivity*

Pathways/Individual	Organ Doses							
	Whole Body	GI-Tract	Bone	Liver	Kidney	Thyroid	Lung	Skin
Total, mrem/yr								
Adult	0.47	0.47	0.22	0.47	0.47	0.99	0.47	0.69
Teen	0.50	0.50	0.24	0.50	0.50	0.90	0.50	0.72
Child	0.61	0.61	0.31	0.61	0.61	0.99	0.61	0.83
Infant	0.37	0.37	0.23	0.37	0.37	0.53	0.37	0.60
Inhalation, %								
Adult	22.3	21.8	6.3	22.7	22.5	10.6	22.5	14.9
Teen	21.0	20.8	6.2	21.6	21.4	11.7	21.4	14.5
Child	15.1	15.0	3.8	15.5	15.3	9.3	15.4	11.0
Infant	14.4	14.3	2.0	14.5	14.4	10.1	14.5	8.9
Ingestion, %								
Adult	41.4	42.4	16.9	41.0	41.0	72.2	40.7	27.5
Teen	44.7	45.3	23.1	44.3	44.4	69.4	44.0	30.4
Child	57.3	57.2	41.2	56.8	56.8	73.6	56.5	41.4
Infant	39.8	39.8	25.5	39.7	39.7	57.8	39.5	24.7
External-Noble Gases, %								
Adult	36.3	35.8	76.5	36.3	36.3	17.1	36.7	57.5
Teen	34.1	33.9	70.7	34.1	34.1	18.9	34.5	55.1
Child	27.6	27.7	54.9	27.8	27.8	17.0	28.0	47.5
Infant	45.8	45.8	72.5	45.7	45.7	32.0	46.0	66.4
External-Ground, %								
Adult	0.03	0.03	0.06	0.03	0.03	0.01	0.03	0.03
Teen	0.03	0.03	0.06	0.03	0.03	0.02	0.03	0.03
Child	0.02	0.02	0.04	0.02	0.02	0.01	0.02	0.02
Infant	0.04	0.04	0.06	0.04	0.04	0.03	0.04	0.03

* At the location of maximum whole-body doses on the SRP buffer-zone boundary (7.1 miles ESE of L-Area) from the maximum-annual L-Area releases and the other annual releases (Table 5.1-1).

TABLE 5.1-6

Percentage of Average Annual Doses to Maximally Exposed Child by Radionuclide —
Average Annual Routine Atmospheric Releases from L Reactor Restartup

Nuclide	Organ Doses, %							
	Whole Body	GI-Tract	Bone	Liver	Kidney	Thyroid	Lung	Skin
Ar-41	13.3	13.2	30.3	13.3	13.3	5.9	13.3	14.4
Kr-85	0.3	0.3	0.8	0.3	0.3	0.2	0.9	26.8
Kr-88	1.1	1.1	2.5	1.1	1.1	0.5	1.1	1.0
H-3	79.4	79.0	—*	79.4	79.4	35.1	79.3	53.7
C-14	4.1	4.0	46.2	4.1	4.1	1.8	4.0	2.7
Sr-90	0.7	0.05	5.8	-	-	-	<0.01	-
Ru-106	0.02	1.4	0.2	<0.01	0.1	<0.01	0.05	<0.01
I-129	0.2	0.03	0.8	0.2	0.4	55.6	0.02	0.02
U-235	0.05	0.02	1.5	<0.01	0.1	<0.01	0.1	<0.01
Pu-238	0.1	0.01	7.9	0.4	0.3	<0.01	0.4	<0.01
Pu-239	0.01	<0.01	1.2	0.06	0.05	<0.01	0.06	<0.01
Others**	0.7	0.8	2.8	1.1	0.9	1.0	0.7	1.3

* Dashes signify no-dose conversion factors.

** Each contributing less than 1%.

TABLE 5.1-7

Percentage of Average Annual Doses to the Maximally Exposed Child by Radionuclide — Maximum Annual Routine Atmospheric Releases from L Reactor Restartup*

Nuclide	Organ Doses, %							
	Whole Body	GI-Tract	Bone	Liver	Kidney	Thyroid	Lung	Skin
Ar-41	22.4	22.5	44.6	22.5	22.5	13.8	22.5	26.4
Kr-85	0.2	0.2	0.3	0.2	0.2	0.1	0.4	13.9
Kr-87	0.6	0.6	1.3	0.6	0.6	0.4	0.7	1.7
Kr-88	3.3	3.3	6.6	3.3	3.3	2.0	3.3	3.4
Xe-135	0.8	0.8	1.5	0.8	0.8	0.5	0.8	1.5
H-3	67.9	68.1	—**	68.3	68.3	41.9	68.2	50.0
C-14	3.3	3.3	33.0	3.3	3.3	2.0	3.3	2.4
Sr-90	0.9	0.1	6.8	—	—	—	<0.01	—
I-129	0.1	0.02	0.3	0.1	0.2	38.0	0.01	0.01
I-131	<0.01	<0.01	<0.01	<0.01	<0.01	1.0	<0.01	<0.01
Pu-238	0.04	<0.01	3.1	0.2	0.2	<0.01	0.2	<0.01
Others*	0.4	1.1	2.5	0.6	0.6	0.2	0.5	0.8

* Each contributing less than 1%.

** Dashes signify no-dose conversion factors.

The whole-body doses are predominately the most significant measure of radiological impact (Section 5.1.3). As indicated by the tables, the maximum whole-body dose is 0.61 millirem per year to the child with about 57% due to ingestion and 28% to external radiation from noble gases (Table 5.1-5). Tritium contributes about 68% of this dose and argon-41, about 22% (Table 5.1-7).

5.1.1.1.4 Average Annual Doses to the 50-Mile Population

The radiation doses to the 50-mile population are based on the average air and ground concentrations of the released radionuclides (Table 5.1-1) in the subdivisions of the 50-mile vicinity (compass-sector segments defined in Section 2.2.1), and the distribution of the population and the food production by the same compass-sector segments (Table 5.1-3). Using the methodology described in Section 5.1.1.1.2, the population dose commitments were calculated for the several body organs.

Tables 5.1-8 and 5.1-9 show these average-annual organ dose estimates by pathway for the cases of average and maximum annual releases, respectively (Table 5.1-1). Tables 5.1-10 and 5.1-11 present the percentage contributions to the organ doses by radionuclide for the two cases.

As indicated by these tables, the maximum whole-body dose commitment is 30.9 man-rem per year of operation, which is for the case of maximum annual releases. Inhalation, ingestion, and external exposure to noble gases account for 44.6%, 36.8% and 18.6% of this dose, respectively. Radionuclides contributing more than 10% of the maximum whole-body dose are tritium (78.4%) and argon-41 (13.3%).

5.1.1.2 Liquid Releases

5.1.1.2.1 Source of Radioactive Liquid Effluents

During routine operations, radioactive materials will be discharged in liquid effluents from L Area to Steel Creek. In addition, some radioactive materials will be discharged to a low-level seepage basin in L Area. Those radioactive materials discharged to the seepage basin will move downward to the ground water and will then be transported laterally to outcrop areas along Steel Creek. These materials will diminish in radioactivity by radioactive decay which occurs during the transit time from the basin to the creek. The release of radioactive materials to liquid effluents and to seepage basins will increase in other SRP areas whose operations will be associated with the restartup of the L-Area reactor. These associated areas include:

TABLE 5.1-8

Average Annual Doses to the 50-Mile Population by Pathway —
Average Annual Routine Atmospheric Releases of Radioactivity

Pathway	Organ Doses, man-rem							
	Whole Body	GI-Tract	Bone	Liver	Kidney	Thyroid	Lung	Skin
Inhalation	11.3 (47.1%)	11.2 (45.0%)	3.85 (36.7%)	12.0 (48.7%)	11.8 (48.2%)	11.5 (17.8%)	11.6 (47.1%)	11.2 (17.5%)
Ingestion	9.4 (39.1%)	10.4 (41.7%)	3.32 (31.7%)	9.3 (37.8%)	9.4 (38.3%)	50.1 (77.2%)	9.2 (37.4%)	9.2 (14.4%)
External-Noble Gases	3.3 (13.7%)	3.3 (13.2%)	3.29 (31.4%)	3.3 (13.4%)	3.3 (13.4%)	3.3 (5.1%)	3.8 (15.4%)	43.5 (68.0%)
External-Ground	0.02 (0.1%)	0.02 (0.1%)	0.02 (0.2%)	0.02 (0.1%)	0.02 (0.01%)	0.02 (0.03%)	0.02 (0.1%)	0.03 (0.05%)
Total	24.0	24.9	10.5	24.6	24.4	64.9	24.7	64.0

Note: Number in parentheses = percentage by pathway.

TABLE 5.1-9

Average Annual Doses to the 50-Mile Population by Pathway —
Maximum Annual Atmospheric Releases from L Reactor Restartup

Pathway	Organ Doses, man-rem							
	Whole Body	GI-Tract	Bone	Liver	Kidney	Thyroid	Lung	Skin
Inhalation	13.8 (44.6%)	13.7 (43.1%)	3.86 (29.2%)	14.4 (45.9%)	14.2 (45.5%)	14.0 (19.4%)	14.1 (44.6%)	13.7 (18.7%)
Ingestion	11.4 (36.8%)	12.3 (38.8%)	3.59 (27.2%)	11.2 (35.7%)	11.3 (36.1%)	52.1 (72.5%)	11.2 (35.4%)	11.2 (15.3%)
External-Noble Gases	5.7 (18.6%)	5.7 (18.1%)	5.74 (43.5%)	5.7 (18.3%)	5.7 (18.4%)	5.7 (8.0%)	6.3 (19.9%)	48.3 (66.0%)
External-Ground	0.02 (0.1%)	0.02 (0.1%)	0.02 (0.2%)	0.02 (0.1%)	0.02 (0.01%)	0.02 (0.03%)	0.02 (0.1%)	0.03 (0.04%)
Total	30.9	31.7	13.2	31.4	31.3	71.9	31.6	73.1

Note: Number in parentheses = percentage by pathway.

TABLE 5.1-10

Percentage of Average Annual Doses to the 50-Mile Population by Radionuclide —
Average Annual Routine Atmospheric Releases from L Reactor Restartup

Nuclide	Organ Doses, %							
	Whole Body	GI-Tract	Bone	Liver	Kidney	Thyroid	Lung	Skin
Ar-41	10.7	10.3	24.6	10.5	10.5	4.0	10.4	7.1
Kr-85	0.9	0.9	2.2	0.9	0.9	0.4	3.0	59.1
Kr-88	1.2	1.1	2.7	1.1	1.1	0.4	1.1	0.6
Xe-135	0.5	0.5	1.2	0.5	0.5	0.2	0.5	0.6
H-3	82.8	79.9	—*	81.0	81.4	30.7	80.5	31.1
C-14	2.3	2.2	26.4	2.2	2.3	0.8	2.2	0.9
Sr-90	0.4	0.1	3.4	—	—	—	<0.01	—
Ru-106	0.02	4.2	0.2	0.01	0.2	<0.01	0.1	<0.01
I-129	0.3	0.05	0.4	0.2	0.2	62.5	0.04	0.03
Pu-238	0.3	0.02	28.9	1.5	1.4	<0.01	1.1	<0.01
Pu-239	0.05	<0.01	4.8	0.2	0.2	<0.01	0.1	<0.01
Am-241	0.07	<0.01	2.2	0.9	0.5	<0.01	0.07	<0.01
Cm-244	0.04	<0.01	1.3	0.5	0.2	<0.01	0.1	<0.01
Others**	0.4	0.7	1.8	0.4	0.5	1.1	0.7	0.5

* Dashes signify no-dose conversion factors.

** Each contributing less than 1%.

TABLE 5.1-11

Percentage of Average Annual Doses to the 50-Mile Population by Radionuclide —
Maximum Annual Routine Atmospheric Releases from L Reactor Restartup

Nuclide	Organ Doses, %							
	Whole Body	GI-Tract	Bone	Liver	Kidney	Thyroid	Lung	Skin
Ar-41	13.3	13.0	31.2	13.1	13.2	5.7	13.1	10.0
Kr-85	0.7	0.7	1.7	0.7	0.7	0.3	2.4	51.7
Kr-88	2.8	2.7	6.4	2.7	2.7	1.2	2.7	1.7
Xe-135	1.0	1.0	2.4	1.0	1.0	0.4	1.0	1.4
H-3	78.4	76.4	—*	77.2	77.6	33.7	76.8	33.1
C-14	1.9	1.8	22.0	1.8	1.9	0.8	1.8	0.8
Sr-90	0.4	0.1	3.7	—	—	—	<0.01	—
Ru-106	0.02	3.3	0.2	<0.01	0.1	<0.01	0.1	<0.01
I-129	0.2	0.04	0.4	0.1	0.2	56.5	0.03	0.02
I-131	<0.01	<0.01	0.01	<0.01	0.01	1.0	<0.01	<0.01
Pu-238	0.3	0.01	22.9	1.2	1.1	<0.01	0.8	<0.01
Pu-239	0.04	<0.01	3.8	0.2	0.2	<0.01	0.1	<0.01
Am-241	0.06	<0.01	1.8	0.7	0.4	<0.01	0.06	<0.01
Cm-244	0.03	<0.01	1.0	0.4	0.1	<0.01	0.05	<0.01
Others**	0.8	1.0	2.5	0.8	0.8	0.3	1.0	1.2

* Dashes signify no-dose conversion factors.

** Each contributing less than 1%.

- Separations Areas (200 Areas) - release to Four Mile Creek and to seepage basins
- Fuel Fabrication Area (300 Area) - release to a seepage basin
- Heavy Water Area (400 Area) - release to Beaver Dam Creek
- Central Shops - release from a heat exchanger repair facility to a seepage basin.

The sources and amounts of these radioactive materials are described in detail in Chapter 3. Estimated annual releases from L Reactor and other associated plant operations to surface streams are tritium — 4.2×10^3 to 5.9×10^3 curies, fission products — 2.4×10^{-1} to 1.1×10^0 curies, uranium — 5.0×10^{-2} curies, and other alpha emitters — 2.9×10^{-3} to 3.0×10^{-3} curies. Estimated total annual releases to all seepage basins are tritium — 1.7×10^4 curies, fission products — 1.9×10^1 curies, uranium — 1.1×10^{-1} curies, and transuranics — 5.6×10^{-2} curies.

5.1.1.2.2 Discharge to Surface Streams

All radioactive materials discharged to surface streams on the SRP site from all operations flow across the site and discharge into the Savannah River. The liquid effluents from L Reactor Area will be discharged to Steel Creek. Steel Creek is entirely on the SRP site, and there is no consumptive use of creek water; fishing is not allowed.

Four Mile Creek and Beaver Dam Creek together receive discharges from the F and H Chemical Separations Areas, the C-Reactor Area, and the D Heavy Water Area. Four Mile Creek is entirely on the plantsite, and there is no consumptive use of creek water; fishing is not allowed.

The Savannah River borders the south boundary of the SRP site for a distance of about 17 miles. The river flows in a southeasterly direction about 120 miles before entering the area of tidal influence, about 20 miles from the Savannah Harbor entrance. The average annual flow rate of the river near the SRP site is about 10,200 cfs, and flow does not increase more than 10% before entering the Savannah Harbor. The flow time to the vicinity of the coastal city, Savannah, Georgia, is approximately three days.

There is no known consumptive use of Savannah River water for a distance of 100 miles downstream from the SRP site. At about this distance, Jasper and Beaufort Counties, South Carolina, withdraw about 5.2 mgd for public use. Downstream from the Beaufort-Jasper withdrawal point, the Cherokee Hill Water Treatment Plant at Port

Wentworth, Georgia, uses about 45 mgd to supply a business-industrial complex near Savannah, Georgia (Section 2.2.3).

There is no known use of river water for crop irrigation downstream from SRP. The river supports limited commercial and recreational fishing downstream, as well as a commercial mollusc and shrimp industry in estuarine waters. River use for commercial traffic has declined, and use for recreational boating, water skiing, and swimming is small (Section 2.2.3).

5.1.1.2.3 Exposure Pathways and Models

Radioactive materials released in liquid effluents expose man through a variety of pathways. The importance of these pathways depends on the radionuclides released. In this report, the following pathways are considered:

- Consumption of water
- Consumption of aquatic foods
- Shoreline exposure
- Swimming
- Boating

Irrigation of food crops with river water was not considered as a pathway of exposure because there is no known use of river water for irrigation purposes.

The method of calculating doses to man from liquid effluent pathways are those recommended by the U.S. Nuclear Regulatory Commission (NRC) in Regulatory Guide 1.109.¹ The NRC LADTAP II computer code⁴ was used to implement the dose models specified in the regulatory guide. Fifty-year, age-specific, dose commitment factors specified in NUREG-0172 were incorporated in the computer code.⁵ Human and site parameters used in the code are listed in Tables 5.1-12 and 5.1-13.

5.1.1.2.4 Individuals and Population Groups Exposed

The individual who will receive the maximum potential dose from liquid releases is a person who lives near the Savannah River, just downstream of where liquid releases enter into the river. It is assumed that this individual uses river water regularly for consumption, consumes river fish, and receives external exposure from the shoreline, swimming, and boating.

TABLE 5.1-12

Human Parameters Used in Dose Calculations

Average Individual	<u>Child</u>	<u>Teen</u>	<u>Adult</u>
Water consumption, L/yr	260	260	370
Fish consumption, kg/yr	2.2	5.2	6.9
Other seafood consumption, kg/yr	0.33	0.75	1.0
Shoreline recreation, hr/yr	9.5	47	83
Boating, man-hours*	-	-	700,000
Swimming, man-hours*	-	-	100,000
Shoreline recreation, man-hours*	-	-	200,000
Maximum Individual			
Water consumption, L/y**	510	510	730
Fish consumption, kg/yr	6.9	16	21
Other seafood consumption, kg/yr	1.7	3.8	5
Shoreline recreation, hr/yr	14	67	20
Swimming, hr/yr	10	10	10
Boating, hr/yr	60	60	60

* For population dose calculations.

** Drinking water consumption for an infant = 330 L/yr.

TABLE 5.1-13

Site Parameters Used in Dose Calculations

River flow rate, average cfs				10,000
River dilution in estuary				3
Transit time, L-Area to river, hr				24
Transit time, SRP to water treatment plants, hr				72
Water treatment time, hr				24
Aquatic food harvest, kg/yr				
Fish — sport				90,700
Fish — commercial				31,800
Invertebrates - salt water				299,000
Irrigation				None
Shore width factor				0.2
Population average (1990-2020)				
Beaufort-Jasper water consumers				40,300
Port Wentworth water consumers				29,200
50-mile radius population				781,000
Age distribution of population, %	Child	Teen	Adult	
Beaufort-Jasper	21	10	69	
Port Wentworth	-	-	100	
50-mile radius population	21	11	68	

The 50-mile radius population receives no river water downstream of SRP for domestic purposes. However, this population is assumed to use the river for recreational purposes and consumes fish and invertebrates from the river and estuary.

There is no known use of Savannah River water for human consumption for a distance of about 100 miles downstream from SRP. At this distance, Beaufort and Jasper Counties, South Carolina, pump water from the river for treatment and service to an estimated 1979 consumer population of about 35,000 people. Several miles farther downstream, the Cherokee Hill Water Treatment Plant withdraws water from the river to supply a business-industrial complex near Savannah, Georgia. This water does not enter normal domestic service, but an estimated 20,000 "effective" consumers used this water during the 1970's.

Although the Beaufort-Jasper and Port Wentworth population groups are beyond the 50-mile radius, drinking water doses are nevertheless computed for these groups and are included in this report.

5.1.1.2.5 Dose to the Maximally Exposed Individual from Surface Stream Releases

The total body and organ doses from all identified pathways of exposure from release of radioactivity to surface streams were calculated for four age groups (adults, teenager, child, and infant). Doses by pathway of exposure for these age groups from the total SRP annual average liquid releases associated with operation of L Reactor are shown in Table 5.1-14. These are 50-year dose commitments for one year of exposure, assuming all of the radionuclides are soluble in water. As seen in this table, most of the dose is from the drinking water and fish consumption pathways. Of the four age groups, a child receives the maximum dose, 9.5×10^{-2} mrem for total body and 1.83×10^{-1} mrem for bone. The radionuclides contributing most of these doses are H-3 (tritium) and Sr-90. During a year of expected maximum releases of radioactive materials to surface streams from L Reactor and other associated plant operations, doses to individuals will increase only slightly (Table 5.1-15).

5.1.1.2.6 Population Dose from Surface Stream Releases

The population dose commitment from one year of exposure is shown in Table 5.1-16 for an average year of releases and for a maximum year of releases. For an average year, the dose from releases from L Reactor and other associated plant operations will be 2 man-rem, body and 2.7 man-rem, bone. Doses for a maximum year are only slightly higher (Table 5.1-16).

TABLE 5.1-14

Dose to the Maximally Exposed Individual - Average Release Rates Associated with L Reactor Operation

Pathway	Dose, mrem per year intake,							
	Skin	Bone	Liver	Total Body	Thyroid	Kidney	Lung	GI-LLI*
Adult Doses								
Fish	-	5.60×10^{-2}	1.07×10^{-2}	2.04×10^{-2}	9.32×10^{-4}	4.28×10^{-3}	2.03×10^{-3}	4.13×10^{-3}
Drinking	-	5.99×10^{-2}	3.62×10^{-2}	5.15×10^{-2}	3.60×10^{-2}	3.68×10^{-2}	3.60×10^{-2}	3.96×10^{-2}
Shoreline	7.98×10^{-5}	6.78×10^{-5}	6.78×10^{-5}	6.78×10^{-5}	6.78×10^{-5}	6.78×10^{-5}	6.78×10^{-5}	6.78×10^{-5}
Swimming	0.0	2.54×10^{-7}	2.54×10^{-7}	2.54×10^{-7}	2.54×10^{-7}	2.54×10^{-7}	2.54×10^{-7}	2.54×10^{-7}
Boating	0.0	7.63×10^{-7}	7.63×10^{-7}	7.63×10^{-7}	7.63×10^{-7}	7.63×10^{-7}	7.63×10^{-7}	7.63×10^{-7}
Total	7.98×10^{-5}	1.16×10^{-1}	4.70×10^{-2}	7.20×10^{-2}	3.70×10^{-2}	4.12×10^{-2}	3.81×10^{-2}	4.38×10^{-2}
Teenager Doses								
Fish	-	5.11×10^{-2}	1.09×10^{-2}	1.59×10^{-2}	7.17×10^{-4}	4.21×10^{-3}	2.06×10^{-3}	3.27×10^{-3}
Drinking	-	4.94×10^{-2}	2.56×10^{-2}	3.80×10^{-2}	2.54×10^{-2}	2.62×10^{-2}	2.54×10^{-2}	2.81×10^{-2}
Shoreline	2.67×10^{-4}	2.27×10^{-4}	2.27×10^{-4}	2.27×10^{-4}	2.27×10^{-4}	2.27×10^{-4}	2.27×10^{-4}	2.27×10^{-4}
Swimming	0.0	2.54×10^{-7}	2.54×10^{-7}	2.54×10^{-7}	2.54×10^{-7}	2.54×10^{-7}	2.54×10^{-7}	2.54×10^{-7}
Boating	0.0	7.63×10^{-7}	7.63×10^{-7}	7.63×10^{-7}	7.63×10^{-7}	7.63×10^{-7}	7.63×10^{-7}	7.63×10^{-7}
Total	2.67×10^{-4}	1.01×10^{-1}	3.67×10^{-2}	5.41×10^{-2}	2.63×10^{-2}	3.06×10^{-2}	2.77×10^{-2}	3.16×10^{-2}
Child Doses								
Fish	-	5.70×10^{-2}	9.78×10^{-3}	1.46×10^{-2}	5.92×10^{-4}	3.63×10^{-3}	1.67×10^{-3}	1.66×10^{-3}
Drinking	-	1.26×10^{-1}	4.90×10^{-2}	8.04×10^{-2}	4.86×10^{-2}	5.03×10^{-2}	4.87×10^{-2}	5.12×10^{-2}
Shoreline	5.59×10^{-5}	4.75×10^{-5}	4.75×10^{-5}	4.75×10^{-5}	4.75×10^{-5}	4.75×10^{-5}	4.75×10^{-5}	4.75×10^{-5}
Swimming	0.0	2.54×10^{-7}	2.54×10^{-7}	2.54×10^{-7}	2.54×10^{-7}	2.54×10^{-7}	2.54×10^{-7}	2.54×10^{-7}
Boating	0.0	7.63×10^{-7}	7.63×10^{-7}	7.63×10^{-7}	7.63×10^{-7}	7.63×10^{-7}	7.63×10^{-7}	7.63×10^{-7}
Total	5.59×10^{-5}	1.83×10^{-1}	5.89×10^{-2}	9.51×10^{-2}	4.93×10^{-2}	5.39×10^{-2}	5.04×10^{-2}	5.30×10^{-2}
Infant Doses								
Fish	-	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Drinking	-	9.18×10^{-2}	4.82×10^{-2}	7.08×10^{-2}	4.78×10^{-2}	4.96×10^{-2}	4.78×10^{-2}	4.94×10^{-2}
Shoreline	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	0.0	9.18×10^{-2}	4.82×10^{-2}	7.08×10^{-2}	4.78×10^{-2}	4.96×10^{-2}	4.78×10^{-2}	4.94×10^{-2}

* Gastrointestinal - large lower intestine.

TABLE 5.1-15

Dose to the Maximally Exposed Individual — Maximum Release Rates
Associated with L Reactor Operation

	Dose, mrem per year intake							
	Skin	Bone	Liver	Total Body	Thyroid	Kidney	Lung	GI-LLI*
Adult	6.11×10^{-4}	2.14×10^{-1}	7.28×10^{-2}	7.63×10^{-2}	5.24×10^{-2}	5.66×10^{-2}	5.35×10^{-2}	7.70×10^{-2}
Teenager	2.05×10^{-3}	2.25×10^{-1}	6.00×10^{-2}	5.83×10^{-2}	3.84×10^{-2}	4.27×10^{-2}	3.98×10^{-2}	5.78×10^{-2}
Child	4.28×10^{-4}	3.09×10^{-1}	9.01×10^{-2}	9.65×10^{-2}	6.95×10^{-2}	7.42×10^{-2}	7.07×10^{-2}	7.85×10^{-2}
Infant	—	3.81×10^{-2}	6.77×10^{-2}	7.60×10^{-2}	6.71×10^{-2}	6.89×10^{-2}	6.71×10^{-2}	6.81×10^{-2}

* Gastrointestinal - lower large intestine.

TABLE 5.1-16

Population Dose Associated with L Reactor Operation

Population Group	Pathway	Population Dose, man-rem per year of intake							
		Skin	Bone	Liver	Total Body	Thyroid	Kidney	Lung	GI-LLI*
Average Year									
Beaufort-Jasper	Drinking water	-	1.49×10^0	7.75×10^{-1}	1.15×10^0	7.70×10^{-1}	7.90×10^{-1}	7.71×10^{-1}	8.38×10^{-1}
Port Wentworth	Drinking water	-	8.85×10^{-1}	5.35×10^{-1}	9.89×10^{-2}	5.32×10^{-1}	5.44×10^{-1}	5.33×10^{-1}	5.86×10^{-1}
50-mile radius	Fish and invertebrates	-	2.94×10^{-1}	5.55×10^{-2}	9.89×10^{-2}	4.43×10^{-3}	2.19×10^{-2}	1.03×10^{-2}	1.86×10^{-2}
50-mile radius	Recreation and river traffic	7.98×10^{-4}	-	-	6.78×10^{-4}	-	-	-	-
	Total	7.98×10^{-4}	2.67×10^0	1.37×10^0	2.01×10^{-0}	1.31×10^0	1.36×10^0	1.31×10^0	1.44×10^0
Maximum Year									
Beaufort-Jasper	Drinking water	-	5.88×10^{-1}	1.09×10^{-1}	1.22×10^0	1.08×10^0	1.10×10^0	1.08×10^0	1.13×10^0
Port Wentworth	Drinking water	-	3.44×10^{-1}	7.52×10^{-1}	8.33×10^{-1}	7.48×10^{-1}	7.59×10^{-1}	7.48×10^{-1}	7.88×10^{-1}
50-mile radius	Fish and invertebrates	-	7.80×10^{-1}	9.51×10^{-2}	8.47×10^{-2}	6.22×10^{-3}	2.36×10^{-2}	1.21×10^{-2}	7.61×10^{-2}
50-mile radius	Recreation and river traffic	6.11×10^{-1}	-	-	6.11×10^{-3}	-	-	-	-
	Total	6.11×10^{-3}	1.71×10^0	1.94×10^0	2.14×10^0	1.84×10^0	1.88×10^0	1.84×10^0	1.99×10^0

* Gastrointestinal - lower large intestine.

5.1.1.2.7 Delayed Dose to the Maximally Exposed Individual from Seepage Basin Releases

As discussed in Chapter 3, low levels of radioactive materials will be discharged to a seepage basin in L Area and to basins in areas with associated operations, i.e., Separations Areas, Fuel Fabrication Area, and Central Shops. Materials discharged to the basins will move downward to the water table under the influence of the hydrostatic head in the basins. Once in the ground water, those radionuclides having no potential for retardation by ion exchange (i.e., $K_d = 0$) will move at the same velocity as ground water. Table 5.1-17 shows data used to calculate travel time of ground water to a surface outcrop area for each of the seepage basin systems considered in this report.

Approximately 30% of the tritium (as tritium oxide) discharged to seepage basins will evaporate to the atmosphere in the year of discharge and will contribute to atmospheric doses. All other radionuclides will travel with the water in the ground at a velocity that is characteristic of the K_d of each nuclei. The K_d 's for radionuclides considered in this report are shown in Table 5.1-18. Travel times to outcrops were calculated for each radionuclide and for each seepage basin system discussed in Chapter 3. After correction for radioactive decay, delayed doses were calculated for the maximum offsite individual. Because of the differing travel times of different radionuclides, the delayed doses will occur from a few years to thousands of years after discharge to the basins. Doses to the offsite individual receiving the maximum dose are shown in Table 5.1-19 along with the source (seepage basin system) and year of exposure (number of years after discharge to basins). Only the age group receiving the highest dose is shown. All doses to the individual receiving the highest offsite dose are less than one mrem, the highest dose being 0.1 mrem total body from L-Area seepage basin 4.4 years after discharge to the basin.

5.1.1.2.8 Delayed Population Dose from Seepage Basin Releases

Offsite delayed population doses from releases of radioactive materials to seepage basins are shown in Table 5.1-20. The highest total body dose of 2.7 man-rem occurs at 4.4 years as a result of discharges to the L Reactor seepage basin.

5.1.1.3 Radiological Impact from Cesium-137 Remobilization

5.1.1.3.1 Transportation of Cesium-137 from the Steel Creek Area

Cesium-137 transport estimates were made from Steel Creek for the first two years following startup of L Reactor. These

TABLE 5.1-17

Groundwater Migration Data for Seepage Basins

	Area				
	<u>100-L</u>	<u>Central Shops</u>	<u>300-M</u>	<u>200-F</u>	<u>200-H</u>
Ground water velocity, ft/day	1.0	1.0	1.0	0.5	1.0
Distance to outcrop, ft	1600	1200	4000	1600	1400
Flow time of ground water to outcrop, yr	4.4	3.3	11.0	8.8	3.8

TABLE 5.1-18

Distribution Coefficients (K_d) of Elements in SRP Ground water

Element	K_d	Element	K_d
Hydrogen	0	Niobium	*
Phosphorus	*	Ruthenium	*
Sulfur	*	Antimony	*
Chromium	*	Iodine	*
Cobalt	*	Cesium	7.3×10^2
Zinc	*	Cerium	*
Strontium	1.0×10^2	Promethium	*
Yttrium	*	Uranium	6.0×10^1
Zirconium	*	Plutonium	1.4×10^3
		Americium	1.0×10^3
		Curium	1.0×10^3

* Value unknown; K_d assumed to be 0.

TABLE 5.1-19

Delayed Doses to the Maximally Exposed Individual from Release to Seepage Basins

Year*	Seepage Basin System-Area	Age Group	Dose, mrem per year intake					Kidney	Lung	GI-LLI**
			Skin	Bone	Liver	Total Body	Thyroid			
1†	All	Child	2.21×10^{-2}	-	2.21×10^{-2}	2.21×10^{-2}	2.21×10^{-2}	2.21×10^{-2}	2.21×10^{-2}	2.21×10^{-2}
3.3	Central Shops	Teen	9.26×10^{-9}	7.91×10^{-9}	9.75×10^{-9}	1.07×10^{-8}	8.96×10^{-9}	8.96×10^{-9}	8.96×10^{-9}	1.92×10^{-8}
3.8	200-F & H	Child	4.78×10^{-5}	5.67×10^{-4}	5.42×10^{-2}	5.40×10^{-2}	5.41×10^{-2}	5.47×10^{-2}	5.40×10^{-2}	6.28×10^{-2}
4.4	100-L	Child	4.92×10^{-7}	1.60×10^{-6}	1.01×10^{-1}	1.01×10^{-1}	1.01×10^{-1}	1.01×10^{-1}	1.01×10^{-1}	1.01×10^{-1}
1500	200-F & H	Infant	-	1.20×10^{-2}	-	8.98×10^{-4}	-	2.50×10^{-3}	-	1.54×10^{-4}
4200	M Area	Infant	-	5.78×10^{-3}	-	4.30×10^{-4}	-	1.20×10^{-3}	-	7.38×10^{-5}
25000	200-F & H	Adult	8.26×10^{-7}	3.50×10^{-4}	3.20×10^{-4}	2.53×10^{-5}	7.20×10^{-7}	1.86×10^{-4}	7.20×10^{-4}	4.10×10^{-5}
29000	Central Shops	Child	3.06×10^{-13}	2.62×10^{-8}	2.80×10^{-9}	6.73×10^{-10}	3.14×10^{-14}	2.48×10^{-9}	3.14×10^{-14}	1.39×10^{-9}
34000	200-F & H	Child	3.06×10^{-9}	2.62×10^{-4}	2.80×10^{-5}	6.73×10^{-6}	3.14×10^{-10}	2.48×10^{-5}	3.14×10^{-10}	1.39×10^{-5}
39000	100-L	Child	9.00×10^{-11}	7.71×10^{-6}	8.25×10^{-7}	1.98×10^{-7}	9.23×10^{-12}	7.29×10^{-7}	9.23×10^{-12}	4.09×10^{-7}

* Number of years after discharge to seepage basins.

** Gastrointestinal - lower large intestine.

† Atmospheric dose from tritium evaporation - occurs during year of discharge to seepage basin.

TABLE 5.1-20

Delayed Population Doses from Releases to Seepage Basins

Year*	Seepage Basin System-Area	Dose, mrem per year intake							
		Skin	Bone	Liver	Total Body	Thyroid	Kidney	Lung	GI-LLI**
1†	All	1.47×10^0	-	1.47×10^0	1.47×10^0	1.47×10^0	1.47×10^0	1.47×10^0	1.47×10^0
3.3	Central Shops	2.76×10^{-8}	-	6.81×10^{-8}	1.12×10^{-7}	7.64×10^{-8}	5.29×10^{-8}	5.29×10^{-8}	2.94×10^{-7}
3.8	200-F & H	6.83×10^{-4}	7.01×10^{-3}	1.43×10^0	1.43×10^0	1.43×10^0	1.44×10^0	1.43×10^0	1.82×10^0
4.4	100-L	7.02×10^{-6}	1.75×10^{-5}	2.68×10^0	2.68×10^0	2.68×10^0	2.68×10^0	2.68×10^0	2.68×10^0
1500	200-F & H	1.83×10^{-5}	2.01×10^{-1}	-	1.20×10^{-2}	1.35×10^{-5}	4.20×10^{-2}	-	1.11×10^{-2}
4200	M Area	8.76×10^{-6}	9.67×10^{-2}	-	5.74×10^{-3}	6.43×10^{-6}	2.02×10^{-2}	-	5.31×10^{-3}
25000	200-F & H	8.26×10^{-6}	8.01×10^{-3}	7.25×10^{-3}	5.73×10^{-4}	7.16×10^{-6}	4.14×10^{-3}	-	8.67×10^{-4}
29000	Central Shops	4.37×10^{-12}	7.31×10^{-7}	8.64×10^{-8}	1.92×10^{-8}	4.48×10^{-13}	7.98×10^{-8}	-	6.29×10^{-8}
34000	200-F & H	4.37×10^{-8}	7.31×10^{-3}	8.64×10^{-4}	1.92×10^{-4}	4.48×10^{-9}	7.98×10^{-4}	-	6.29×10^{-4}
39000	100-L	1.29×10^{-9}	2.15×10^{-4}	2.54×10^{-5}	5.64×10^{-6}	1.32×10^{-10}	2.35×10^{-5}	-	1.85×10^{-5}

* Number of years after discharge to seepage basins.

** Gastrointestinal - lower large intestine.

† Atmospheric dose from tritium evaporation - occurs during year of discharge to seepage basin.

estimates were made based upon the resuspension of sediment and desorption of cesium-137 from the sediments by thermal effluent in Steel Creek.

About 6% of the cesium-137 inventory of 160 curies is expected to be transported from the creek the first year of operation and about 4.5 percent, the second year (Table 5.1-21), and decreasing amounts in subsequent years. The main loss is due to resuspension of sediments (7.6 ± 4.4 Ci) the first year. The contribution from hot water desorption is 1.8 Ci in the first year and about 0.4 Ci from decomposition and leaching of vegetation. In the second year, the hot water and biological components of the cesium-137 transport are expected to be very small whereas the cesium-137 transported with suspended sediments is estimated at about 7.2 ± 4.3 Ci. An estimated 2.2 Ci of cesium-137 could be deposited on Creek Plantation Swamp the first year of L Reactor operation and possibly 1.7 Ci the second year (Table 5.1-21). Based upon these cesium-137 releases, the concentrations in the Savannah River will be about 1.8 pCi/L the first year and about 1.3 pCi/L the second year (Table 5.1-22). The highest concentration measured previously in the Savannah River was 2.7 pCi/L in 1966.

5.1.1.3.2 Cesium-137 Dose Estimates

The calculated maximum adult individual whole body dose* from the release and transport of 9.8 Ci of cesium-137 from Steel Creek to the Savannah River will exceed the maximum individual dose estimated from present SRP radionuclide releases (Table 5.1-23). The maximally exposed offsite individual whole body dose from SRP operations would increase from 2.3 mrem/yr to 10.8 mrem/yr (principally from the consumption of fish (Table 5.1-23) using the same NRC methodology used throughout this report. As reported in Table 5.1-23 the average individual on the site boundary dose is 0.95 mrem/year using the standard SRP methodology. The cesium-137 maximum adult individual whole body dose addition from L-Reactor startup will be greater than that from current operations for the first 7 years of operation (Table 5.1-24) and will approach 4 mrem/yr following 10 years of L-Reactor operation. The maximum adult individual whole body dose is about equal to the SRP Technical Standard limit of 10 mrem/yr the first year (all effluent pathways), but is expected to be less than this guideline in the second year of L-Reactor operation. The NRC limit for maximum adult individual whole body dose via the aquatic pathway from a multireactor site is 5 mrem/yr. This limit will be exceeded for the first two years of L-Reactor operation (Figure 5.1-1 and Table 5.1-24).

* The discussion will use only whole body doses, but individual organ doses, doses to teenagers and infants are included in Appendix D.

TABLE 5.1-21

Estimated Cesium-137 Transport from SRP Following L-Reactor Startup

	<u>First Year</u>	<u>Second Year</u>
I. To Savannah River from Current Operations	0.2	0.2
II. From Steel Creek via		
a. Sediments	7.6±4.4	7.2±4.3
b. Hot water dissolution	1.8	0
c. Biota	0.4	0
III. Fate of Steel Creek Cs-137		
a. Creek Plantation Swamp	0	0
Savannah River	9.8	7.2
b. Creek Plantation Swamp*	2.2	1.7
Savannah River	7.6	5.5

* Deposition on Creek Plantation Swamp based on 23% flooding frequency of the Savannah River.

TABLE 5.1-22

Comparison of Current and Expected Cesium-137 Concentrations in the Savannah River and Steel Creek.*

	<u>First Year, pCi/L</u>	<u>Second Year, pCi/L</u>
I. Current Operations		
a. Savannah River	0.02	0.02
b. Steel Creek	<10	<10
II. Savannah River (6100 cfs)**		
a. No deposition on Creek Plantation Swamp	1.8	1.3
b. Deposition on Creek Plantation Swamp	1.4	1.0
III. Steel Creek	24.4	17.9

* Highest concentration measured in the Savannah River to date was 2.7 pCi/L in 1966.

** Assumes low river water flow. Average river water flow is about 10,200 cfs.

TABLE 5.1-23

Comparison of Maximally Exposed Offsite Individual Whole Body Dose from SRP
Reactor Operations

	Maximally Exposed Individual Dose mrem/yr			
	L Reactor and Support Facilities*	Current SRP Operations	Reported Average Individual, Current SRP Operations**	Total Operations
<u>Cs-137</u>				
Fish†	8.2(1.0)	0.15	-	8.35(1.15)
Drinking Water†	0.09(0.01)	0.0008	0.0005	0.09(0.01)
<u>Other</u>				
River	0.051(0.095)	0.30	0.22	0.35(0.40)
Atmospheric	0.15(0.51)	1.8	0.73	1.95(2.31)
Total	8.5(1.6)	2.3	0.95	10.8(3.9)

Annual natural radiation exposure = 93††

* Values are for the first year of operation except values in parentheses which are for the tenth year of operation.

** Data from Reference 6 for average individual doses. These values are not directly comparable with other doses shown in this table because they are based on average intake of food and water and a different dose methodology.

† First column is for minimum river flow of 6100 cfs, and second column is for average river flow of 10,200 cfs.

†† Average annual radiation exposure to persons living within a 80-km radius.

TABLE 5.1-24

Impact of Discharge of Cesium-137 to the Savannah River from
L-Reactor Operation

<u>Fiscal Year</u>	<u>Ci/yr</u>	<u>Total Transported, Ci</u>	<u>River Cs-137 Concentration pCi/L</u>	<u>Aquatic Dose L-Reactor Cs-137, mrem/yr</u>
1984	9.8	9.8	1.80	8.19
1985	7.2	17.0	1.32	6.02
1986	5.76*	22.8	1.06	4.81
1987	4.61	27.4	0.85	3.85
1988	3.69	31.1	0.68	3.08
1989	2.95	34.0	0.54	2.46
1990	2.36	36.4	0.43	1.97
1991	1.89	38.3	0.35	1.58
1992	1.51	39.8	0.28	1.26
1993	1.21	41.0	0.22	1.01

* Beginning in 1986 a 20% reduction per year in cesium-137 transport from Steel Creek is assumed.

FIGURE 5.1-1. Comparison of Anticipated SRP Dose From L-Reactor Startup Maximum Adult Individual (low river water flow of 6100 cfs)

5.1.1.3.3 Cesium-137 Accumulation and Dose on Creek Plantation Swamp

Flooding of the SRP and Creek Plantation Swamp at river stages above 91 feet msl (15,500 cfs) will cause the flow from Steel Creek to be diverted from the Savannah River and into the swamp paralleling the Savannah River. Using sediment measurements, about 25 Ci of cesium-137 were estimated to be present on the Creek Plantation in 1974.⁹ This has decayed to an estimated 20 Ci of cesium-137 in 1984 (Figure 5.1-2).

It is expected that cesium-137 will again be deposited on Creek Plantation during the first 10 years of operation of L-Reactor as a result of river flooding and transport of cesium-137 out of Steel Creek. The maximum cesium-137 inventory estimate, corrected for radioactive decay, will be about 25 Ci in 1989 (Figure 5.1-2 and Table 5.1-25).

This increase in cesium-137 contamination may increase the external cesium-137 radiation field on Creek Plantation Swamp from about 92 mrem/year in 1984 to about 115 mrem/year in 1989 (about 25%) (Table 5.1-25). An average individual whole body dose would be increased by 13% to about 230 mrem/yr in 1989 (Figure 5.1-3). The current dose rates in Creek Plantation now range from 40 to 480 mrem/yr.¹⁰ The estimate of cesium-137 external radiation dose increase was developed using Creek Plantation Swamp data, see Appendix D for details.

5.1.1.4 Occupational Radiation Exposure to SRP Employees

The Department of Energy has established occupational dose limits for the conduct of its operations such that no employee will receive a dose equivalent commitment in excess of five rems per year and no more than three rems in a calendar quarter to the whole body, head and trunk, gonads, lenses of the eye, red bone marrow, and active blood-forming organs.¹¹ These limits apply to combined external penetrating dose and internal dose. At SRP, it is the policy to limit exposure to employees to the lowest practical level and within radiation exposure guides of three rem per year and/or three rems per calendar quarter.¹²

At SRP, occupational exposure is maintained as low as practical by use of 1) shielding, 2) exposure time limits, 3) protective equipment, specialized equipment for reducing exposure (where feasible), and 4) preplanned procedures for jobs involving exposure to radiation. Occupational exposure information is developed and maintained for all individuals exposed to ionizing radiation while engaged in activities associated with operation of SRP. Personnel are assigned personnel monitoring devices if they enter

FIGURE 5.1-2. Increase in Cesium-137 on the Creek Plantation Swamp

TABLE 5.1-25

Cesium-137 Accumulation and Dose on the Creek Plantation Swamp

<u>Fiscal Year</u>	<u>Ci/Yr Transported out of Steel Creek</u>	<u>Ci/Yr Deposited on Creek Plantation** Swamp</u>	<u>Ci Accumulated</u>	<u>Avg. Dose from Cs-137 mrem/yr</u>
			19.9**	92
1984	9.8	2.25	22.1	102
1985	7.2	1.66	23.3	107
1986	5.76	1.32	24.1	111
1987	4.61	1.06	24.6	113
1988	3.69	0.85	24.9	114
1989	2.95	0.67	25.0	115
1990	2.36	0.54	25.0	115
1991	1.89	0.43	24.8	114
1992	1.51	0.35	24.6	113
1993	1.21	0.28	24.3	112

* Assume flooding of the Savannah River occurs 23% of the time.

** Expected inventory on Creek Plantation in 1984.

FIGURE 5.1-3. Increase in Dose on Creek Plantation Swamp Due to Transport of Cesium-137 From Steel Creek

or work in areas that have radiation-exposure potential. In addition, a comprehensive bioassay program is maintained for all employees who work in locations where there is a potential for biological uptake of radioactivity. Permanent records of occupational radiation exposure are maintained in DOE's Radiation Record Repository.

Most of the occupational radiation exposure received by employees at SRP is from reactor operations and the associated chemical processing of spent reactor fuel elements and targets. Table 5.1-26 shows the SRP employees' whole body radiation dose equivalents for the five most recent years of operation (1976-1980). These data represent exposure received during operation of three production reactors and other associated operations.

During this five-year period, the average individual annual exposure to radiation workers was 197 mrem with a maximum exposure to an individual of about 2.9 rems.

The restartup and operation of the L Reactor are expected to cause an incremental increase in total occupational exposure equivalent to about one-third of current SRP experience, i.e., an increase of about 360 person-rems per year or a total SRP occupational exposure of about 1432 person-rems. The incremental increase in occupational exposure will be distributed about 125 person-rems to new employees and about 235 person-rems to employees currently at SRP. This means that the average individual occupational dose at SRP will increase about 22% to 232 mrem per year as the result of restartup of the L Reactor and other associated plant operations.

5.1.1.5 Radiological Impact of Transportation

Seventy ton casks are loaded with irradiated reactor fuel reassembled and prepared for shipment by Reactor Department personnel. One or two spacer cars separate the locomotive from the cask car during transit to 200-F or 200-H Separations Areas. Therefore, the additional cumulative radiation exposure to the rail crew from L-Area operations is very small, as their average radiation exposure rate is much less than one mrem per hour. The incremental exposure to the rail crew is estimated to be less than 10 mrem per year each, based upon 1979 and 1980 exposure records.

Casks used to ship irradiated materials from reactor areas by truck are mounted on an assigned trailer and do not require rigging. The radiation exposures, averaged over a six-year period, were 330 mrem per year and 110 mrem per year to two

TABLE 5.1-26

SRP Occupational Exposure For Three-Reactor Operation

<u>Year</u>	<u>Occupational Exposure, person-rems</u>			
	<u>Reactors</u>	<u>Chemical Processing</u>	<u>Rest of Plant</u>	<u>Total</u>
1976	217.2	684.5	150.4	1052.1
1977	231.2	656.1	167.9	1055.2
1978	202.0	664.3	173.4	1039.7
1979	184.4	759.8	140.5	1084.7
1980	<u>203.7</u>	<u>779.7</u>	<u>144.6</u>	<u>1128.0</u>
Average	207.7	708.9	155.4	1072

drivers who exclusively transport reactor area scrap metal and deionizer casks from the three operating reactors. Radiation exposure records show that T & T exposures per reactor area average about two to three rem per year.

5.1.2 Summary of Radiological Impacts

The radiological impacts of the normal operation of the L Reactor and other associated SRP facilities are summarized in this section. As discussed in previous sections, these impacts result from the following sources of population and worker exposure:

- Atmospheric Releases - direct releases of radioactive materials to the atmosphere from ventilation exhaust stacks
- Atmospheric Releases - indirect releases of tritium oxide to the atmosphere by evaporation from seepage basins used for discharge of some liquid radioactive effluents
- Liquid Releases - direct releases of radioactive materials in process effluents to surface streams
- Liquid Releases - indirect releases of radioactive materials to surface streams via migration from seepage basins
- Liquid Releases - redistribution of cesium-137 in Steel Creek sediments as the result of discharge of thermally hot cooling water from L Reactor to the creek.
- Occupational Exposure - occupational exposure of SRP employees

The incremental radiological impacts from operation of L Reactor and other associated SRP facilities are summarized in Table 5.1-27. The data shown in this table are for an average year of operation with the exception of cesium-137 redistribution in Steel Creek; for cesium-137 redistribution, the population dose in the first year (the year of anticipated maximum redistribution and release to the river) is shown. This dose is expected to decrease in succeeding years of operation at about 20% per year.

As shown in Table 5.1-27, the maximum exposure to any group, from L-Reactor startup, i.e., 360 man-rems total body, is to occupationally exposed SRP employees. The sum of total body dose commitment from L-Reactor startup to offsite population groups is 43 man-rems, of which 59% is from atmospheric releases and 41% is from liquid releases.

Table 5.1-28 compares the incremental effect of L Reactor operation (and associated facilities) with other current SRP operations. The operation of L Reactor and the associated SRP facilities represents about a 32% increase in radiological impact over current (1978-1980) SRP operations. The total radiological impact from SRP operations after startup of L Reactor (1570 man-rems, total body) is only 2% of the population dose of about 81,000 man-rems from natural radiation sources.

TABLE 5.1-27

Radiological Impact Summary - Operation of L Reactor and Associated Facilities, Average year

	Population Dose Commitment, man-rem per year of operation							
	Skin	Bone	Liver	Total Body	Thyroid	Kidney	Lung	GI-LLI*
<u>Offsite Population</u>								
Atmospheric Releases								
Direct Releases	6.40×10^1	1.05×10^1	2.46×10^1	2.40×10^1	6.49×10^1	2.44×10^1	2.47×10^1	2.49×10^1
Tritium evaporation from seepage basins**	1.47×10^0	-	1.47×10^0	1.47×10^0	1.47×10^0	1.47×10^0	1.47×10^0	1.47×10^0
Total Atmospheric	6.55×10^1	1.05×10^1	2.61×10^1	2.55×10^1	6.64×10^1	2.59×10^1	2.62×10^1	2.64×10^1
Liquid Releases								
Direct releases to streams	7.98×10^{-4}	2.67×10^0	1.37×10^0	2.01×10^0	1.31×10^0	1.36×10^0	1.31×10^0	1.44×10^0
Seepage basin migration†	6.90×10^{-4}	7.03×10^{-3}	4.11×10^0	4.11×10^0	4.11×10^0	4.12×10^0	4.11×10^0	4.50×10^0
Cesium redistribution - Steel Creek††	6.78×10^{-2}	1.81×10^1	2.26×10^1	1.17×10^1	5.80×10^{-2}	7.60×10^0	2.62×10^0	3.58×10^{-1}
Total Liquid	6.93×10^{-2}	2.08×10^1	2.81×10^1	1.78×10^1	5.48×10^0	1.31×10^1	8.04×10^0	6.30×10^0
Grand Total Offsite	6.56×10^1	3.09×10^1	5.42×10^1	4.33×10^1	7.19×10^1	3.90×10^1	3.42×10^1	3.27×10^1
<u>Onsite Population</u>								
Occupational Exposure - SRP Employees	-	-	-	3.60×10^2	-	-	-	-

* GI Tract - lower large intestine.

** Occurs during year of discharge to seepage basins.

† Occurs 3 to 4 years after discharge to seepage basins.

†† Based upon a maximum release of 9.8 Ci of cesium-137 to the river in the first year of operation.

TABLE 5.1-28

Radiological Impact - Comparison of L Reactor With Current SRP Operation

	Population Dose Commitment, man-rem per year of operation							
	Skin	Bone	Liver	Total Body	Thyroid	Kidney	Lung	GI-LLI*
<u>Current SRP Operations (1978-1980 Average)</u>								
Offsite population	1.67×10^2	2.90×10^1	9.89×10^1	9.94×10^1	1.76×10^2	9.86×10^1	9.91×10^1	1.01×10^2
Occupational exposure - SRP	-	-	-	1.07×10^3	-	-	-	-
Total	1.67×10^2	2.90×10^1	9.89×10^1	1.17×10^3	1.76×10^2	9.86×10^1	9.91×10^1	1.01×10^2
<u>L Reactor and Associated Operations</u>								
Offsite population	6.56×10^1	3.09×10^1	5.37×10^1	4.31×10^1	7.19×10^1	3.88×10^1	3.42×10^1	3.27×10^1
Occupational exposure - SRP	-	-	-	3.60×10^2	-	-	-	-
Total	6.56×10^1	3.09×10^1	5.37×10^1	4.03×10^2	7.19×10^1	3.88×10^1	3.42×10^1	3.27×10^1
Grand Total	2.33×10^2	5.99×10^1	1.53×10^2	1.57×10^3	2.48×10^2	1.37×10^2	1.33×10^2	1.34×10^2
Natural Radiation Exposure**	-	-	-	8.08×10^4	-	-	-	-

* GI Tract - lower large intestine.

** Based upon an annual average dose of 95 mrem per person.

5.1.3 Potential Health Effects

Population dose from normal operations is equated in this section to potential excess health effects. Potential health effects from radiation are cancer, genetic disorders, and somatic effects other than cancer. The National Academy of Sciences BEIR Committee¹³ believes that cancer induction is the most important effect of low-dose radiation, i.e., up to a few rads per person per year. Population doses from L-Reactor operations and from total operations at SRP are well below this level of exposure. The BEIR III Report¹³ concludes that low-dose exposure of the population does not increase somatic effects other than cancer and developmental changes in unborn children. Thus, only cancer and genetic disorders are considered in this analysis of potential health effect risk.

BEIR III¹³ considers several different methods of extrapolating the incidence of potential cancers induced by high dose - high dose rate data to the low levels of population exposure considered in this report. Also considered are the "absolute" risk model and the "relative" risk model which are discussed in detail in BEIR III. Models are constructed which represent lower bound, most probable, and upper bound representation of risks. In this analysis of L-Reactor operation health effects, only the model which represents the most probable risk is used. The risk as determined by the lower bound model could approach zero, while the risk determined by the upper bound model is almost four times higher than the risk determined by the most probable model. Health risk factors for cancer were developed from data in the BEIR III report and are presented in Table 5.1-29.

The BEIR III Report, Table IV-2,¹³ gives estimates of between 60 and 1100 genetic disorders (autosomal dominant and irregularly inherited) from a dose of one rem per generation per million live-born offspring in an equilibrium population. An equilibrium population is one in which there is one liveborn offspring per person per generation (two children per family). This is equivalent to saying that from 60 to 1100 disorders will occur from 10^6 man-rem. The geometric mean of these two values, i.e., 257 disorders per 10^6 man-rem, is used in calculation of genetic effects in this report. Since gonad exposure is not calculated separately in the dosimetry models used for this analysis, total body exposure is used to calculate genetic effects.

Table 5.1-30 shows the potential health effects associated with the radiological impacts (Table 5.1-27) per year of operation of L Reactor and operations in other associated facilities. Also shown are the potential health effects for current SRP operations. L-Reactor operation will increase the current potential health effects by 36%. The potential health effects were calculated from

TABLE 5.1-29

Potential Excess Cancer Deaths From Ionizing Radiation

<u>Cancer Type</u>	<u>Probable Risk: Cancer Deaths per 10⁶ organ-rems**</u>
Lung	34
Kidney	4
Thyroid	0*
Liver	7.9
Intestine	6.4
Other	48
Total (excluding bone cancer and leukemia)	<u>100†</u>
Bone Cancer and Leukemia	20††
Total - all cancers	<u>120</u>

* Although thyroid cancer can be induced by radiation, the type of cancer induced is rarely fatal (p. 367, BEIR III).¹³

** Calculated by method recommended in BEIR III¹³ to sum to 100 cancer deaths (excluding bone cancer and leukemia).

† Average of relative and absolute risk, linear-quadratic model (Table V-19, BEIR III).¹³

†† From continuous exposure, linear-quadratic model (Table V-16, BEIR III).¹³

TABLE 5.1-30

Potential Health Effects

	Potential Health Effects per Year of Exposure		
	<u>Fatal Cancers</u>	<u>Genetic Effects</u>	<u>Total</u>
L Reactor and Associated Operations			
Offsite Population	0.005	0.011	0.016
SRP Workers	<u>0.043</u>	<u>0.093</u>	<u>0.14</u>
Total	0.048	0.10	0.16
Current SRP Operations*			
Offsite Population	0.011	0.026	0.037
SRP Workers	<u>0.13</u>	<u>0.28</u>	<u>0.41</u>
Total	0.14	0.31	0.45
Grand Total	0.19	0.41	0.61
Natural Background Radiation	9.7	20.8	30.5

* Average for years 1978-1980.

probable risk factors in Table 5.1-29 and from the estimated frequency of 257 genetic disorders per 10^6 man-rems discussed in the preceding paragraph. The potential health effects of L-Reactor operation are largely associated with occupational exposure at SRP (88%). The potential health effects to offsite population groups are 0.037 effects from current operations and 0.016 effects from L Reactor startup, a total of 0.053 effects. When combined with potential occupational health effects, there will be a potential for 0.61 effects per year. The meaning of 0.61 health effects per year is not clear. This points to the probabalistic nature of this analysis. These estimates are based upon mathematical models and statistics and the assumption that any amount of radiation is capable of causing cancer and genetic disorders.

To put the potential health effects from L-Reactor operations, combined with current SRP operations, into perspective; they are compared in Table 5.1-30 with potential health effects that the same population groups will experience from one year of exposure to natural radiation sources. The potential health effects from SRP operations, with L Reactor operating, is only 2% of the health effects expected from natural radiation. Expressed in another way, normal SRP operations will have a health effect risk equal to one week of exposure to background radiation.

5.2 EFFECTS OF HEAT DISSIPATION

5.2.1 Thermal Impacts of Operation

Present plans call for release of the cooling water effluent from L Area directly to Steel Creek via the L-Area cooling water canal. The cooling water volume will be about 175,000 to 180,000 gpm and will be discharged at about 70-80°C. Heat will be dissipated in the cooling water canal, Steel Creek, and Steel Creek delta area before entering the Savannah River at the mouth of Steel Creek. The cooling water flow from L Area will mix with the cooling water from K Area and part of the flow from C Area before the combined flows enter the Savannah River. During the summer, the temperature of the cooling water effluent will be 10 to 15°C higher at the mouth of Steel Creek than the Savannah River water. Impacts to Steel Creek, the Steel Creek delta area, and the Savannah River will be similar to those which occurred during operation of L Reactor from 1954 to 1968 and similar to those observed in Four Mile Creek and Pen Branch today.

5.2.1.1 Impact to Steel Creek and the Steel Creek Delta

Steel Creek and its floodplain received cooling water effluent from 1954 until early 1968, when L Reactor was placed on standby (Figure 2.5-2). Today Steel Creek supports a diverse community of organisms from fish to waterfowl (Section 2.6.2.4). Emergent aquatic macrophytes and shrubs are common throughout the floodplain (Figures 2.6-11 through 2.6-19). Amphibians, reptiles, birds, and mammals common to wetlands are abundant.¹⁴

The reintroduction of cooling water effluent to Steel Creek from L Reactor will essentially eliminate the biota of the main channel of Steel Creek from the L-Area thermal canal downstream to the delta. Expected temperatures of Steel Creek and its adjacent floodplain under typical August and April weather conditions are shown in Figure 5.2-1. In this figure, temperature is given as a function of distance from the L-Area cooling water outfall to the mouth of Steel Creek at the Savannah River. In the spring (April), water temperature would exceed 40°C to about 6.8 miles below the L-Area outfall (Figure 5.2-1) and in the summer (August), water temperature would exceed 40°C to about 7.8 miles below the outfall (Figure 5.2-1). Anticipated biotic changes are summarized below.

Based upon information from the thermal streams (Four Mile Creek and Pen Branch) on SRP, few if any, higher organisms will survive in the main stream channel of Steel Creek where temperatures tend to exceed about 40°C. As water temperature gradually

FIGURE 5.2-1. Temperature Profiles for Steel Creek

declines with increasing distance from the L-Area outfall, organisms will invade the stream and floodplain beginning with the most thermally tolerant types. Near the confluence of Steel Creek and the Savannah River, the creek temperature will generally be low enough to allow the creek to have a composition more characteristic of warm water streams of the southeast.

However, in the warmer portions of Steel Creek, species composition and abundance will change, especially in those groups that inhabit the stream itself. Populations of thermotolerant fungi and algae such as the bluegreen algae would be expected to increase.^{15,16} These species may thrive in areas where species more sensitive to elevated temperatures can no longer compete successfully.

Most organisms will be confined to cooler refuges characterized by sluggish, silty pools rather than moving water. In such backwater pools, the only insect larvae that would be expected to be found would be those of dragonfly nymphs of the subfamily Libellulinae and fly larvae of the family Chironomidae.¹⁷⁻²¹ Tubificid worms would be expected in the silts and muds of backwater areas.

Many game fish which now live in Steel Creek will be eliminated.²² The most common fish remaining in the Steel Creek area will be the mosquito fish, although a few centrarchids may be found in backwater areas and side streams such as Meyers Branch.²³⁻²⁷ Also, the warmer waters of Steel Creek may effectively prevent access by fish in the river to the rest of the SRP Savannah River swamp. Steel Creek may be used as a spawning site by American shad or blueback herring.²² The majority, if not all, of this spawning activity by these anadromous fish could be eliminated by the addition of cooling effluent.

Amphibians normally use quieter backwater areas to breed, and these areas will receive less thermal impact. However, temperatures, especially in upstream areas, may reach lethal limits for most amphibian eggs and larvae. Water snakes and turtles will not be found in high-temperature areas but may be found in peripheral areas of moderate temperature. The Steel Creek area will no longer be a suitable habitat for the American alligator.

Although terrestrial animals are not considered to be directly affected by elevated water temperatures, they would be affected if the thermal effluent modifies their habitat or effects their food source. The use of Steel Creek by aquatic mammals such as the beaver would decline. Those birds which feed on small fish or amphibians would also be affected.

Several hundred waterfowl feed in the Steel Creek floodplain, especially the Steel Creek delta, during the winter.²⁸ Common species include woodducks, mallards, blue-winged teals, green-winged teals, hooded merganser, and American widgeon. The thermal effluent will kill much of the aquatic food supply of these birds, and their use of the swamp is expected to decline. Wood duck nesting in the Steel Creek area is expected to decline since the temperatures along the creek will exceed the tolerances of these birds.

Nonaquatic birds do not seem greatly affected by the direct action of thermal effluents.²⁹ The differences observed in bird populations between natural swamps and thermal swamps of SRP appear to have resulted from habitat changes caused by the thermal effluents. Woodpeckers, crows, herons, as well as smaller birds, are more abundant where the canopy has been destroyed, leaving standing dead trees for nest sites and marsh-like vegetation.

In addition to the thermal impacts from L-Reactor restart, the increase in flooding and siltation will impact the vegetation along Steel Creek and in the Steel Creek delta. Average flow will increase from about 50 cfs to about 450 cfs throughout much of the year. About 725 acres of floodplain along Steel Creek and an additional 285 acres in the Steel Creek delta for a combined total of 1010 acres of wetlands will be reimpacted after the first year or two of renewed L-Area operations. The present post-thermal communities will be essentially eliminated. Based upon information from Four Mile Creek and Pen Branch, the woody species, such as willow, will be eliminated, and herbaceous species characteristic of early successional habitats will dominate the stream on isolated islands and cypress logs and stumps.³⁰⁻³² Thermally tolerant species such as Ludwigia leptocarpa and L. decurrens will become more common³³ (Table 2.6-7). In addition, the delta area of Steel Creek could be expected to expand into areas of Savannah River swamp at a rate of 3 to 11 acres per year based upon expansion rates observed in delta areas of SRP.^{14, 31, 34} The growth rate of the Steel Creek delta prior to shutdown in 1968 was about 7.5 acres per year.¹⁴

5.2.1.2 Thermal Impact on the Savannah River

SRP currently has three thermal discharges to the Savannah River. These are at the mouth of Beaver Dam Creek, Four Mile Creek, and Steel Creek (Figure 5.2-2). L Reactor will contribute to an increase in thermal discharge from the mouth of Steel Creek and the resulting thermal plume in the Savannah River. Comparisons of the three thermal plumes of each creek discharge and an estimate of the overall cumulative thermal impact on the Savannah River are given below.

FIGURE 5.2-2. SRP Thermal Releases to the Savannah River

5.2.1.2.1 Beaver Dam Creek

Beaver Dam Creek has the smallest of the thermal effluents from SRP. It receives flow from the D-Area coal-fired power plant and some flow from C Reactor via the Four Mile Creek delta. Flow ranges from 110 to 190 cfs divided about equally between D Area and Four Mile Creek. The temperature at the mouth of Beaver Dam Creek typically ranges 10 to 20°F (5.5 to 11.1°C) above Savannah River water temperatures during the warmer months of the year. The thermal plume downstream from the mouth of Beaver Dam Creek is confined to the South Carolina shore (Figure 5.2-3) for a relatively short distance before becoming mixed with the Savannah River.^{10,35} Data collected during monitoring by SRP indicates that the permitted limit of 2.8°C above ambient 100 yards downstream of the mouth of Beaver Dam Creek is not exceeded (Figure 5.2-3).^{*} Likewise, a boundary limit of 2.8°C for one-third of the surface area and one-fourth of the cross-sectional area is not exceeded (Figures 5.2-3 and 5.2-4).¹⁰ No significant change is expected in thermal discharges from Beaver Dam Creek as a result of L Reactor restartup.

5.2.1.2.2 Four Mile Creek

Four Mile Creek receives cooling water discharge from C Reactor. The average flow in Four Mile Creek is about 480 cfs at Road A (Figure 5.2-2). C Reactor accounts for about 400 cfs of this flow. When the creek reaches the Savannah River swamp, part of the flow discharges to Beaver Dam Creek; part discharges to the Savannah River at the mouth of Four Mile Creek; and a third part flows through the swamp, eventually mixing with flow from Pen Branch and Steel Creek to discharge to the Savannah River at the mouth of Steel Creek. The amount of discharge from Four Mile Creek ranges from about 60 to 140 cfs. Maximum temperatures observed at the mouth of Four Mile Creek were 30 to 35°F (16.7 to 19.4°C) above the Savannah River water temperature during the late spring and summer months. The mixing zone of the thermal plume extends beyond the present SRP NPDES permit limit of 2.8°C at 300 yards below the mouth of Steel Creek, as determined during monitoring of the thermal plume (Figures 5.2-4 through 5.2-7).^{6,10} Measurements during May 1977, for example, showed a maximum temperature of 3.7°C above ambient at 300 yards, decreasing to 2.8°C at 350 yards.¹⁰ Cross-sectional and surface limits of 1/4 and 1/3, respectively, are not normally exceeded. However, under

* The South Carolina water quality standards limit thermal discharges to no more than 5°F (2.8°C) with a limit of no more than one-third of the surface area and one-fourth of the cross-sectional area.³⁶

FIGURE 5.2-3. Temperatures in River 100 Yards Below Beaver Dam Creek

FIGURE 5.2-4. Mixing Zone Cross Sections Showing Measured Temperature Areas Versus Total Area

FIGURE 5.2-5. Temperatures in River Below Four Mile Creek

FIGURE 5.2-6. Temperature in River 300 Yards Below Four Mile Creek In May 1980

FIGURE 5.2-7. Temperatures in the Savannah River 300 Yards Below Four Mile Creek in July 1980

conditions of low flow in the Savannah River as experienced during 1981, monitoring by SRP in December indicated that as much as 43 percent of the surface area 100 yards below the Four Mile Creek mouth could have a temperature in excess of 2.8°C. Traces of the plume can be detected for a few miles below the mouth of Four Mile Creek.³⁵ No change is expected in the thermal discharges from Four Mile Creek as a result of L-Area operations.

5.2.1.2.3 Steel Creek

At one time, three reactor areas (P, L, and K) discharged cooling water effluent at the Steel Creek mouth. The effluent from P Area was diverted to Par Pond in 1963, and L-Area operations were terminated in 1968. Since 1968, the thermal discharge from K Area through the Steel Creek mouth to the Savannah River has been only a fraction of that when both L and P Areas were also discharging cooling water to Steel Creek.

The present discharge from Steel Creek to the Savannah River is usually in excess of 530 cfs depending upon runoff conditions and SRP reactor operations. K Area accounts for 400 cfs of this flow. When L and K Areas were both operating, the Steel Creek discharge was approximately 950 cfs.

Under the present SRP operating conditions, the temperature of water released from the mouth of Steel Creek is typically less than 10°F (5.6°C) above Savannah River water temperature during the spring and summer months. The temperature at the limit of the present mixing zone of 100 yards does not exceed 2.8°C (Figures 5.2-4 and 5.2-8).¹⁰ In fact, in the winter months, the water from Steel Creek may even be lower than the ambient river water temperature¹⁰ (Figures 5.2-9 and 5.2-10).

With the restartup of L Reactor, the thermal plume that will result in the Savannah River is expected to be similar to that observed from 1963 to early 1968 when both K and L Reactors discharged from the mouth of Steel Creek. According to monitoring data, instantaneous temperature differences between Steel Creek and the Savannah River are expected to range up to a maximum of about 25°F (13.9°C). For example, in May 1965, the maximum temperature differences ranged from 11 to 22°F (6.1 to 12.2°C) with a monthly average of 15°F (8.3°C). Similarly, in August 1965, the maximum daily temperature ranged from 13 to 23°F (7.2 to 12.8°C) with a monthly average of 14.7°F (8.2°C). In general, the monthly averaged temperature difference is nominally about 15°F in the warmer months (Figure 5.2-11). Historic data also indicate that the thermal plume from Steel Creek remains essentially on the

FIGURE 5.2-8. Temperatures in River 100 Yards Below Steel Creek

FIGURE 5.2-9. Temperature in River 100 Yards Below Steel Creek

FIGURE 5.2-10. Daily Max-Min Temperatures on the Savannah River and Steel Creek

FIGURE 5.2-11. Daily Max-Min Temperatures on the Savannah River and Steel Creek

South Carolina side of the Savannah River until about 1.5 miles (2.4 kilometers) downstream from the mouth of Steel Creek where the plume becomes completely mixed with the river (Figure 5.2-12).

Computer simulations were used to predict the temperatures within the Steel Creek thermal plume downstream of the Steel Creek mouth. (See Appendix E for a description of the DISPER1 computer code³⁷ and its use.) Figure 5.2-13 for example assumes a temperature difference of 15°F (8.3°C) between the river and the Steel Creek discharge. This figure indicates that a river temperature rise of 5°F (2.8°C) is approached at 25 percent of the river width at a downriver distance of about 0.4 mile for normal low flow conditions in the Savannah River of 6100 cfs (Figure 2.5-2). Beyond this distance, the temperature gradually declines. At 33 percent of the width, the maximum temperature rise is about 3.4°F (1.9°C) at about 1.2 miles downstream. Figure 5.2-14, based upon a temperature difference of 20°F (11.1°C) between the river (6100 cfs) and Steel Creek, indicates a maximum river temperature increase of about 6.5°F (3.6°C) at 25% of the width of the river. The temperature increase is about 5°F to a distance of about 1.2 miles below Steel Creek. The maximum increase at 33% of the river width is about 4.5°F (2.5°C), which occurs within 0.5 mile of the Steel Creek mouth.

As Savannah River flow decreases, thermal impact on the river from thermal discharges at the mouth of Steel Creek increases and conformity to regulatory criteria³⁶ becomes more difficult. Under flow conditions below 6100 cfs, it becomes likely that the 5°F limit will be exceeded periodically with the restart of L Reactor (Appendix E). As shown in Figure 5.2-15, if both K and L Reactors are operating, it takes only about 12.5°F (7.8°C) to reach a 5°F increase within the mixing zone boundary. Monitoring data indicate that when L Area was operating, the average daily water temperature in the Steel Creek mouth could exceed the Savannah River water temperature by 12.5°F at least 40 days per year.

Beyond about 1.5 miles below the Steel Creek mouth, the thermal effluents of SRP are completely mixed with the Savannah River. Figures 5.2-16 through 5.2-18 summarize the anticipated thermal increase in the Savannah River from operation of L Area. In general, SRP increases the overall temperature of the Savannah River one to two degrees centigrade depending upon time of year, flow conditions, and SRP operating conditions (Figure 5.2-16). L-Reactor operation is expected to add from one-fourth to one-half degree centigrade to the overall temperature of the Savannah River depending upon time of year, flow, and operating conditions (Figures 5.2-17 and 5.2-18).

FIGURE 5.2-12. Map of Savannah River in Vicinity of Steel Creek

FIGURE 5.2-13. Boundary Temperatures Above Ambient Savannah River Temperature for a Mixing Zone Comprising 25% of the Cross Section and 33% of the Surface Area of the River for a Thermal Discharge From Steel Creek With a Delta T = 15°F and a Flow of 950 CFS and a Savannah River Flow of 6100 CFS

FIGURE 5.2-14. Boundary Temperatures Above Ambient Savannah River Temperature for a Mixing Zone Comprising 25% of the Cross Section and 33% of the Surface Area of the River for a Thermal Discharge From Steel Creek With a Delta T = 20°F and a Flow of 950 CFS and a Savannah River Flow of 6100 CFS

FIGURE 5.2-15. Minimum Delta-T Required for 5 Degree F at Mixing Zone Boundary.

FIGURE 5.2-16. Monthly Average Temperatures for 1960-1970 (Daily Maximum)

FIGURE 5.2-17. Expected Increases in Savannah River Water Temperatures Caused by L-Area Operations (Based on Flow of 6000 CFS)

FIGURE 5.2-18. Expected Increases in Savannah River Water Temperatures Caused by L-Area Operations (Average River Water Flow ~10,600 CFS)

The restartup of L Area is expected to have no significant thermal impact on the Savannah River except in the immediate vicinity (a few hundred yards) of the mouth of Steel Creek. The temperatures in the vicinity of the mouth of Steel Creek may be high enough to exclude Steel Creek and its floodplain as a potential spawning area for riverine and anadromous fish such as the blueback herring in the spawning season. However, the thermal plume does not extend across the Savannah River, but remains sufficiently close to the South Carolina shore to permit a zone of passage for migratory fish such as the American shad, blueback herring, and striped bass.

A series of 16 surveys by the Academy of Natural Sciences of Philadelphia (ANSP) was conducted beginning prior to SRP operations to determine if SRP had a significant impact on the physical, chemical, or biological conditions in the river.³⁸⁻⁴⁵ The locations of the ANSP stations are shown in Figure 6.2-1. Station 1 is above SRP and is not influenced by the addition of heat from SRP operations. Station 3 is about six miles downstream of Four Mile Creek. Station 5 is located about six miles downstream of Steel Creek. Stations 3 and 5 are below the direct effects of thermal plumes from these creeks. The dates of the surveys are given in Table 2.6-1. Biological groups investigated during each ANSP survey included algae and diatoms, protozoa, macroinvertebrates, and fish (see Section 2.6.2.2). Sampling, preservation, and laboratory methodology are described in each report. Emphasis was placed on taxonomic identification. The number of species is highly variable between surveys (Figures 2.6-6 through 2.6-8).

The ANSP surveys provide a taxonomic data base to assess the effects of SRP thermal discharges on the biological community in the Savannah River. A review⁴⁶ of these surveys indicated that there is no definite evidence that addition of heat either from Four Mile Creek or Steel Creek has been detrimental to the aquatic communities at Stations 3 and 5. Because these stations are located about six miles downstream from the sources of heated effluent, the effects of the thermal plumes were not studied. The stations were beyond the area where an effect from the plumes might have been damaging. A slight warming at the stations would be expected, but the data indicate that this is not sufficient to affect the aquatic life.⁴⁶ Since 1951, before the operation of SRP began, there has always been a relatively high diversity of species at all ANSP stations. The past operation of L Reactor did not produce discernible effects on aquatic communities at the stations.⁴⁶

5.2.1.3 Species of Concern

5.2.1.3.1 Red-Cockaded Woodpecker (Picoides borealis)

The red-cockaded woodpecker has been studied at SRP for the past several years. These surveys have produced a listing and description of all known colonies of red-cockaded woodpeckers on SRP. This information indicates that only one active colony is located near the area that will be impacted by the startup of L Reactor. This colony is located in an upland loblolly-longleaf pine stand near SRP Road A-19.1, about one-half mile from the Steel Creek floodplain. Since this colony is located on land that is about 40 feet higher in elevation than the floodplain which would receive thermal effluents, there is little likelihood of any direct effects on this colony as a result of L-Reactor operations. Furthermore, no red-cockaded woodpeckers have been seen to forage in the vicinity of the Steel Creek floodplain or swamp delta. The bottomland and floodplain habitats that are likely to be altered by L-Reactor effluents cannot be considered critical to this woodpecker.^{29, 47}

No suitable habitat for red-cockaded woodpecker was found in a survey of the vicinity of L Area or the proposed K-L steam lines (Appendix A).

5.2.1.3.2 American Alligator (Alligator mississippiensis)

American alligators have been seen in the Steel Creek floodplain and delta area, including adults, juveniles in the two-and-one half to four-foot size range, and one to two year old juveniles (Figure 5.2-19).¹⁴ A former nest has been located near Highway 125 along with a cohort of juveniles; one active nest (1981) was located near the periphery of the Steel Creek delta.¹⁴

The release of thermal effluent from L Area to Steel Creek would be expected to eliminate the floodplain communities along Steel Creek and the delta area making this wetland habitat unsuitable for alligators. Alligators have not been observed in similar thermal areas at SRP such as Four Mile Creek and Pen Branch and their deltas.^{14, 48}

Adult alligators can avoid thermal waters and migrate considerable distances overland. Thus, adult alligators would be expected to migrate to nonthermal swamp areas, Carolina bays, or abandoned farm ponds in the area. Overwintering alligators could be killed by thermal effluent if they were in a torpid condition.

FIGURE 5.2-19. Distribution of Signs, Tracks, and Nests of American Alligator in the Steel Creek Area, 1981

Juveniles would also be expected to avoid thermal effluents, but smaller alligators would have more difficulty migrating to suitable habitats and would be more subject to predation. The extent to which young juveniles might migrate upstream along Steel Creek between periods of full cooling water flow is unknown. Upstream migration would make alligators more subject to being trapped by thermal discharge during reactor startup.

Nesting sites and eggs could be flooded by cooling water flow and destroyed.

Also, once thermal effluents become established in the Steel Creek area, higher levels of red-sore disease bacterium, Aeromonas hydrophila, could contribute to possible reduction in alligators which migrate to the thermally peripheral areas of the Steel Creek delta and floodplain.^{49,50}

Field studies are being conducted to plan any required mitigation to protect this species.

5.2.1.3.3 Wood Stork (Mycteria americana)

The wood stork is listed as a "threatened" species in South Carolina, and its numbers are declining in the southeast.⁵ The species is under consideration for listing by the U.S. Fish and Wildlife Service as an endangered species. Wood storks breed in large colonies, chiefly in south Florida, during the dry season of mid-to-late winter. These birds are most commonly seen at SRP during the summer months during periods of post-breeding dispersal. They have been observed in the Savannah River swamp bottomlands, including Steel Creek where the open habitat and large dead cypress trees would provide roosting habitat for these birds.⁵²

The reintroduction of thermal effluent to the Steel Creek floodplain and delta area would tend to eliminate fish populations from small pools and backwater areas which wood storks may use for feeding. The wood stork would be expected to use other small ponds, larger Carolina bays, or backwater pools within the Savannah River swamp bottomland with the loss of wetland habitat in the Steel Creek floodplain and delta area.

5.2.1.3.4 Other Species

Table 2.6-10 lists other species which are of concern on a Federal or state level which may occur in the Steel Creek area. A few of these, such as the bald eagle and osprey, have been observed at Par Pond and may be observed in the Savannah River swamp bottomland. Operation of L Area should have no significant effect on these species.

Cooper's hawk, a resident of SRP, has been observed in the swamp, but it is commonly an upland species and should not be affected by L-Area operations.

Swainson's warbler is an uncommon species of lowland swamp forests. Its status in the Steel Creek area is unknown. Reintroduction of thermal effluent would be expected to reduce habitat availability for this species. The species is apparently not in danger of extinction in South Carolina.⁵¹

The Mississippi kite has been observed in the swamp bottomlands of SRP.^{51,52} Its status on SRP and in South Carolina is basically unknown.

The red-headed woodpecker and the hairy woodpecker have been observed in the Steel Creek area. These woodpeckers are also common in the thermally influenced Four Mile Creek and Pen Branch deltas where they use cavities in the standing dead cypress trees.²⁹ These woodpeckers are not expected to be eliminated by the thermal effluents from L Reactor.

The black bear has been sighted occasionally on SRP, but these are probably migrants. Presently, SRP is assumed not to have a resident population.

The bobcat is common on SRP, both in uplands and the swamp bottomlands. The restart of L Reactor should have no deleterious effect on the bobcat population of SRP.

The longtail weasel occurs in the swamps of SRP as well as woodlands and open fields.⁵¹⁻⁵³ Considering its varied habitat range, it would probably be little affected by the L-Area restart.

The river otter is a resident of the Savannah River swamp bottomland and tributary streams.^{54,55} Its status along Steel Creek is unknown, but local populations, if they exist along Steel Creek, would lose Steel Creek as a habitat with release of thermal effluent from L Area.

Reptiles and amphibians in the Steel Creek area would be influenced by thermal releases from L Area. Elevated temperatures would eliminate food sources and would be directly lethal to adults, larvae, and eggs. The bird-voiced treefrog, the tiger salamander, and the pickerel frog, if they use the Steel Creek floodplain area, would be affected by the thermal effluents. Locally abundant populations of the bird-voiced treefrog and the tiger salamander are found at SRP.^{14,56,57}

The Carolina swamp snake and the spotted turtle could also be affected by habitat loss. The striped mud turtle of Florida (Kinosternon bauri) has been reported at Steel Creek.^{14, 58} Its presence would constitute a 150-mile range extension and would qualify it for special consideration. Steel Creek is being surveyed to determine the extent of use by this turtle. This turtle was observed along Steel Creek during previous L-Reactor operations.⁵⁸

Both the American shad and the blueback herring have been reported in the Steel Creek delta and Savannah River swamp areas. Introduction of thermal effluent would eliminate Steel Creek and backwater areas of the Steel Creek delta area as a breeding habitat for these anadromous species.

One species of crayfish of concern has been reported from Steel Creek.⁵⁹ Thermal effluents would eliminate this species from Steel Creek. This crayfish occurs in other streams of SRP as well as drainages of the Edisto and Salkehatchie Rivers.

No plant species of special concern have been found near Steel Creek. Five species listed in Table 2.6-10 have been found in moist habitats on SRP.⁶⁰ They are the spatulate seedbox, Annpetaled meadow beauty, pink tickseed, little burhead, and green fringed orchid. None of the five species is locally abundant on SRP. None is known from the Steel Creek area. If the five species were to occur in thermally or flood-influenced areas of the L-Area Reactor effluent, they would be adversely affected or eliminated.

5.2.2 Impacts of Increased Cooling Water Withdrawal From the Savannah River (Impingement and Entrainment)

5.2.2.1 Cooling Water Requirements

SRP is on the middle reach of the Savannah River where it withdraws cooling water for nuclear production reactors, fossil fuel steam and electric generators, and other facilities. The flow characteristics of the Savannah River at SRP are controlled by the effects of four dams upstream of SRP, particularly Clarks Hill Dam and Reservoir operated by the U.S. Corps of Engineers. The mean annual discharge for Augusta is 10,200 cfs ($289 \text{ m}^3/\text{sec}$).⁶¹ Peak flow and variability are found in March and April; the lowest flow and least variability are in summer and fall (Figure 2.5-2). The daily variation in river elevation and discharge is quite extensive in response to varying hydroelectric generation requirements. The seven-day, ten-year minimum flow for the Savannah River near SRP during the period 1953-1963 is 4530 cfs ($128.3 \text{ m}^3/\text{sec}$). The seven-day low flow for the years 1963 to 1979 is about 5630 cfs ($159 \text{ m}^3/\text{sec}$). The nominal low flow is typically above 6100 cfs ($170 \text{ m}^3/\text{sec}$). Velocity of the Savannah River is 0.74 m/sec at mean annual discharge (10,200 cfs) and 0.65 m/sec at 4530 cfs.⁶¹

SRP operates three pumping stations on the Savannah River (Figure 5.2-20). Two of these, 1G and 3G, are identical ten-pump units, each located at the end of an intake canal. The third station, 5G, operates six smaller pumps on a small inlet cove of the river. The rated capacities of the pumping stations are given in Table 5.2-1. Eleven to 12 pumps in the 1G and 3G pumping stations are needed to supply cooling water for C, K, and P Areas when all three reactors are operating. Sixteen to 18 pumps will be needed to supply the reactor areas when L Reactor is restarted. Historically, the U.S. Corps of Engineers has attempted to maintain a minimum flow of 6100 cfs ($170 \text{ m}^3/\text{sec}$) at SRP. The removal of the full 1470 cfs ($41.6 \text{ m}^3/\text{sec}$) rated capacity (Table 5.2-1) would consume 24.5% of the river discharge at minimum flow of 6100 cfs. Present operations typically remove about 6.9% of the average annual Savannah River flow of 10,200 cfs (Figure 5.2-21 and Table 5.2-2).⁶¹ Daily variation in river discharge and cooling water flow are shown in Figure 5.2-22 for a typical year (1977).

5.2.2.2 Cooling Water Intake Structures

The cooling water intake structures of SRP are described in detail in Reference 61. The 1G intake canal is 550 meters long. The Savannah River fluctuates about 4.3 meters in elevation seasonally and the canal varies in width from 30 to 70 meters in response to river level with a minimum depth of 2 meters. The 3G

FIGURE 5.2-20. SRP Pumping Stations and Nearby Reference Points

TABLE 5.2-1

Savannah River Plant Pumping Station Capacities

<u>Pumping Station</u>	<u>Number of Pumps</u>	<u>Rated Pump Capacity, gal/min</u>	<u>Maximum Sustained Station Flow</u>		
			<u>m³/sec</u>	<u>m³ x 10⁶/day</u>	<u>cfs</u>
1G	8*	32,500	16.4	1.4	580
3G	10	32,500	20.5	1.8	725
5G	6	12,500	<u>4.7</u>	<u>0.4</u>	<u>165</u>
Total SRP Capacity			41.6	3.6	1470

* Ten pumps will be available for use when L Reactor is restarted.

FIGURE 5.2-21. The Relationship Between (a) River Discharge, (b) Cooling Water Withdrawn, and (c) Percent of Discharge Withdrawn

TABLE 5.2-2

Monthly Averages for River Discharge and Cooling Water Withdrawal
(cubic meters per second)

<u>River Discharge</u>	<u>Months</u>	<u>Mean</u>	<u>Std. Dev.</u>	<u>Coef. Var.</u>	<u>F*</u>
1974	12	281.13	113.139	40.3	
1975	12	364.26	102.908	28.3	1.65
1976	12	353.68	132.176	37.4	
3-yr total	36	333.02	122.416	36.8	
<u>Cooling Water Withdrawn</u>					
1974	12	20.35	4.382	21.5	
1975	12	19.88	5.054	25.4	0.32
1976	12	21.30	2.991	14.1	
3-yr total	36	20.48	4.241	20.7	
<u>Percent of Discharge Withdrawn</u>					
1974	12	7.9	2.52	31.8	
1975	12	6.0	2.83	46.8	1.52
1976	12	6.7	2.34	34.8	
3-yr total	36	6.9	2.69	39.0	

* Analyses of variance F (for 0.95 level of significance and 2 and 33 degrees of freedom) = 3.29. Lesser numbers indicate no significant difference.

FIGURE 5.2-22. Daily Variation in River Discharge (a) and Cooling Water Withdrawal (b) from December 1, 1976 to November 30, 1977

canal is 410 meters long, with a width which varies from 27 to more than 90 meters and a minimum depth of 2 meters. The 5G intake is on a small cove 12 meters wide and 20 meters from the river. The minimum depth of the cove is 2 meters. Water enters the 1G and 3G pumphouses through individual bays for each pump. Water is drawn from each bay through a rectangular gate, through a vertical trash screen, and enters the conduit to the pump.

All of the SRP pumping stations use vertical traveling screens to remove trash from the cooling water. The screens are normally cleaned once per day, a procedure requiring 15 to 30 minutes. Water jets wash trash into a trough and to a 0.3-meter-diameter pipe which empties into a swale. There is no opportunity for impinged organisms to return to the river.⁶¹

Intake velocities for typical low flow and high flow conditions for present operations are shown in Figures 5.2-23 and 5.2-24 and Table 5.2-3. With the added operation of L Area, velocities will tend to remain in the higher ranges if not exceed those shown in these two figures. Higher velocity ranges would also occur as average river flow decreases below 10,200 cfs.

Figure 5.2-25 shows the frequency distribution of pumps in operation during 1977. Typically, three to five pumps are operating in the 1G and 3G pumphouses at any given time, although a total of 12 pumps may be required at low river water flow. With the startup of L Reactor, the number of pumps operating at each pumphouse will be expected to be typically six to eight pumps with a maximum of ten pumps in each pumphouse.

The design of the 1G and 3G intake canals dictates that cooling water is withdrawn primarily from the upper layers of the river. Water is removed from the upper third of the water column at low river elevation, and from the upper two-thirds at high elevation. The proximity of Upper Three Runs Creek (Figure 5.2-20) results in 45 to 95% of the creek discharge being drawn into the 1G canal, depending upon flow rates.⁶¹

5.2.2.3 Impingement

This section estimates the potential losses of fish held against the traveling screens of the SRP pumphouses by the force of pumping the cooling water. The basic assumption used for these estimates is that supplying cooling water to C, K, and L Reactors will increase water demand by about 50 percent above the requirements of C and K Reactors only. This represents "worst case conditions." Furthermore, these estimates use data collected from a previous SRP impingement and entrainment study in 1977.⁶¹ It is

FIGURE 5.2-23. Velocity Profile of 1G Canal

Velocity profile of 1G canal at 7 pump, high flow (a-c) and at 2 pump, low flow (d-f). Transects were located 100 m downstream from inlet (a, d) near canal midpoint (b, e) and immediately upstream of pumphouse training walls (c, f). Measurements were taken 0.5 m below the surface and 0.5 m above the bottom at 5-m intervals along the transect.

FIGURE 5.2-24. Velocity Profile of 3G Canal

Velocity profile of 3G canal at 7 pump, high flow (a-c) and at 2 pump, low flow (d-f). Transects were located 100 m downstream from inlet (a-d) near canal midpoint (b, e) and immediately upstream of pumphouse training walls (c, f). Measurements were taken 0.5 m below the surface and 0.5 m above the bottom at 5-m intervals along the transect.

TABLE 5.2-3

Intake Canal High-Flow Water Velocity

Velocity, m/sec	Near Inlet		Midcanal		At Pumphouse	
	mean	SD	mean	SD	mean	SD
1G	0.17	0.115	0.15	0.078	0.24	0.037
3G	0.22	0.093	0.15	0.026	0.28	0.030

FIGURE 5.2-25. Frequency Distribution of Number of Pumps in Operations, December 1, 1976 to November 30, 1977

assumed that 1977 was a typical year. From January to December 1977, the average discharge was 9,680 cfs (274 m³/sec). From March 1977 to February 1978, the average discharge was 11,265 cfs (319 m³/sec). When compared to recent excursions in annual discharge (Figures 2.5-2 and 5.2-21), it is apparent that 1977 represents conditions close to average.

For lack of comparative data, it is not possible to evaluate how typical the fish community, particularly the anadromous species was in 1977. It is assumed to be typical. For comparative purposes, the commercial catches of American shad from 1970 through 1979 ranged from 19,000 to 127,000 pounds with an average catch of 68,100 pounds. The catch in 1977 was 45,900 pounds (Table 2.2-12).

5.2.2.3.1 Fish Fauna

More than 5000 fish of 59 species were collected during 1977 studies of the Savannah River and SRP intake canals (Table 5.2-4).⁶¹ Figure 5.2-26 indicates that the resident fish community of the intake canals is similar in species composition to the river but different in relative species abundance from the riverine community. Sunfish tend to reside in the canals more so than in the river.

5.2.2.3.2 Fish Impingement

A summary of the fish impingement in 1977 is presented in Table 5.2-5. An average of 11.2 fish impinged per day would extrapolate to 4087 fish per year. More fish were impinged during periods of higher river water flow and colder water temperatures.^{61,62} The most common species impinged were the channel catfish, warmouth, yellow perch, and threadfin shad. Typical canal residents, such as spottail shiner, redbreast sunfish, and bluegill, were impinged less than might be expected.

Increasing water volume 50 percent would lead to an additional 1,715 fish being lost for a total of 5,802 fish (Table 5.2-5). The volume of water pumped at the 5G pumphouse will not be affected by reactivation of the L Reactor.

The 1977-78 data indicated that impingement was very poorly correlated to the volume of water pumped, and was also affected by river elevation and temperature.⁶² The relationship between the number of fish impinged and these three parameters is presented in Table 5.2-6. The analysis is based on least squares linear regression, $y = mx + b$, where y is the number of fish impinged, m is the slope of the regression line, x is the independent variable

TABLE 5.2-4

The Fish Fauna of the Savannah River in the Vicinity
of the Savannah River Plant, and Their Distribution
and Relative Abundance in Recent Collections

Species	Status ¹	Distribution			Number Captured
		River	1G	3G	5G
Atlantic Sturgeon, <i>Acipenser oxyrinchus</i>	R				
Longnose Gar, <i>Lepisosteus osseus</i>	C	+	+	+	61
Florida Gar, <i>Lepisosteus platyrhincus</i>	R	+			1
Bowfin, <i>Amia calva</i>	C	+	+	+	48
American Eel, <i>Anguilla rostrata</i>	A	+	+	+	117
Blueback Herring, <i>Alosa aestivalis</i>	A	+	+	+	124
Hickory Shad, <i>Alosa mediocris</i>	R				
American Shad, <i>Alosa sapidissima</i>	A	+	+	+	190
Gizzard Shad, <i>Dorosoma cepedianum</i>	C	+	+	+	70
Threadfin Shad, <i>Dorosoma petenense</i>	U	+	+	+	22
Eastern Mudminnow, <i>Umbra pygmaea</i>	R		+		1
Redfin Pickerel, <i>Esox americanus</i>	C	+	+	+	35
Chain Pickerel, <i>Esox niger</i>	C	+	+	+	54
Carp, <i>Cyprinus carpio</i>	U	+	+	+	14
Silvery Minnow, <i>Hybognathus nuchalis</i>	A	+	+	+	339
Rosyface Chub, <i>Hybopsis rubrifrons</i>	U	+	+	+	31
Blueface Chub, <i>Nocomis leptcephalus</i>	R				
Golden Shiner, <i>Notemigonus crysoleucas</i>	U	+	+	+	30
Ironcolor Shiner, <i>Notropis chalybaeus</i>	R			+	1
Dusky Shiner, <i>Notropis cummingsae</i>	R				
Pugnose Minnow, <i>Notropis emiliae</i>	R	+	+	+	3
Spottail Shiner, <i>Notropis hudsonius</i>	A	+	+	+	866
Ohoopee Shiner, <i>Notropis leedsi</i>	U	+		+	28
Taillight Shiner, <i>Notropis maculatus</i>	R	+	+		5
Whitefin Shiner, <i>Notropis niveus</i>	U	+	+		25
Coastal Shiner, <i>Notropis petersoni</i>	U	+	+	+	55
Quillback, <i>Carpiodes cyprinus</i>	R	+			1
Creek Chubsucker, <i>Erimyzon oblongus</i>	R			+	1
Lake Chubsucker, <i>Erimyzon sucetta</i>	R		+	+	4
Spotted Sucker, <i>Minytrema melanops</i>	A	+	+	+	354
Silver Redhorse, <i>Moxostoma anisurum</i>	U	+	+	+	60
Snail Bullhead, <i>Ictalurus brunneus</i>	R	+	+	+	8
White Catfish, <i>Ictalurus catus</i>	R	+	+	+	11
Yellow Bullhead, <i>Ictalurus natalis</i>	R	+		+	3
Brown Bullhead, <i>Ictalurus nebulosus</i>	R				
Flat Bullhead, <i>Ictalurus platycephalus</i>	C	+	+	+	141
Channel Catfish, <i>Ictalurus punctatus</i>	C	+	+	+	96
Tadpole Madtom, <i>Noturus gyrinus</i>	R				
Speckled Madtom, <i>Noturus leptacanthus</i>	R		+		1
Swampfish, <i>Chologaster cornuta</i>	R				
Pirate Perch, <i>Aphredoderus sayanus</i>	R	+	+	+	11

- A - abundant: very likely to be collected in large numbers every time its habitat is sampled at the proper season.
 C - common: may be collected most of the time or in smaller numbers under the same circumstances.
 U - uncommon: may be collected quite regularly in small numbers in the appropriate habitat and season.
 R - rare: seldom encountered at any locality.

TABLE 5.2-4 (Cont'd)

Atlantic Needlefish, <i>Strongylura marina</i>	R		+			2
Starhead Topminnow, <i>Fundulus lineolatus</i>	R				+	1
Mosquitofish, <i>Gambusia affinis</i>	C	+		+	+	10
Brook Silverside, <i>Labidesthes sicculus</i>	C	+		+	+	68
White Bass, <i>Morone chrysops</i>	R			+		1
Striped Bass, <i>Morone saxatilis</i>	R					
Mud Sunfish, <i>Acantharchus pomotis</i>	R			+	+	2
Flier, <i>Centrarchus macropterus</i>	R	+		+	+	13
Banded Pygmy Sunfish, <i>Elassoma zonatum</i>	R					
Bluespotted Sunfish, <i>Enneacanthus gloriosus</i>	R			+	+	35
Redbreast Sunfish, <i>Lepomis auritus</i>	A	+		+	+	862
Green Sunfish, <i>Lepomis cyanellus</i>	R					
Pumpkinseed, <i>Lepomis gibbosus</i>	U	+		+	+	52
Warmouth, <i>Lepomis gulosus</i>	C	+		+	+	140
Bluegill, <i>Lepomis macrochirus</i>	A	+		+	+	702
Dollar Sunfish, <i>Lepomis marginatus</i>	R				+	2
Redear Sunfish, <i>Lepomis microlophus</i>	C	+		+	+	150
Spotted Sunfish, <i>Lepomis punctatus</i>	U	+		+	+	61
Largemouth Bass, <i>Micropterus salmoides</i>	C	+		+	+	92
White Crappie, <i>Pomoxis annularis</i>	R			+		1
Black Crappie, <i>Pomoxis nigromaculatus</i>	C	+		+	+	113
Swamp Darter, <i>Etheostoma fusiforme</i>	R				+	1
Christmas Darter, <i>Etheostoma hopkinsi</i>	R				+	1
Tessellated Darter, <i>Etheostoma olmstedii</i>	R			+	+	5
Yellow Perch, <i>Perca flavescens</i>	C	++		+	+	164
Blackbanded Darter, <i>Percina nigrofasciata</i>	R	+				1
Striped Mullet, <i>Mugil cephalus</i>	U	+		+	+	32
Hogchoker, <i>Trinectes maculatus</i>	U	+		+	+	12
Total Species	69	44	48	47	18	59
Total Fish						5357

- A - abundant: very likely to be collected in large numbers every time its habitat is sampled at the proper season.
- C - common: may be collected most of the time or in smaller numbers under the same circumstances.
- U - uncommon: may be collected quite regularly in small numbers in the appropriate habitat and season.
- R - rare: seldom encountered at any locality.

FIGURE 5.2-26. Relative Abundance of Fish in the Savannah River and SRP Intake Canals

TABLE 5.2-5

Summary of Fish Impingement (March 1977 to February 1978)

	<u>1G</u>	<u>3G</u>	<u>5G</u>	<u>Total</u>
Number of Sample Days	39	44	44	
Average Number of Fish Per Day*	3.3	6.1	1.8	11.2
Estimated Annual Impingement	1205	2226	657	4087
Fifty Percent Increase	1808	3339	657	5802

* Average of monthly averages, due to unequal sample sizes per month.

TABLE 5.2-6

Lineal Relationship Between Number of Fish Impinged
and Water Volume, River Elevation, and River Temperature

	Pumphouse	
	<u>1G</u>	<u>3G</u>
Water Volume		
Slope	0.553	0.623
Intercept	-0.064	-0.716
Correlation Coefficient	0.182	0.271
River Elevation		
Slope	0.049	0.509
Intercept	-0.994	-38.665
Correlation Coefficient	0.054	0.306
River Temperature		
Slope	-0.101	-0.373
Intercept	9.792	29.244
Correlation Coefficient	-0.254	-0.546

(water volume, river elevation or river temperature), and b is the y-intercept of the regression line. The goodness-of-fit, expressed as the correlation coefficient (r), is poor in all cases. Additional increase in impingement is not expected to have any significant impact on the fishery of the Savannah River.

A recent survey of fish impingement at 33 power plants on inland waters indicates that the SRP impingement of fish at SRP is low.⁶³ Impingement at these power plants ranged from 0.5 fish to 2.2 million fish per month.

5.2.2.4 Entrainment

This section estimates the potential losses of fish eggs and larvae taken into the pumphouses along with volume of cooling water pumped to the SRP reactors. The same assumptions as in Section 5.2.2.3 are used.

5.2.2.4.1 Fish Eggs

Previous studies of entrainment at SRP indicate that the most commonly entrained fish eggs are those of American shad.⁶¹ Eggs of American shad comprised 96.4% of all the fish eggs collected in the spring of 1977. The changes in egg density in the Savannah River upriver and downriver of SRP pumphouses are shown in the upper graph of Figure 5.2-27. Although some spawning began in March, the primary activity began in late April with the peak in mid-May. Spawning was completed by early June. The trend in vertical distribution for shad eggs is given in Table 5.2-7. There is a tendency for greater egg density near the bottom. Since the bottom of the river is three meters below the bottom of the intake canal entrances, those eggs suspended in the lower water column are not as susceptible to entrainment. No fish eggs were collected from Upper Three Runs Creek, and the main channel of this creek does not appear to be used as a spawning site by anadromous fish. The adjacent floodplains along the Savannah River, however, could be used by blueback herring which lay adhesive eggs; thus their eggs would not be as subject to collection in main channels.

Table 5.2-8 is an estimate of fish egg entrainment during the 1977 spawning season. Based upon the cooling water withdrawn during this period and the estimated density of shad eggs in the river, 6.8 million eggs could have been taken into the canals and potentially entrained. This is equivalent to the reproductive potential of 19 females and 9.5% of the eggs transported past the intake canals.⁶¹

FIGURE 5.2-27. Seasonal Trends in Density of Fish Eggs (Above) and Larval Fish (Below)

TABLE 5.2-7

Vertical Distribution of American Shad Eggs Based upon Composite Data from Six Upriver and Four Downriver Samples at Each Depth

Date	Surface Water			Bottom Water		
	Number of Eggs	m^3 Sampled	Eggs/ m^3	Number of Eggs	m^3 Sampled	Eggs/ m^3
April 25	11	919	0.012	30	729	0.041
May 9	36	739	0.049	77	4132	0.186
May 23	50	929	0.054	56	709	0.079
June 6	3	939	0.003	38	774	0.049

TABLE 5.2-8

Estimated "Worst Case" Fish Egg Entrainment (Millions of Eggs)

<u>Date</u>	<u>Upriver Population</u>	<u>Entrained</u>				<u>Percent of Upriver Population</u>
		<u>1G Canal</u>	<u>3G Canal</u>	<u>5G Intake</u>	<u>Total</u>	
April, 1977	23.117	0.341	0.651	0.062	1.054	4.6
May, 1977	41.810	1.756	2.898	0.340	4.994	11.9
June, 1977	7.398	0.262	0.461	0.070	0.793	10.7
Total, 1977	72.325	2.359	4.010	0.472	6.841	9.5
Fifty percent increase		3.539	6.015	0.472	10.0	

Assuming a 50 percent increase in cooling water withdrawn, the number of eggs estimated to be lost, had another reactor been operative, would have been about 10.0 million eggs or 13.9 percent of the total number (Table 5.2-8). This represents the reproductive capacity of 27.5 female American shad. If at lower flows ranging from 4,500 cfs to 6,100 cfs, similar spawning conditions were to occur, from 16.7 to 22.7 million eggs or from 23 to 31 percent of the shad eggs passing SRP could be entrained under worst case conditions. This represents the potential reproductive capacity of 46 to 62 female shad.

In perspective, the commercial shad fisheries took an estimated 2,280 to 15,240 ($\bar{x}$ 8380) female American shad from the Savannah River between 1970 to 1979. Thus, the number of eggs potentially from 19 to 62 females taken under worst case conditions at SRP represent less than 1% of the average commercial catch from the Savannah River and would be a minor impact compared to the total shad removal from the river.

5.2.2.4.2 Fish Larvae

The most commonly entrained fish larvae during the 1977 study of SRP pumping were blueback herring, Dorosoma sp., and other unidentified clupeids (Table 5.2-9). The seasonal trends in density of fish larvae are shown in Figure 5.2-27. The April peak in larval density represents an emission of blueback herring larvae which were swept from the Savannah River floodplain into the river at the mouth of Upper Three Runs Creek and thence into the vicinity of the SRP intake canals. Higher larval densities of blueback herring appear to be related directly to higher water levels in the river and adjacent floodplains as shown in Table 5.2-10 and Figure 5.2-28.

An estimate of the number of fish larvae entrained at each pumping station during April and May of 1977 is shown in Table 5.2-11. The total entrainment of 19.6 million fish larvae represents 9.1% of the 216 million fish larvae susceptible to entrainment. As indicated in Table 5.2-10, Upper Three Runs Creek and the Savannah River floodplain contribute significant numbers of larvae to the Savannah River. For example, it is estimated that in a 6.6-kilometer reach of the Savannah River near SRP, 75 million fish larvae were added to the river from adjoining floodplains and streams.⁶¹

Under conditions similar to those of the 1977 survey, an increase in cooling water pumping for L Reactor could result in 29 million larvae being entrained or 13.5% of the total larvae in the river near SRP pumphouses (Table 5.2-11).

TABLE 5.2-9

Relative Abundance of Clupeid Larvae Collected

<u>Species</u>	<u>Number</u>	<u>Percent</u>
Blueback herring	503	60.6
American shad	4	0.5
<u>Dorosoma</u> sp.	120	14.5
Unidentifiable clupeid	203	24.5

TABLE 5.2-10

The Relative Densities of Fish Larvae on Two Selected Dates

	<u>April 11-12</u>	<u>April 25-26</u>	<u>Distance, km</u>
River elevation	29 m, steady	27 m, falling	
Floodplain	Submerged	Exposed	
Larvae Per Cubic Meter			
Upriver	0.065	0.104	0.0
Upper Three Runs Creek	0.679	0.011	2.0
1G Canal	0.532	0.146	2.2
3G Canal	0.316	0.200	5.0
Downriver	0.080	0.172	6.6
Oxbow inlet	0.036	0.112	0.0
Oxbow outlet	0.136	0.137	0.9

FIGURE 5.2-28. The Input of Fish Larvae from Submerged Floodplain.

The mean, 95% confidence limits, and ± 2 std. errors are indicated by the horizontal bar, vertical line, and rectangle, respectively. Sampling stations designated by: UR — upriver, OX-I — oxbow inlet, OX-O — oxbow outlet, U3R — Upper Three Runs, 1G — 1G canal, 3G — 3G canal, and DR — downriver

TABLE 5.2-11

Estimated Fish Larvae Entrainment (As Millions of Larvae, 1977)

	<u>Upriver</u>	<u>Downriver</u>	<u>Entrained</u>		<u>5G</u>	<u>Total</u>
			<u>1G</u>	<u>3G</u>		
April, 1977	109.89	158.50	4.952	7.688	0.317	12.957
May, 1977	31.00	38.03	2.152	4.243	0.275	6.670
Total, 1977	140.89	196.53	7.104	11.931	0.592	19.627
Fifty percent increase			10.656	17.896	0.592	29.144
Total larvae downriver		196.53	196.53			
Total larvae upriver		<u>-140.89</u>				
		55.64				
Total larvae entrained		<u>+ 19.63</u>	<u>19.63</u>			
Total larvae gained						
in river segment		75.27				
Total larvae population			216.16			
Entrained larvae = 9.1% of total larvae						

5.2.2.4.3 Entrainment Uncertainties Under Different River Discharge Conditions

At no time during April or May of 1977 was river discharge at Augusta below 6990 cfs ($198 \text{ m}^3/\text{sec}$). In order to maintain committed electrical generation rates, COE normally plans to maintain a minimum discharge of 6,100 cfs ($170 \text{ m}^3/\text{sec}$), and sufficient water is usually available for this flow. However, under conditions of extended drought, this flow may fall to 4,500 cfs ($128 \text{ m}^3/\text{sec}$) or lower. When river discharge is low, the SRP will typically withdraw a larger fraction of the river volume for its needs. Equal spawning effort in a lesser volume of water would increase the density of shad eggs in the water column. But the decreased velocity and increased temperature at reduced discharge may affect spawning effort and egg survival. Commercial catch statistics for South Carolina and Georgia demonstrate that year class reproductive success is highly variable, but causative factors are speculative (Figures 2.2-3 through 2.2-5).

Similar uncertainty is associated with blueback herring reproduction. High river elevations and the associated submerged floodplains may be critical to spawning success. Herring are known to spawn over submerged aquatic vegetation in the SRP swamp. The floodplain is suspected of playing a critical role as a nursery area for larval herring. Therefore, the number of larvae susceptible to entrainment would not be necessarily similar to 1977 if flow conditions were significantly lowered, and would likely be less.

5.2.2.5 Species of Concern

The only endangered species of fish known from the Savannah River is the shortnose sturgeon. This fish is restricted to tide-water regions and has never been reported near SRP. The only commercial species of significance are the American shad and the channel catfish. These species are exploited to a limited degree by nonprofessional local fishermen: Sportfishermen are the principal consumers of river fishes, primarily pursuing sunfishes and crappie. The striped bass is a favorite quarry of fishermen in the Augusta area, but spawns near the coastal reaches of the Savannah River.⁶⁴ The blueback herring is an anadromous forage fish spawning in the SRP vicinity.

5.3 EFFECTS OF POWER PRODUCTION AND USE

L Area will need two forms of energy to operate:

- Electricity for lighting and operation of machinery and equipment (Section 3.2.2)
- Steam for heating (Section 3.2.3).

Also, L-Reactor operation will require cooling water to be pumped from the Savannah River (Section 5.2.2). These pumps consume large amounts of electricity.

5.3.1 Electric Power Demand

SRP electric demand is currently 150 to 160 megawatts. SRP power plants supply about half of this demand, or 80 megawatts. The remainder is purchased from the South Carolina Electric and Gas Company (SCE&G) power network.

By 1984, when L Reactor is operating, SRP will need approximately 200 megawatts of electricity. Current plans are to maintain SRP electrical production at the present rate (80 megawatts), and increase offsite purchases by about 50 megawatts (for a total of 120 megawatts) to meet future demand.

L Area is expected to consume about 11 to 13 megawatts.* An additional 21 megawatts per year will be needed by the river pumps to supply L Area with cooling water. Consequently, most of the anticipated 40 to 50 megawatts increase in SRP electricity demand will be due to L-Reactor operations. Most, if not all, of this additional power will be purchased from offsite sources. Therefore, L-Area electrical demand will have no direct impacts on SRP coal consumption or local air quality.

5.3.2 Steam Use

Steam is required in L Area for process services and to provide heat for the building ventilation equipment (Section 3.2.3). Peak steam demands occur during the mid-winter months, when up to 30,000 pounds per hour steam would be needed by L Area (Table 5.3-1). During the summer months, L-Area steam requirements would fall to 7000 pounds per hour. The average annual steam demand is about 14,000 pounds of steam per hour.

* Estimates based upon K-Area operations in 1979 and 1980 when 150,000 to 179,000 MWh were consumed. Assumes 24 hr/day, 7-day week, and 35% reactor downtime.

TABLE 5.3-1

Average Range of Steam Demands for L Area

<u>Period</u>	<u>Lb Steam/hr</u>
January-March	16,000 to 22,000
April-June	11,000 to 13,000
July-September	10,000 to 13,000
October-December	13,000 to 16,000
Maximum	30,000
Minimum	7,000
Average	~14,000

The K-Area power plant will supply L Area with steam. A steam line will connect the two areas (Figure 5.3-1). Presently, the two K-Area boilers operate, on the average, at only 30% of their rated capacity.* Under average L- and K-Area steam loads, one K-Area boiler can supply steam to both areas, and in addition, produce electricity. Even under peak loads, one boiler could maintain steam demand in L and K Areas, but electrical generation would be sacrificed. Therefore, the two K-Area boilers can easily accommodate L-Area steam needs without an upgrade in rated capacity.

5.3.2.1 Coal Consumption

In 1980, SRP consumed about 445,100 tons of coal. Of this total, the K-Area plant burned 46,400 (Table 5.3-2). The steam line tie-in to L Area will increase coal consumption in K Area by 7000 tons per year (15%).

5.3.2.2 Air Quality Impacts

Coal combustion produces SO_x , NO_x , and total suspended particulates (TSP). Presently, the K-Area coal-fired plant is considered a "major source" of SO_x and NO_x to the atmosphere under EPA and SCDHEC definitions. A "major" coal-fired facility as defined by both agencies

- Is rated at 250 M Btu per hour or greater
- Emits more than 100 tons per year of a "criteria" pollutant - TSP, SO_x , NO_x , HC, or CO.

Table 5.3-3 lists projected 1982 emissions from the K-Area plant as well as the incremental additions from supplying L-Area steam requirements in 1984.

SO_x , TSP, and NO_x emissions will exceed "de minimus" levels set by EPA (Table 5.3-3, Footnote ††). Normally, if a "major" source is modified and emissions increase more than the "de minimus" level, Prevention of Significant Deterioration (PSD) premonitoring and/or modeling would be required to determine air quality impacts. However, PSD review will not be needed for the K-Area boilers because the maximum-rated steam generation capacity of the plant will not be increased from the steam export modifications. Increases in hours of operation and/or production rates from existing "major" facilities that raise pollutant emissions are exempt from PSD review, as long as maximum-rated generation capacity remains unchanged.

* Rated input: 194×10^6 Btu/hr each

Total Maximum Generation Capacity: 140,000 lb/hr each

FIGURE 5.3-1. Location of the K-L Steam Line

TABLE 5.3-2

SRP Coal Consumption*

Area	Tons/yr
A	17,600
C	5,900
K	46,400
P	53,900
D	250,900
F	38,900
H	31,500
L (supplied from K)	7,000
Total	452,100

* Table 5.2.2-3 in Reference 65.

TABLE 5.3-3

K-Area Powerhouse Air Pollutant Emissions*

Pollutant	Projected 1982 Annual Emissions** K Area, tons/yr	Projected 1984 Annual Emissions L Demand,† tons/yr	Total tons/yr	PSD "de minimus" Levels,†† tons/yr
TSP	187	28	215	25
SO _x	870	130	1000	40
NO _x	345	52	397	40
CO	46	7	53	100
VOC	23	4	27	40

* Based upon EPA emission factors for bituminous coal combustion in Spreader-Stoker boilers, except for TSP and SO_x projected 1982 emissions from K Area which were extrapolated from measured 1981 emission tests.

** Based upon the present coal consumption rate of 46,400 tons/yr.

† Based upon 7000 tons/yr coal consumption for L-Area steam.

†† EPA/SCDHEC Standard to determine whether additional emissions from an existing source are significant or not.

SCDHEC regulates air pollutant releases in two ways:

- 1) South Carolina Air Pollution Control Regulations set emission rate limits from the stack for TSP and SO_x. K-Area power plant emission rates for these pollutants were recently measured and were within limits. Emission rates will remain within SCDHEC guidelines once L Area begins receiving steam from K Area (Table 5.3-4).
- 2) SCDHEC sets standards for ambient air quality over a given time period. Emissions increase from K Area due to L Reactor restartup will have little effect on current average annual air pollutant levels at the SRP boundary (Table 5.3-5).

5.3.2.3 Water Quality and Solid Waste Impacts

The K-Area power plant uses water for two major purposes:

- 1) to sluice fly ash to the ash disposal basin and 2) to generate steam. L-Area steam demand will have an effect on both uses, especially on water used for steam generation.

Well water is heated by the coal-fired boilers to generate steam. The water needs to be treated before being sent to the boilers because of its physical and chemical characteristics. To prevent corrosion of the boiler heating surfaces, boiler feedwater is conditioned to remove dissolved oxygen and to maintain proper pH. To prevent scaling the feedwater is treated by pumping sulfite solution to the deaerator and phosphate solution to the boiler drum.

A new hydrogen water softening unit and a silica absorbing unit will be needed. Other existing facilities are adequate to neutralize demineralizer waste streams to meet NPDES requirements. Currently, the K-Area water treatment facility handles 350 gpm. L-Area startup will increase water flow by 70 gpm.

The additional coal burning required in K-Area to supply steam to L Area will produce about 900 tons per year of ash and fly ash. Ashes from the boiler are sluiced to the K-Area ash basin. The annual ash input due to L Area will consume about 0.2 acre per year of the K-Area ash basin. Increases in sluice water use due to L Area will be minimal.

5.3.3 Diesel Generators

In addition to electric and coal requirements, L Area will also use diesel fuel to supply 14 diesel generators located in the two 108 buildings. Some are operated full time, and some are used for emergency purposes only.

TABLE 5.3-4

K-Area Pollutant Emission and SCDHEC Standards

<u>Pollutant</u>	<u>Average Operating Emission Rate with L-Area Tie-In,* lb/10⁶ Btu</u>	<u>SCDHEC Maximum Allowable Emission Rate,** lb/10⁶ Btu</u>
TSP	0.3	0.6
SO _x	1.5	3.5

* Based on measured stack emission rates

** For Class III Regions - Barnwell County

TABLE 5.3-5

Air Pollutant Contributions to Air Quality at the SRP Boundary

<u>Pollutant</u>	<u>Average Annual Contribution $\mu\text{g}/\text{m}^3$</u>			<u>SCDHEC Standard $\mu\text{g}/\text{m}^3$</u>	
	<u>Current K Area</u>	<u>Estimated K and L</u>	<u>SRP*</u>	<u>Maximum Air Concentration</u>	<u>Annual Allowable Increase**</u>
SO ₂	0.29	0.34	12-33	80	40
NO _x	<1	<1	15-23	100	-
TSP	NA	NA	NA	60	37

* Reference 66

** TSP - annual geometric mean; SO_x-annual arithmetic mean

NA - Information not available

P, K, and C Reactors have the same number and type of diesel generators as those in L Area. Estimates of annual diesel fuel consumption in L Area are based upon operating experience in P, K, and C Reactor Areas.

Each 108 building has four 180 hp Caterpillar diesel engines which drive 103 kW DC generators. Six of these units are normally operated at all times, and the remaining two are on standby. The units supply electricity for six process pump DC motors which maintain process cooling water flow to the reactor in case of AC electric power outage.

Each 108 building also has a General Motors 1000-kW generator which supplies emergency backup power. Four other diesel generators are located throughout L Area and provide backup power for ventilation fans, street lights, and other equipment.

To operate the six Caterpillar diesels full time, over 250,000 gallons of diesel fuel per year are consumed. Burning this volume of diesel fuel will result in air pollutant releases listed in Table 5.3-6. Substantially more NO_x is emitted compared to other pollutants (total from 6 diesels = 59 tons per year). This amount of NO_x release is similar to what a coal-fired plant in L Area would emit (Section 9.2.1.2) and additional NO_x releases from K Area as a result of supplying steam to L Area (Section 5.3.2).

Projected diesel emissions from L Area do not include releases from operating emergency diesels. These generators are used infrequently (primarily for testing), and diesel fuel consumption would be only several thousand gallons per year.

5.3.4 Other Facilities Affected

L Reactor production will increase the amount of fuel and target material processing in F, H, and M Areas. The main environmental impact of increased operations in these facilities will be the added release of NO_x to the atmosphere.

Projected 1985 NO_x releases from F Area will rise at least two-fold due to both L Reactor restart and other SRP program changes. NO_x emissions from H Area will decrease by a factor of two. About 25% of the total F, H, and M Area emissions in 1985 will result from processing L-Reactor materials (Table 5.3-7). Air emissions permits for these facilities will be revised to reflect process changes.

TABLE 5.3-6

Air Pollutant Emissions from Diesel Generators

Pollutant	Tons/yr		
	L-Area Diesels*	L-Area Power Plant**	K-Area Increase†
CO	13	5	7
SO _x	4	19	130
TSP	4	5	28
NO _x	59	45	52

* Based upon six Caterpillar diesels operating full time and consuming 250,000 gal of diesel fuel/yr.

** Based upon 6000 tons/yr coal, if a power plant were built.

† Based upon 7000 tons/yr additional coal consumed due to L-Area tie-in.

TABLE 5.3-7

NO_x Emissions Increase from L Reactor Restart in SRP Processing Areas

Area	Tons/year		
	Present Emissions*	1985 Forecast	
		Total	Due to L
F	250	600**	150†
H	61	30**	8†
M	7	10	3†

* Based upon release rates listed in January 1978 SCDHEC air emissions permit application.

** Includes other future process changes besides L Reactor Restartup.

† Based upon approximately 25% of the total 1985 releases.

5.3.5 Transportation

Cars and light trucks assigned to L Area are expected to operate about 400,000 miles per year and to use about 39,000 gallons of fuel per year (gasohol). Trucks of 10-ton capacity or less will be operated about 150,000 to 180,000 miles per year hauling a variety of materials, supplies, and wastes to and from the area. These trucks will consume about 17,000 gallons of fuel per year for a combined total of 56,000 gallons of fuel per year. The incremental traffic increase will be about 8% of the present SRP vehicular traffic. The effects of this fuel consumption on the air quality of SRP will be negligible.

5.3.6 Summary of Air Quality Impacts

NO_x releases resulting from L-Reactor operations are higher than other air pollutant emissions increases (Table 5.3-8). Overall, L Reactor restartup will increase future SRP NO_x emissions by about 5%. SO₂ and TSP releases will add about 1%. Releases related to L-Reactor operations will contribute 1.1 µg/m³ NO_x to the ambient air at the SRP boundary. This compares to 15-23 µg/m³ NO_x estimated from all other SRP sources in 1985. Total SO₂ and TSP releases from L Reactor restart will add less than 1 µg/m³ each.

TABLE 5.3-8

Summary of Air Pollutant Releases from L-Reactor Operation

Area	Projected 1984-1985 Emission tons/yr*		
	SO _x	TSP	NO _x
F	-	-	150
H	-	-	8
M	-	-	3
K	130	28	45
L-Area Diesels	4	4	59
Total L Reactor	134	32	265
Total SRP**	10,000	2500	5500

* Emissions less than 1 ton/yr not listed.

** Based on adjusted ERDA 1537 values, Reference 66.

5.4 EFFECTS OF WATER USE AND NONRADIOLOGICAL LIQUID DISCHARGES

5.4.1 L-Area Liquid Discharge

L-Area will release wastewater and storm runoff from outfalls along Steel Creek and Pen Branch (Figure 5.4-1 and Table 5.4-1).⁶⁷ P Area and the SRP railroad classification yard also discharge to Steel Creek (Figures 5.4-2 and 5.4-3). The estimated flows from L Area, P Area, and the classification yard are listed in Figures 5.4-4 through 5.4-6. Only four L-Area outfalls to Steel Creek will contain any appreciable quantities of chemicals — L-3, L-7, L-8 and L-10. The remaining outfalls discharge storm runoff (Table 5.4-1 and Appendix F).

L-Area liquid effluents will have similar chemical compositions as those from other SRP reactor areas (Table 5.4-2). A portion of the pollutants discharged through the main process sewer (L-7) originates from Savannah River water pumped to cool the reactor. Present Steel Creek water quality is typical of a relatively unimpacted stream at SRP (Table 5.4-3 and Figures 5.4-7 and 5.4-8).

Releasing 400 cfs of cooling water from L Reactor will eliminate Steel Creek as a Class B stream suitable for the propagation and survival of fish and other flora and fauna.⁶⁸ Even though discharges from L Area will contain quantities of inorganic chemicals and heavy metals in the once-through cooling water (Tables 5.4-4 through 5.4-6), concentrations in the cooling water effluent will be low (Appendix F), and impacts to the creek will be minimal from these chemicals. The flow of cooling water will probably transport most of the chemicals from Steel Creek through the Savannah River swamp and eventually into the river itself.

The chemical impacts on the swamp are unknown but probably small compared to thermally related impacts from the cooling water. Chemicals reaching the Savannah River will be further diluted to about 25-fold above concentrations in Steel Creek.

5.4.2 Suspended Sediment Discharge from the 186-L Basin

The 25 million-gallon emergency cooling water basin (186-basin) is cleaned annually to control the Asiatic clam, Corbicula. Sediments accumulated at the bottom of the basin are flushed to Steel Creek. Suspended solids concentrations in the effluent

FIGURE 5.4-1. Location of L-Area Discharges

FIGURE 5.4-2. Location of P-Area Discharges to Steel Creek

FIGURE 5.4-3. Location of Classification Yard Discharges to Steel Creek

L Area, (M³/d)

Water Supply —————

Sanitary - - - - -

Process Process

Nonprocess -

Steam - - - - -

(Area is on Standby)

 $\frac{M^3/d}{2.446} = \text{ft}^3/\text{sec}$

(a) Discharges to Pen Branch and some discharges to the ground are not shown

FIGURE 5.4-4. L-Area Discharges(a)

FIGURE 5.4-5. P-Area Discharges to Steel Creek^(a) (b)

FIGURE 5.4-6. Classification yard Discharges to Steel Creek^(a)

TABLE 5.4-1

L-Area Discharges

<u>Outfall No.</u>	<u>Type Water</u>	<u>Volume, (ft³/sec)</u>	<u>Source</u>
<u>Discharges to Steel Creek</u>			
L-1	Storm	Varies	Ground Area
L-2	Storm	Varies	Ground Area
L-3	Storm and Process Overflow	0.11*	Water Plant
L-4	Storm	None	Seepage Basin
L-7	River, Sanitary Treated	381.82	Reactor, Sanitary Treatment Plant, Cooling Water Basin
L-8	Nonprocess Cooling	1.90	Reactor and Cooling Water Basin
L-9	Storm	Varies	Substation and Gatehouse
L-10	Storm and Cooling	0.02*	Office and Service Buildings
L-11	Storm	Varies	Gatehouse and Patrol Building
<u>Discharges to Pen Branch</u>			
L-13	Storm	Varies	Office and Service Buildings
L-14	Ash Basin Overflow (No longer in use, therefore, no overflow expected)	Varies	Ash Basin
L-15, -16, -17	River Pipeline to L Area	Varies	Settling/Seepage Basin
<u>Discharges to Ground or Seepage Basin</u>			
L-5	Process Sewer	Not Used	Contaminated Equipment Workshop
L-6	Process Sewer	Varies	Reactor Building
L-12	Discharge from Transfer Line and Emergency Cooling Water	Varies	Reactor Building
Unlisted	Steam Condensate	0.02	Steam Line

* Does not include storm water which varies.

TABLE 5.4-2

Similar Reactor Outfalls Used to Predict L-Area Liquid Discharges

<u>Chemical Analysis in NPDES Permit Application*</u>	<u>Corresponding L-Area Outfall</u>	<u>Use</u>	<u>Flow L/min</u>	<u>Approximate Percent Time in Use</u>
C-4	L-7	Cooling Water Process Water Cooling Reservoir	651,000	65%
K-1	L-10	Heating/Cooling Offices	70	100%
K-3	L-3	Water Treatment Plant	1720	100%
K-8	L-8	Cooling Water for Engine Building	3220	65%

* Reference 67

TABLE 5.4-3

Water Quality Monitoring Data for Steel Creek at SRP Road A for 1980

Parameter	Units	1/10 Jan.	2/8 Feb.	3/6 March	4/9 April	5/8 May	6/9 June	7/10 July	8/7 Aug.	9/4 Sept.	10/8 Oct.	11/6 Nov.	12/2 Dec.
Temperature	°C	11	10	12	20	22	23	29	27	27	16	12	10
pH	pH	6.8	6.7	7.3	6.5	7.5	7.3	7.4	7.5	7.3	7.2	7.6	7.3
Dissolved Oxygen	mg/l	13	9.8	13	11	10	8.4	5.4	7.1	6.1	10	10	9.5
Alkalinity (CaCO ₃)	mg/l	17	16	13	61	20	20	21	21	19	31	22	18
Suspended Solids	mg/l	7.0	4.0	4.0	16	8.0	6.0	40	5.0	9.0	8.0	15	4.0
Volatile Solids	mg/l	16	12	19	29	4.0	14	29	31	18	18	19	3.0
Total Dissolved Solids	mg/l	51	40	44	43	25	38	62	51	44	50	51	37
Total Solids	mg/l	58	44	48	59	33	44	100	56	53	58	66	41
Fixed Residue	mg/l	42	32	29	30	29	30	73	25	35	40	47	38
COD	mg/l	10	6.0	8.0	22	12	12	14	7.0	8.0	<5	5.0	21
Kjeldahl N	mg/l												
Chloride (Cl)	mg/l	6.0	4.1	4.0	3.2	3.2	3.5	4.4	5.1	4.1	4.2	4.2	3.7
Nitrite (NO ₂ -N)	mg/l	-	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Nitrate (NO ₃ -N)	mg/l	-	0.11	0.08	<0.02	0.20	0.22	0.22	0.14	0.14	0.14	0.13	0.16
Sulfate (SO ₄ -S)	mg/l	2.0	3.0	2.0	<2	2.0	2.0	3.0	2.0	2.0	2.0	2.0	<2
Orthophosphate (O-PO ₄ -P)	mg/l	-	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Total Phosphate (PO ₄ -P)	mg/l	-	0.02	0.02	0.03	0.02	0.02	0.10	0.02	0.02	0.02	0.03	0.02
Aluminum (Al)	mg/l	0.50	0.50	<0.5	<0.5	<0.5	0.50	<0.5	<0.5	<0.5	0.50	0.75	<.5
Ammonia (NH ₄)	mg/l	-	0.03	0.02	0.01	0.03	0.02	0.01	0.03	0.01	0.02	0.02	0.01
Calcium (Ca)	mg/l	10.65	9.0	8.0	7.0	8.0	15	7.4	12	9.8	12	13	8.1
Sodium (Na)	mg/l	5.9	7.1	6.5	5.9	5.0	5.5	4.8	6.7	7.1	5.2	6.2	2.4
Total Iron (Fe)	mg/l	0.50	0.60	1.0	0.75	0.70	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.23
Lead (Pb)	mg/l	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5

FIGURE 5.4-7. Steel Creek Water Quality
 (A) Temperature and Dissolved Oxygen,
 (B) pH, and (C) Solids

FIGURE 5.4-8. Steel Creek Water Quality
 (A) Hardness (B) Common Ions

TABLE 5.4-4

L-Area Liquid Effluents: General Chemical and Physical —
Pollutant Loads, Metric Ton/yr

Pollutant	Outfall				Total
	L-3	L-7	L-8	L-10	
BOD	3	725	<2	<1	730
COD	5	4627	13	<1	4640
TSS	2	1700	4	<1	1700
Ammonia	<1	145	<1	<1	145
Cl	1	29	<1	<1	30
NO ₃ -NO ₂	<1	37	<1	<1	37
Oil/Grease	<6	1450	<11	<1	1450
Total Phosphate	<1	1	<1	-	1
Surfactants	15	5	<1	-	20
SO ₄ -SO ₃	<17	1017	<10	<1	1017

TABLE 5.4-5

L-Area Liquid Effluent Loads — Organics, kg/yr

<u>Pollutant</u>	<u>Outfall</u>				<u>Total</u>
	<u>L-3</u>	<u>L-7</u>	<u>L-8</u>	<u>L-10</u>	
α , ν BHC	-	-	0.05	-	0.05
Cyanide	<18	<4500	<34	<1	<4500
Benzene/Ethylbenzene	-	450	<2	<1	<450
Chloroform	32	<223	-	<1	<250
Bis (2 Chloroisopropyl) ether	-	450	-	-	450
Heptachlor	-	-	0.01	-	0.01
Total Phenol	1.8	<450	<3	<1	<450
Methylene Chloride	<1	<223	<1	<1	<225
Phthalates	-	223	-	<1	<223
Tetrachloroethylene	-	-	3	<1	<3
Trichloroethane	-	<223	-	-	<223
Toluene	<1	223	2	<1	225

TABLE 5.4-6

L-Area Liquid Effluents Loads — Trace and Heavy Metals, kg/yr

Pollutant	Outfall				Approximate Total
	L-3	L-7	L-8	L-10	
Al	438	<22,300	<511	10	<23,000
Fe	<36	90,155	694	4	91,000
Mg	913	23,725	1812	<1	27,000
Mo	1	2230	<17	<1	2,200
Mn	<9	10,914	77	24	11,000
Cd	<1	<664	<5	<1	<670
Cr	<1	<8778	17	<1	<8800
Cu	<9	<2230	22	<1	<2250
Pb	2	223	2	<1	225
Hg	<1	66	<1	<1	66
Ni	<1	<6643	12	<1	<6650
Se	<2	877	<3	<1	880
Ag	<1	88	<1	<1	90
Zn	8	15,659	17	<1	15,700

(about 60-160 ppm) will exceed both normal stream conditions (Figure 5.4-7), and the current NPDES permit limitation of 50 ppm.⁶⁷ SRP has recently requested a variance from SCDHEC to discharge these high-sediment loads.⁶⁷

The basin is cleaned while the reactor is shut down. Three days are normally required to flush the basin. About 7 tons of sediment per day will be discharged to Steel Creek. Presently, only 0.8 ton of sediment per day is transported in the SRP creeks when the reactors are shut down. When the reactors are operating up to 5 tons per day of sediment is moved.³

Because stream flow is low during cleaning operations, most of the suspended solids released from the 186 basin will settle in the stream bed before reaching the swamp. However, once the reactor becomes operational again, a portion of the sediment settled in the stream bed will remobilize and reach the swamp. The thermal stress on the Steel Creek ecosystem from thermal discharges will most likely mask any effect due to sediment discharge and deposition.

5.4.3 Sanitary Discharges

Sanitary waste water will be chlorinated (NaOCl) and discharged to the L-Area Reactor cooling-water sewer (L-7). The sanitary waste water treatment plant is designed for a flow of 35,000 gallons per day (Section 3.2.4). These discharges will meet NPDES Permit Requirements and have no significant impact on Steel Creek.

5.5 DECOMMISSIONING AND DISMANTLING

A plan for decontaminating and decommissioning all facilities at SRP has not been developed; therefore, the decommissioning plan for L Area is based upon the following:

- NRC Program Status Paper, May 1980⁶⁹
- The decommissioning plan for the DWPF⁶⁵
- The Decommissioning Handbook⁷⁰
- The decommissioning plan for the 100-F production reactor at Hanford⁷¹
- The shutdown plan used for L Area in 1968

Three* basic decommissioning options are defined according to the NRC Program Status Paper of May 1980.⁶⁹ These options are DECON, SAFSTOR, and ENTOMB. L-Area decommissioning is expected to follow the SAFSTOR option.

DECON is defined as the immediate removal of all radioactive materials to levels which are considered acceptable to permit the property to be released for unrestricted use.⁷² This option uses a chemical decontamination of the structure and the internals. Decontamination is followed by dismantlement, transportation, and burial of the internals. In a final step, the outer structure is demolished, and the site is restored to its precommissioning status.

ENTOMB is the encasement of the facility in a material possessing long-lived structural integrity until such a time when the dose level is amenable to unrestricted use. This option is intended for sites where the radioactivity will decrease the acceptable limits within a reasonable time period. A reasonable time period for ENTOMB is approximately 100 years.⁷² The ENTOMB option is not viable for facilities such as L Reactor in which isotopes with long half-lives contribute to a major portion of the radioactivity.

SAFSTOR is defined as the conditions necessary to place a facility in temporary storage within acceptable risk levels for subsequent decontamination and unrestricted facility use. L-Area decommissioning is expected to follow this option. The SAFSTOR option is divided into six major phases:

- Chemical decontamination
- Mechanical decontamination and fixing of residual radioactivity
- Equipment deactivation

* The No-Action option is not considered.

- Preparation for interim care
- Interim care (surveillance and maintenance)
- Final dismantlement

Chemical decontamination involves rinsing, chemical cleaning, and flushing of internal surfaces of process lines, vessels, and equipment. External surfaces or process equipment, lines, and structures will be sprayed remotely with a series of chemical solutions or steam.

Next, all equipment and systems not needed during this interim care period are deactivated. Typical activities include final draining of process lines, closing, or opening valves depending upon the function, blanking flanges, and disconnecting utilities. Cooling water systems for the diesels are drained, and fuel oil is removed from tanks.

During preparation for the interim care period, security locks are installed on all exterior doors and on doors leading to highly contaminated areas. Intrusion alarms, fire detection systems, radiation monitoring equipment, and ventilation systems are inspected to assure safety during the interim care period.

During interim care, the facility and total site are kept inaccessible to the public and unavailable for other than nuclear use. Surveillance, maintenance, certain operations such as ventilation, and security activities are conducted to assure safe confinement of the radioactivity. Scheduled programs of periodic inspections and monitoring are continued.

Final dismantlement begins with a planning phase. The equipment that is necessary for dismantlement but was previously made inoperable is activated and refurbished as necessary. The other phases of final dismantlement are removal of contaminated equipment, mechanical decontamination of structures, demolition of structures, and restoration of the site.

Removal of contaminated equipment involves disconnecting and cutting where necessary, packaging, loading, and transportation of the equipment to a waste disposal facility and final disposal. A remote operational capability is added to accomplish equipment removal where high radiation levels prohibit contact operations.

In the demolition and restoration phase, all above-grade portions of the plant structures are demolished by conventional methods, such as explosive and impact balls. The site is then graded and revegetated.

5.6 EFFECTS ON OTHER SRP OPERATIONS

The Savannah River Plant was constructed during the 1950's to produce the basic materials used in the fabrication of nuclear weapons, primarily plutonium-239 and tritium. The uranium necessary for this production is received from Oak Ridge, Tennessee (enriched uranium) and Fernald, Ohio (depleted uranium). The plutonium and tritium products are sent to DOE weapons plants, primarily the Rocky Flats Plant in Colorado. Only DOE facilities at Hanford in Washington State are also capable of producing plutonium for weapons purposes.

The SRP facilities (Figure 2.1-2) consist primarily of

- The Savannah River Laboratory - a process development laboratory to support production operations and administrative facilities (A Area)
- A coal-fired power plant (D Area)
- Heavy water production facility (D Area)
- River water pumps to supply once-through cooling water for the production reactors
- A fuel and target fabrication facility (M Area)
- The operating production reactors (P, K, and C Areas)
- The separations areas for processing irradiated materials (F and H Areas)
- Waste storage facilities, including the F- and H-Areas high-level waste tank farms and
- The SRP low-level burial ground between F and H Areas.

Those areas most affected by L-Reactor restart will be the fuel and target fabrication facility (M Area), the separations areas (F and H Areas), waste storage facilities, including both the tank farms and the burial grounds, and the river water pumps. K Area will be affected slightly along with the heavy water rework facility (D Area).

Two other facilities are being planned for SRP. These include the Fuel Materials Facility (FMF) for possible construction near the present facilities in F Area. This facility would produce fuel materials for naval reactors. The restart of L Reactor will not affect this facility. A second facility is the Defense Waste Processing Facility (DWPF), which is planned north of H-Area at the proposed S-Area site. This plant would convert SRP high-level liquid waste currently stored in the tank farms into an inert form suitable for long-term storage. The restart of L Reactor would have incremental effects on the long-term use of the proposed DWPF.

5.6.1 Fuel and Target Fabrication

The fuel and target fabrication area (M Area) is about 10.8 miles northwest of L Area (Figure 2.1-2). The area contains facilities for manufacturing, bonding, extruding, and testing target and fuel elements to be irradiated in SRP reactors. Test facilities include an analytical laboratory, two test reactors, and a metallurgical laboratory.

The additional fuel and target fabrication for L-Area Reactor, coupled with proposed changes in the mode of operation will require an increase in the number of employees. About 60 additional wage roll and about 18 monthly salaried employees will be needed. Present schedules call for additional materials to be ordered in September 1981 and 52 additional employees to be hired by July 1983. Another 26 employees will be hired around January 1984.

5.6.2 Production Reactors

SRP originally operated five production reactors: P, K, C, R, and L (Figure 2.1-2). R and L Reactors were placed in standby condition in 1964 and 1968, respectively.

The restart of L Reactor will have little if any affect on other SRP reactors. L Reactor will obtain its steam supply from the K-Area powerhouse, and the effects on the operation of this powerhouse are given in Section 5.3.2.

5.6.3 Separations Facilities

SRP has two main chemical separations areas: 200-F and 200-H. F and H Areas are both NNW of L Area and are about 6.3 and 5.6 miles from L Area, respectively (Figure 2.2-2). Each area contains a large shielded "canyon" building for processing irradiated fuel and/or targets, a waste concentration and storage system, seepage basins, powerhouse, an office complex, and miscellaneous service facilities. F Area also contains the main analytical laboratory and two buildings for housing plutonium processing facilities. H Area contains the buildings for processing tritium, the Receiving Basin for Offsite Fuels (RBOF), and the Resin Regeneration Facility (RRF).

Restart of L Reactor will increase the workload and manpower needs in the 200 Areas. About 80 additional employees will be required.

5.6.4 Heavy Water Facilities

The heavy water production area (D Area) is located about eight miles west of L Area (Figure 2.1-2) and was shut down in early 1982 except for the heavy water rework unit. Sufficient heavy water is in storage at SRP so that additional heavy water will not be needed for L restart. Eventually, as more heavy water must be reworked from L Area operations, the use of the rework unit in D Area will increase by about one-third.

The largest steam power plant at SRP is located in D Area. The steam power plant will not be affected by L-Area operations.

5.6.5 Waste Facilities

5.6.5.1 Tank Farm

The liquid radioactive wastes produced at SRP are stored in large (250,000 to 1,300,000-gallon) underground tanks in F and H Areas where most of the radioactive waste is generated. F and H Areas are located about 5.5 miles from L Area on relatively high ground between Upper Three Runs Creek and Four Mile Creek (Figure 5.6-1). At present, 37 tanks are in use; 18 in F Area (Figure 5.6-2) and 19 in H Area (Figure 5.6-3). An additional 14 tanks of a new design are in various stages of construction to give a total of 51 tanks. The new tanks will be used to replace some of the tanks of older design and to provide safe interim storage of radioactive waste from current operations.

Additional processing resulting from the operation of L Reactor will generate about 300,000 to 600,000 gallons of liquid waste per year. This waste, like other highly radioactive SRP liquid waste, will be stored in waste tanks in F or H Area. The waste will be concentrated by evaporation to about 100,000 to 200,000 gallons to minimize the needed storage capacity. A maximum of three waste tanks will be required per decade of L-Area operation, one for storage of fresh waste and two for storage of concentrated salt. This need can be filled by using three of the 14 new tanks already planned; therefore, the operation of L Reactor will not create an immediate need for additional tanks.^{73,74} Future waste tank use is also dependent on construction and operation of the proposed DWPF.

5.6.5.2 Burial Ground

Solid radioactive waste generated at SRP and occasional special shipments from offsite are stored underground in one centrally located storage site.⁶⁶ The storage site (burial

FIGURE 5.6-1. Relative Locations of Tank Farms and Separations Areas

FIGURE 5.6-2. F-Area Waste Tank Locations

FIGURE 5.6-3. H-Area Waste Tank Locations

ground) occupies 195 acres between F and H (Figure 5.6-1), approximately 5.5 miles from L Area and about 6 miles from the nearest plant boundary. The area is fenced, and unpaved roads are provided to permit trucks to transport waste within the area. Three railroad spurs permit transportation of large pieces of contaminated equipment from the plant operating areas into the burial ground.

The burial ground is divided into sections to accommodate different types and levels of radioactivity in waste materials. Waste is buried in earthen trenches which are nominally 20 feet deep and 20 feet wide. The exact location of burial trenches is defined, and accurate records are kept of the contents. About 36 acres of the burial ground space is available for future use, with an expected life of the burial ground of about 11.5 years.

Operation of L Reactor and its support facilities will result in an additional 200,000 cubic feet of low-level waste to the burial ground per year beginning in 1984. This volume of waste will occupy about one acre of the burial ground space for each year of operation of L Area. The additional waste associated with L Reactor operation will reduce the estimated fill time of the burial ground to about 9 years.

5.6.5.3 Future High-level Waste Solidification Facilities

Present plans are to construct a new facility, the Defense Waste Processing Facility (DWPF), to immobilize the radioactive defense waste stored at SRP.⁶⁵ The immobilized waste consists of a vitrified glass (reference case)⁶⁵ product which will be sealed in steel containers for later permanent disposal. The DWPF and the burial site for decontaminated salt product mixed with concrete ("saltcrete") will be located in two new areas designated as 200-S and 200-Z (Figure 5.6-4). These areas are adjacent to the 200-H Area which is about 5.8 miles north of L Area.

The high-level waste associated with L Reactor will generate an additional 6,300 to 12,000 cubic feet of vitrified waste per ten years of operation. This glass product will require about 250 to 500 steel canisters compared to about 8000 canisters which are projected to be required for other SRP wastes. The "saltcrete" produced per ten years of L Reactor operation and subsequent high-level waste processing in the DWPF will require about 0.75 acre of the proposed "saltcrete" burial site. Presently, 25 acres of land is required for the "saltcrete" from all other SRP waste reprocessing.

FIGURE 5.6-4. Location of Proposed and Z Areas

5.6.6 Pumping Facilities

SRP facilities for pumping water from the Savannah River consists of three stations, 1G, 3G, and 5G. The two pumps in Station 1G which are inoperable will be renovated and put into service.

5.6.7 Transportation Systems

Restart of L Area will increase the total number of onsite shipments by an amount typical of the individual reactor areas now operating. Rail shipments can be made with existing casks and equipment with current rail crews. Truck shipments involving unirradiated reactor fuel, deionizer casks, and wastes probably can be made with existing equipment using Traffic and Transportation (T&T) crews currently assigned to these tasks. Higher volume shipments, such as scrap metal, waste dumpsters, and D₂O drums, may require purchase of additional equipment and a modest increase in T&T crews. Also, the operation of L Area would require about the same number of nonradioactive shipments by T&T and vendor trucks as the other individual reactor areas. No significant impact on SRP transportation systems is expected from the operation of L Area.

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6. EFFLUENT AND ENVIRONMENTAL MEASUREMENTS AND MONITORING PROGRAMS

6.1 SAVANNAH RIVER PLANT RADIOLOGICAL MONITORING PROGRAM

An extensive surveillance program has been maintained since 1951 (before SRP startup) to determine the concentrations of radio-nuclides in a 1,200-square-mile area in the environs of the plant and the radiation exposure of the population resulting from SRP operations. Samples representing most segments of the environment that may conceivably be affected by SRP radioactive emissions are monitored to ensure a safe environment. Air and water are the major dispersal media. The results of this monitoring program are reported annually to the public.¹

Locations of sampling points for water and atmospheric samples are shown in Figures 6.1-1 through 6.1-5. Samples collected and analyses performed are shown in Table 6.1-1. Details of the sampling program may be obtained from Reference 1. Annual reports from 1972 to the present are available in the DPSPU-30-1 Series.

6.2 SRP NONRADIOLOGICAL MONITORING PROGRAM

6.2.1 Academy of Natural Sciences of Philadelphia Surveys

Since 1951, surveys of the aquatic environment and water quality of the Savannah River have been made by the Academy of Natural Sciences of Philadelphia (ANSP) upstream, adjacent to, and downstream from SRP. ANSP river sampling locations are shown in Figure 6.2-1. Quarterly surveys by ANSP include diatom flora, other algae, insects, invertebrates, and fish.² Periodically, ANSP makes comprehensive surveys of the biota and chemical water quality of the Savannah River.³

6.2.2 SRP Water Quality Monitoring

Water quality analyses for nonradioactive materials in the Savannah River became a part of the routine environmental monitoring program at SRP in 1959. Routine water quality analyses were begun on plant streams in 1972. Sampling locations are shown in Figure 6.2-2. Analyses and the sensitivities of each analysis are listed in Table 6.2-1. Details of the monitoring program from 1972 to the present may be obtained from Reference 1.

FIGURE 6.1-2. Continuous Air Monitoring Stations and Public Water Sample Locations for SRP

FIGURE 6.1-3. Distant Air Monitoring Stations for SRP

FIGURE 6.1-4. Vegetation Sample Locations at Plant Perimeter and at 25-Mile Radius from SRP

FIGURE 6.1-5. Food Sample Locations

TABLE 6.1-1

Typical Analyses for Potential SRP Radionuclides in the Environment

Location Type	Sample Collected	Collection	Analysis	Sensitivity	Instrumentation
Air Monitoring Station	Particulates	Weekly	α	0.0002 pCi/m ³	1
			β, γ	0.0088 pCi/m	2
	Rain Water	Weekly	α	0.0007 nCi/m ²	1
			β, γ	0.02 nCi/m ²	2
			⁹⁰ Sr	0.004 nCi/m ²	3
			³ H	0.3 pCi/mL	4
			²³⁸⁻²³⁹ Pu	0.001 pCi/m ²	5
	Atmospheric Moisture	Weekly	³ H	0.3 pCi/mL	4
	Iodine	Weekly	¹³¹ I	1.0 pCi/m ³	5
	Vegetation	Monthly	α	0.12 pCi/g	1
			β, γ	3.5 pCi/g	2
	TLD Dosimeter	Quarterly	dose	0.02 mR/day	6
Drinking Water	Water	Semi-annually	α	0.25 pCi/L	1
			β, γ	7.0 pCi/L	2
			³ H	300 pCi/L	4
Stream and River Water	Water	Weekly	α	0.25 pCi/L	1
			β, γ	7.0 pCi/L	2
			³ H	300 pCi/L	4
			⁹⁰ Sr	0.02 pCi/L	3
			¹³⁷ Cs	7 pCi/L	2

1. Zinc Sulfide alpha counter.
2. Gas flow proportional beta counter.
3. Low background beta counter.
4. Liquid Scintillation counter.
5. NaI (tL) detector, 9 x 9 inches.
6. Photometric TLD Reader.

FIGURE 6.2-1. Survey Stations on the Savannah River

FIGURE 6.2-2. Water Quality and Fecal Coliform Sampling Locations

TABLE 6.2-1

Water Quality Analyses

<u>Parameter</u>	<u>Sensitivity mg/L</u>
pH* (tenth of a unit)	0.0
Alkalinity	1
Hardness	0.1
Conductivity (umhos)	1
Suspended Solids	1
Volatile Solids	1
Total Dissolved Solids	1
Fixed Residue	1
Biochemical Oxygen Demand	1.0
Chemical Oxygen Demand	5
Lignin	1.0
Surfactant	0.02
Chloride	0.1
Nitrite	0.02
Nitrate	0.02
Sulfate	2
Sulfide	1.0
Ortho-Phosphate	0.02
Total Phosphate	0.02
Aluminum	0.5
Ammonia	0.1
Calcium	0.1
Sodium	0.1
Total Iron	0.1
Lead	0.5
Fecal Coliform (#/100 mL)	-

* Field analysis.

6.2.3 Ambient Air Monitoring

The SRP air monitoring network consists of five stations, all of which monitor for total suspended particulates (TSP) and nitrogen dioxide (NO₂), three monitor for sulfur dioxide (SO₂), and two monitor for ozone (O₃) (Figure 6.2-3 and Table 6.2-2).

The instrumentation has been approved by the U. S. Environmental Protection Agency as a reference or equivalent method (Table 6.2-3).

6.2.4 U. S. Geological Survey Monitoring Program

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 Creek, Four Mile Creek, and Steel Creek, Figure 6.2-4.

6.3 L-REACTOR PREOPERATIONAL MONITORING PROGRAM

To supplement the existing onsite radiological monitoring program described in Section 6.1, two monitoring devices, thermoluminescent dosimeters (TLD's) and paddlewheel water samplers, were installed in L Area.

Thermoluminescent dosimeters were installed at the four corners of L Area on February 6, 1981. The TLD's are mounted one meter above ground. Dosimeters are changed every three months and the accumulated dose is measured.

A paddlewheel water sampler was installed on February 27, 1981, in Steel Creek at Road B (SC-2) to serve as a control station for L-Area discharges. Another paddlewheel sampler (SC-3) was installed in the cooling water canal to monitor liquid releases from L Area. Locations of the monitors are shown in Figure 6.1-1. Water samples are collected weekly from the monitors.

The existing SRP air and water quality monitoring programs are adequate to monitor nonradioactive pollutants from L Area. No additional water quality monitoring is planned.

FIGURE 6.2-3. Locations of Ambient Air Monitoring Stations at the Savannah River Plant

TABLE 6.2-2

SRP Ambient Air Monitoring Stations

	SRP Map Coordinates		Parameter			
	North	East	TSP	NO _x	SO	O
614-36G	39,149.4	35,310.1	x	x	x	x
614-38G	87,821.86	42,230.00	x	x		
614-39G	89,285.6	66,235.1	x	x	x	x
614-40G	66,990.7	16,811.7	x	x	x	
614-41G	56,103.13	76,440.15	x	x		

TABLE 6.2-3

SRP Ambient Air Analytical Instruments

Parameter	Manufacturer	Model No.	USEPA Method No.*
NO	Monitor Labs	8440E	Reference Method RFNA 0677-021
O	Monitor Labs	8410E	Reference Method RFOA 1176-017
SO	Monitor Labs	8450E	Equivalent Method EQSA 0876-013
TSP	General Metal Works	2310 Accu-Vol	Reference Method - High Volume Sample

* These instruments are referenced in the Federal Register as follows:

NO : FR 42, 37,434 (7/21/77)
 O : FR 41, 53,684 (12/8/76)
 SO : FR 41, 36,245 (8/27/76)
 TSP: FR 40, 7,044 (2/18/75)

FIGURE 6.2-4. USGS-Temperature and Flow Locations

6.4 REFERENCES

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7. ENVIRONMENTAL EFFECTS OF ACCIDENTS

7.1 INTRODUCTION

SRP reactors have operated for a total of 115 reactor-years without an unusual operating incident that resulted in the release of radioactivity to the public.

Over 500 man-years of technical effort have been spent on analyzing the operation of SRP reactors, the technical limits of operation, and the course of possible accidents. What follows is a summary of these analyses.

Section 7.2 describes the mitigation by design of the effects of accidents caused by natural phenomena — earthquakes, hurricanes, etc. Section 7.3 describes the mitigation of accidents by reactor design. Section 7.4 describes the accidents considered and the limits imposed on operation to mitigate the accidents and limit the consequences. Section 7.5 describes the radiological consequences if different kinds of accidents could progress to the point of releasing radioactivity offsite.

In general, the reactors are operated at a power limit which is determined by an accident analysis for each reactor charge. This limit is the highest power at which the reactor can operate under normal conditions and still allow the protective instrument system to terminate any anticipated transient without exceeding prescribed damage criteria (for example, an approach to fuel melting). Two such limits are established, and the reactor is operated at the lower of the two limits:

1. The first limit is defined by assuming that the safety rod scram system works on demand.
2. The second limit is defined by assuming that the safety rod system fails and that an automatic backup system (called the Automatic Backup Shutdown--Safety Computer, or ABS-S/C) is required to terminate the transient.

This second limit defines the confinement protection limit, which is based on the criterion that the airborne activity confinement system not be damaged.

7.2 MITIGATION OF EFFECTS OF NATURAL PHENOMENA

7.2.1 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 up to an acceleration of 0.2 g. Revisions included:

- Strengthening the base of the control rod actuator tower.
- Strengthening the 200-foot-high building exhaust stack.
- Improving anchors on the twelve track-mounted process heat exchangers.
- Improving the lateral support for the Emergency Cooling System piping and the Supplementary Safety System piping.

On the basis of 300 years of recorded history of earthquakes, an earthquake above an intensity corresponding to a ground acceleration of 0.13 g would not be expected on the Savannah River Plant site.¹ Seismic recorders installed in the reactor buildings are set to alarm at 0.002 g and to shut down the reactor at 0.02 g. In over 28 years of reactor operation the seismic alarm at 0.002 g has never been received.

7.2.2 Tornado and Hurricane Effects

About ten tornadoes strike the Georgia-South Carolina area each year (Section 2.4.4.4.2). Maximum wind speeds in the extreme tornadoes would be about 260 miles per hour (Section 2.4.4.4.2). A specific study² for SRP on tornado risk indicates that the probability of any one reactor building encountering tornadoes with wind speeds greater than 280 mph is 10^{-7} per year. A 280-mph tornado is capable of creating a pressure drop across a building surface of 1.5 psi. The reactor building itself is blast-resistant to an external pressure of about 7 psi. An analysis of the Disassembly Area, structurally the weakest portion of the reactor building, indicated it could withstand a pressure drop of 3 psi.

Exceptions to the wind resistance capability are: the existing 200-foot exhaust stack (capable of withstanding 125 mph winds), 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. Occurrence of a tornado causing damage to

the filter compartments and/or stack after an independently caused reactor accident would increase offsite dose effects. Such multiple-series accidents are not considered in this accident analysis. 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 South Carolina can be expected about once in seven years. However, SRP is about 100 miles inland from the coast, and hurricane winds are diminished when the hurricane passes over land. Winds of 75 mph from a hurricane have been measured only once at the SRP site (hurricane Gracie in 1959). Wind velocity expected from a hurricane would be less than that from a tornado.

7.2.3 Floods

The L-Reactor Area is not subject to being flooded. The area is well-drained, being located at an elevated area 250 feet above sea level. Pen Branch Creek on the west and north and Steel Creek on the east and south both have an elevation of 200 feet and provide adequate drainage. The Savannah River elevation of 85 to 90 feet is controlled by Clarks Hill Dam, located above the plant site. Dam failure analysis³ shows that only the river pumphouse, which supplies cooling water to the reactor, would be flooded. The onsite storage of cooling water (25 million gallons in each area) is adequate to remove shutdown heat from the reactors. Also, that cooling water can be recirculated. Each reactor also has sufficient onsite power generation to maintain the reactor in a safe shutdown condition if flooding should cause the loss of offsite power.

7.2.4 Other Local Site Effects

Prior to the recent shutdown of the heavy water plant at SRP, the most significant local non-reactor environmental effect would have been the release of H₂S gas from the heavy water facility located about 7 miles from L-Reactor. The effect would have been to require a temporary evacuation of the reactor building. L-Reactor can be shut down and maintained in a safe condition with no personnel in the control room. The control required to monitor and control the safe reactor shutdown condition would be from the remote control station located at a distance of eleven miles from L-Reactor (See Section 7.3.5.7).

The heavy water plant was shut down in 1982. The H₂S gas was removed from the facility.

7.3 MITIGATION OF ACCIDENTS BY REACTOR DESIGN

7.3.1 Mitigation by Location

L-Reactor is located near the center of the 300-square-mile Savannah River Plant site. Access to SRP is controlled; security clearances are required for access to the reactor area itself, making it inaccessible to the casual visitor. Approximate distances from L-Area to the nearest boundary are:

	<u>Miles</u>	<u>Kilometers</u>
North	13	20.9
East	8.4	13.5
South	8.0	12.9
West	8.2	13.2

Thus, the nearest public individual (excluding transients on Highway 125) is at least 8.0 miles (12.9 km) from the reactor itself. The distance helps to mitigate the effect of an accidental release of radioactivity. Populations of and distances to urban centers near SRP are given in Table 2.2-1. The nearest urban center (New Ellenton, SC) is located 8.3 miles from the center of SRP (1970 population of 2500), and the largest urban center (Augusta, GA) is located at 20 miles (1970 population of 60,000 and an urbanized area population of 149,000).^{*} The relatively large distances to these population centers also help to mitigate the calculated effects of hypothetical accidental releases.

7.3.2 Mitigation by Reactor Charge Design

Each tritium or plutonium producing reactor charge is moderated and cooled by D₂O and has the same spacing between fuel and target assemblies. But changes in moderator and coolant temperature coefficients during the charge exposure time and changes in the average and relative fissile content of the fuel assemblies, among others, require that an accident analysis be made for each charge. Some of the analyses can be generic in nature (such as confinement heat limits), but the more important analyses actually fix the operating limits for the charge. A summary of the

^{*} Preliminary information from the 1980 census are New Ellenton, 2600 and Augusta 45,000. The final census report is not yet available.

analyses required for a tritium or plutonium producing charge is given in Table 7.3-1. The analyses are completed by a technical group of physicists and engineers associated with the day-to-day operation of the reactors. Longer-range and in-depth safety analyses are performed by technical groups in the Savannah River Laboratory. The two technical groups correspond freely, hold frequent meetings together, and provide quality assurance checks on their respective calculations.

The range of operating variables experienced during the 28 years of reactor operation at SRP are given in Table 7.3-2. The large ranges shown here demonstrate the flexibility available in charge design. L-Reactor is currently scheduled to operate with a plutonium producing charge at reactor startup, as shown in Table 7.3-3.

7.3.3 Reactor Shutdown Systems

7.3.3.1 Safety Rods

The function of the safety rods (Section 3.3.5.2) is to provide the primary rapid shutdown mechanism for the reactor and thus prevent exceeding operating limits and prevent core damage. Upon receipt of a scram signal (Section 7.3.3.4), the safety rods drop into the reactor core in about one second. L-Reactor has 66 safety rods made of cadmium -- an efficient neutron absorber. These are located in positions shown in Figure 7.3-1. The reactivity worth or reactivity reduction, of the safety rods must be at least 1% k greater than the reactivity gained by cooling down the metal, moderator, and coolant.

Safety rod worth and the reactivity gained from power reductions (related to the power coefficient) are calculated for each reactor charge. The calculated coefficients and safety rod worths have been verified by measurements conducted in both the production reactors (Δk rod tests to measure temperature coefficients) and in a full-scale test reactor (to measure safety rod worth).

Safety rod insertion time following a shutdown (or scram) signal is measured periodically. Safety rods free fall by gravity after a negative pulse breaks the current to the electromagnets holding the safety rods. Safety rods can also be driven in. The holding current can also be reduced to zero by physical disconnects as well as by electrical switching.

Safety rods are inserted automatically upon receipt of a scram signal (Section 7.3.3.4), or can be inserted by a manual switch.

TABLE 7.3-1

Summary of Data and Analyses Required for Each Reactor Charge

1. Technical Limits and Transient-Protection Limits for assembly effluent temperature.
2. Technical Limits and Transient-Protection Limits for burnout risk.
3. Technical Limits and Transient-Protection Limits for reactor effluent temperature.
4. Confinement Protection Limits for accidents with assumed inoperative safety rods.
5. Criticality during withdrawal of safety rods.
6. Shutdown system worths.
7. Primary and secondary scram circuit designation.
8. Natural convection cooling.
9. Mechanical and metallurgical properties during discharge.
10. Protection against criticality during charge-discharge operations.
11. Storage and handling of enriched uranium assemblies.
12. Shield heat loads.
13. Emergency cooling of irradiated fuel.
14. Heat removal from safety and control rods.
15. Temperature and void coefficients.
16. Startup accident analysis.
17. Xenon oscillations.
18. Compliance with Technical Standards and safety analyses.

TABLE 7.3-2

Range of Operating Variables in SRP Reactor Charges

Thermal Neutron Flux (full power)	5×10^{13} to 7×10^{15} ** n/(cm ²)(sec)
Reactor Power (full power)	650 to 2915 Megawatts, thermal
Assembly Power	Up to 21 Megawatts, thermal
Prompt Coefficient	$+2 \times 10^{-5}$ to -15×10^{-5} k/°C*
Moderator Coefficient	-1×10^{-5} to -35×10^{-5} k/°C
Reactivity in Control Rods	Up to 30% k at cycle beginning; to 0.5% k at cycle end
Reactivity in Xenon After Shutdown	Up to 60% k
Irradiation Cycle Length	4** to 400 days
Fuel Heat Flux	Up to 2,900,000 Btu/(hr)(ft ²)
Total D ₂ O Flow	90,000 to 163,500 gpm
D ₂ O Flow per Assembly	Up to 1050 gpm
Assembly Coolant Velocity	Up to 72 ft/sec
²³⁵ U Loading	Up to 1650 kg per charge; up to 4 kg per assembly

* Overall temperature coefficient (prompt plus moderator) is always negative. k is the multiplication factor of the reactor -- effectively the number of neutrons present at the end of a neutron generation for each neutron present at the start of that generation.

** Special High Flux Charge

TABLE 7.3-3

Nominal Values of Operating Parameters for Typical SRP Reactor Charges

	<u>Tritium Producer (Uniform)</u>	<u>Plutonium Producer (Mixed-Lattice)</u>
Principal Driver	Enriched Uranium	Enriched Uranium
Principal Target	Lithium Housings	Depleted Uranium
D ₂ O Flow, gpm		
Per Driver	355	415
Per Target	-	235
Total Reactor	155,000	155,000
D ₂ O Velocity, ft/sec		
Driver	23	19
Target	-	25
H ₂ O Flow, gpm	100,000-175,000	100,000-175,000
Power, MW Thermal		
Per Driver	6.0	7.4
Per Target	-	2.5-4.8
Total Reactor	2400	2150
Driver Surface Heat Flux, 10 ⁶ Btu/(hr)(ft ²)	0.7	0.7
Assembly Effluent D ₂ O Temperature, °C		
Driver	109	113
Target	-	85-110

Figure 7.3-1. Safety Rod and SSS Injection Locations for L Reactor

7.3.3.2 Control Rods

When a shutdown (scram) signal is received, the 61 clusters of control rods (Section 3.3.1.2) are driven in automatically. The rate of insertion is less than for the safety rods. The worth of the control rod system must be such that the reactor is subcritical when safety rods are withdrawn. The control rods can be driven in singly, or by a gang drive. Gang I consists of control clusters 1-19; Gang II, clusters 20-37; and Gang III, clusters 38-61 (Figure 7.3-1).

7.3.3.3 Supplementary Safety System

The Supplementary Safety System (see Section 3.3.5.5) is a fully independent system that acts as a backup shutdown device for the safety system. As described in Section 3.3.5.5, the system has redundant tanks, piping, and valves. Gadolinium nitrate, an efficient neutron absorber, is injected into the moderator space through six sparger positions (see Figure 7.3-1). The reactivity worth of the SSS must be such that the reactor can be maintained subcritical by at least 1% k even if all safety and control rods are in the fully withdrawn condition. The readiness of the injection system is monitored at all times; readiness is a necessary condition for reactor startup and operation. The solution is injected by a parallel system of pneumatic and explosive-operated valves. Dispersion of the nitrate solution has been measured under different coolant flow conditions; the rate of injection is controlled to maintain a sufficient quantity of solution in the reactor core even under full coolant flow conditions.

The SSS can be actuated manually or automatically if safety rods fail to shut down the reactor.

The gadolinium nitrate solution can be removed from the D₂O by the moderator purification system. Removal takes several days.

7.3.3.4 Scram Instruments

The scram, or shutdown instruments, installed in L-Reactor are listed in Table 7.3-4. There are a total of 1235 circuits that monitor reactor operation and will cause the safety rods to fall and control rods to drive in. The setpoints of the circuits are adjusted to meet the changing requirements of reactor charge designs and operating conditions. Some circuits, such as the High Level Flux Monitor, are adjusted to maintain a specified margin

TABLE 7.3-4

Automatic Scram Circuits

<u>Variable Measured</u>	<u>Number Provided*</u>
Neutron Flux (High-Level Flux Monitor)	Four
Operability of Neutron Flux Monitors	One
Rate of Change of Neutron Flux (Period)	Two
D ₂ O Plenum Pressure	Two
Blanket Gas Pressure	Two
H ₂ O Supply Header Flow	One for each of two H ₂ O headers
Individual Heat Exchanger H ₂ O Flow	One for each of twelve heat exchangers
Control Rod Coolant Supply Pressure	One
Moderator Level	One
D ₂ O Pump Power Supply	One for each of six pump motors
Assembly Coolant Flow	600 in L-Reactor
Assembly Average Effluent Temperature**	600 in L-Reactor
Control System Power Supply	One
Seismic Activity	Two of three coincidence

* A manual scram circuit is also provided.

** Four thermocouples in each of 600 monitor pins provide maximum and average assembly effluent temperature. Monitoring and scram signals are provided for each of the 2400 monitoring thermocouples.

from an operating variable, while others are set to initiate a scram for a fixed value of the monitored variable.

Scram setpoints are checked by written procedures, to verify that they are set at the specified value. Bypass of scram instruments is rigidly controlled by operating procedures. Bypasses are monitored by a circuit board and by the online computers. The scram instruments for a particular signal (e.g., neutron flux, plenum pressure, coolant temperature, etc.) are set to produce a scram at the operating limits described in the next section (Section 7.3.4). A reactor scram at the set point will prevent damage to the fuel, reactor, or confinement system. Prevention of damage prevents release of radioactivity to the environment.

7.3.3.5 Automatic Backup Shutdown — Safety Computer (ABS-S/C)

The ABS-S/C is a backup system that will actuate the Supplementary Safety System to shut down the reactor if a requested scram is ineffective. It will terminate all identified transients for which the primary shutdown mechanism -- safety rod insertion -- fails. Each of two safety computers monitors the average of 300 assembly effluent temperatures every 0.36 second. After a safety rod scram signal, three tests are applied immediately to the average temperature signals. If any one of the three test criterion is satisfied, the Supplementary Safety System is actuated automatically. The tests are:

- (1) Ramp Test: Successive delta T averages are compared for one minute. The criterion is that two of three successive scans show an increase of 0.36°C between scans.
- (2) Rise Test: The highest average delta T value in storage is selected as a reference. The criterion is that after 1.1 seconds (3 scans) the average delta T has increased by 2°C .
- (3) Drop Test: The criterion is that the average delta T, measured 3.9 to 4.3 seconds after the scram signal, must be less than 75% of the value that was current upon receipt of the scram signal for two of three scans. A typical reactor power transient after a scram signal is shown in Figure 7.3-2.

The tests are actually more complex than described briefly above. The tests are not applied at low power (below 20°C delta T).

7.3.4 Limits System

Limits are imposed for safe operation of the Savannah River reactors in the normal mode and under postulated transient

Figure 7.3-2. Reactor Power Transient for Safety Rod Scram

conditions. The most important set of limits are those called thermal-hydraulic limits. These limits directly govern reactor power. Other limits are used to maintain reactor operation within well defined bounds but do not normally restrict reactor power directly.

Thermal power of the Savannah River Plant reactors is not limited to a specific value, but attains a value, under thermal-hydraulic limits, that is a function of charge design and cooling water temperature. For example, a full-core charge may attain power ranging from 1500 to ~3000 MW thermal. In order of importance, these thermal-hydraulic limits are:

- Assembly Effluent Temperature - to protect against bulk boiling and subsequent gross melting of assemblies.
- Burnout Risk (BOR) - to protect against increasing the risk of damage from film boiling burnout beyond acceptable limits.
- Reactor Effluent Temperature - to protect against reduction in reactor flow caused by cavitation and subsequent aggravation of an incident protected by assembly effluent temperature and BOR limits. This limit is less important than the first two limits because of the relatively slow response of reactor effluent temperature.

The principal thermal-hydraulic limits structure is defined in terms of five types of limits:

- Technical Limits
- Transient Protection Limits
- Confinement Protection Limits
- Emergency Cooling Limits
- Operating Limits

Typical values are shown in Table 7.3-5.

Technical Limits are specified to protect the primary and secondary fission product barriers; i.e., the fuel and target cladding, and the reactor structure, during continuous operation at the limit. Technical Limits are established on assembly effluent temperatures, burnout risk, and reactor effluent temperature.

Transient Protection Limits (TPL) are specified to protect against significant damage to the reactor complex or significant fission product release as a result of postulated power increases or flow or pressure reductions that have a significant probability

TABLE 7.3-5

Typical SRP Reactor Thermal-Hydraulic Limits*

	<u>Technical Limit</u>	<u>Transient Protection Limit</u>	<u>Confinement Protection Limit</u>	<u>Emergency Cooling Limit</u>	<u>Operating Limit</u>
Assembly Effluent Temperature, °C					
Assembly Average	115	112	112**	112**	110
Channel or Quadrant	115	112	-	-	109
Burnout Risk, MW	0.03	-	-	-	0.02
Reactor Effluent Temperature, °C	104	100	-	-	95

* These limits vary with river water or Par Pond temperatures, which range from about 5 to 30°C.

** Confinement Protection Limits and Emergency Cooling Limits are normally specified by assembly power. The temperature shown is consistent with typical assembly power limits.

of occurrence. The limits system should prevent adverse consequences not only during normal operation, but also during transient situations. The adverse consequences are fission product release resulting from cladding failure of fuel or target elements and damage to the reactor tank from overpressure resulting from steam generation. The postulated incidents for which the Transient Protection Limits are determined are listed in Table 7.3-6.

Confinement Protection Limits are set to maintain the integrity of the airborne activity confinement system during specified transients not terminated by safety rod insertion. The limits are implemented by requiring the automatic backup shutdown system to activate the supplementary safety system and end the transient before steam-generated forces breach the reactor tank.

The specified transients are:

- Loss of target caused by flow reduction to that target.
- Local power increase caused by withdrawal of one control rod.
- Reactor power increase caused by withdrawal of a gang of control rods.
- Reduction of H_2O and/or D_2O flow caused by failure of electrical power.
- Sudden reduction of D_2O flow caused by spurious rotovalve closure or by breakage of a pump drive shaft.

Emergency Cooling Limits are imposed on reactor and/or assembly power to ensure that the Emergency Cooling System is capable of preventing fuel damage if the following postulated accidents occur:

- Slow or fast D_2O leak
- Loss of D_2O circulation immediately after reactor shutdown.

Operating Limits are the highest authorized level of continuous operation. These limits are lower than the Transient Protection Limits, and can be equal to the Confinement Protection Limit if it is lower than the TPL. Operating Limits are monitored by personnel and the process control computer. Allowances for inaccuracies in monitoring are included as part of the limit derivation.

Miscellaneous reactor operating restrictions are also placed on the bulk moderator temperature, the D_2O quality (pH, conductivity, impurity levels), the blanket gas composition (O_2 , D_2 concentrations), the axial flux distribution, and heat generation

TABLE 7.3-6

Incidents for Which Transient-Protection Limits are Determined

Possible Fission Product Release		
Incidents	Mechanism	Primary Protection System
a. Slow, uniform flow reduction in a fuel coolant channel to the setpoint of rod reversal (no rod reversal)	Fuel cladding failure	No scram assumed*
b. Local power increase	Single control rod withdrawn at the control rod drive speed	Safety Computer, and/or High-Level Flux Monitor
c. Reactor power increase	Gang of control rods withdrawn at the control rod drive speed	Safety Computer, and/or High-Level Flux Monitor
d. Reduction in heavy water flow	Loss of AC motor power	Plenum Pressure Monitor
e. Sudden reduction in heavy water flow	Pump failure	Plenum Pressure Monitor
f. Sudden reduction in H ₂ O flow in one header	Pump failure	Heat Exchanger Flow Monitor
g-1. Slow reduction in blanket gas pressure to the scram setpoint (no scram)	Leak	No scram assumed*
g-2. Sudden reduction in blanket gas pressure	Blown vacuum breaker	Blanket Gas Pressure Monitor
h. Uniform flow reduction in one assembly to the scram setpoint (no scram)	Partial pluggage	No scram assumed*

Overpressure

If flow instability occurs, the resulting overpressure in the reactor tank must be less than that required to counterbalance the weight of the loaded top shield and plenum.

* Incidents a, g-1, and h are transients base on phenomena that may not progress all the way to the scram setpoint (incidents g-1 and h) or the rod reversal set point (incident a). The setpoints are derived such that continuous operation at temperatures just below the setpoint will not have consequences exceeding specific criteria. The criteria are to prevent subchannel boiling in the assembly and to restrict damage from film boiling burnout. Protection at the setpoint is provided by either the control computer or safety computer.

in neutron-absorbing targets (control and safety rods, and often targets).

7.3.5 Engineered Safety Systems

The primary shutdown mechanism is safety rod and control rod insertion. Reactor power is reduced significantly within one second. The secondary shutdown system is the Supplementary Safety System (automatic or manual injection of gadolinium nitrate). Besides these, there are other engineered safety systems, which are discussed below. Each has been analyzed for single component and common mode failure, and for separation of protection and control circuits.

7.3.5.1 Emergency Cooling System (ECS)

The ECS is designed to remove decay heat following a reactor shutdown by the direct addition of H_2O to the reactor core in case of loss of D_2O coolant or D_2O circulation (See Section 3.3.5.7). Four sources of H_2O are available, two of which have to be online for reactor operation.

- 1) A diesel-driven booster pump which supplies H_2O from the 25-million-gallon basin.
- 2) A 42-inch header pressurized by five pumps drawing H_2O from the 25-million-gallon basin.
- 3) Another 42-inch header pressurized by five additional pumps.
- 4) A line directly from the river pumphouse, pressurized by the river water pumps.

The ECS is actuated by Automatic Incident Action logic circuits that are caused to act by changing liquid levels in the reactor tank. When the ECS is actuated, the diesel-driven booster pump starts, and valves are automatically opened or closed to couple the reactor system with the primary sources of H_2O . If the booster pump does not start, the other sources of emergency cooling are sufficient.

7.3.5.2 Water Removal and Storage

If the D_2O system ruptures, the D_2O and H_2O emergency cooling water would flow to sump pumps in the basement of the reactor building. (The D_2O system contains 50,000 gallons). The sump pumps pump the water first to a 60,000-gallon underground tank;

the flow then goes to a 0.5-million-gallon tank that sits in the 50-million-gallon emergency earthen basin. Some of the water on the 0-level process room floor would drain directly to the 0.5-million gallon tank. If this tank should become full, the additional water spills out into the emergency basin. The 0.5-million-gallon tank is vented to the ventilation confinement system in the reactor building. In the event of Emergency Cooling System activation, it is important to remove the water from the building to prevent flooding necessary equipment.

7.3.5.3 Activity Confinement System

This system is described in Section 3.3.5.9.

7.3.5.4 Confinement Heat Removal System

This system is designed to provide cooling for a dry full-core meltdown of the reactor core. It protects against heat failure of the confinement system. The system (described in Section 3.3.5.8) is designed to be actuated either manually or automatically. Automatic actuation depends on heat sensors encased in monitor pins located at the bottom of the reactor tank. The sensors are made of fusible metal that would melt at a temperature lower than the melting point of reactor core materials, but higher than the boiling point of water.

7.3.5.5 Reactor Room Spray System

This system is described in Section 3.3.5.10.

7.3.5.6 Automatic Backup Shutdown — Gang Temperature Monitor (ABS-GTM)

The ABS-GTM is a second automatic backup shutdown system that is independent of the safety rod scram system. The sensors are provided by dual monitor pin thermocouples in three fuel assembly positions associated with each of the three gangs of control rods. The sensors are set to actuate the Supplementary Safety System when their average delta T approaches specified limits. The GTM can protect against a specific incident: inadvertent gang rod withdrawal without safety rod scram.

7.3.5.7 Remote Control Station

A remote control station 11 miles from L-Area is manned full time. The station is a data display and control facility for the reactors that can provide remote control of important fuel cooling and activity confinement systems in the event the control room in the reactor building cannot be occupied. Data and control signals are transmitted through underground electrical cables. The station can monitor 90 states of equipment and 50 process variables and can control 20 functions (such as dampers or valves). This station is the reactor control room backup, and is capable of maintaining the reactor on a safe shutdown condition and mitigating accident consequences if the reactor control room is not manned.

7.3.5.8 Component Handling — Cooling During Discharge Operations

During the interval between removal of irradiated fuel (or targets or other heat-producing assemblies) from the reactor and insertion in the cooling basin, the irradiated assemblies are cooled by water. Five sources of water are available to the discharge machine from four independent systems. Except at the final point of discharge to the assembly, each source has separate hoses, pipes, and actuation valves.

In normal practice, primary H_2O cooling is started automatically as soon as the assembly is withdrawn from the reactor and the water pan swings under the assembly. If primary H_2O flow stops, a secondary H_2O source is switched on automatically. Primary and secondary D_2O cooling is available if the assembly is partially in the reactor, or if the assembly is over the reactor and the water pan does not move under the assembly.

A reactor room spray system (Section 3.3.5.10) is available if an assembly is dropped onto the floor of the reactor room. Assemblies are not discharged unless the maximum decay heat generation rate is less than could be dissipated by the discharge machine cooling water or the reactor room spray system (with assembly horizontal).

7.3.6 Assembly Area

Fuel, target, control rod and safety rod components are received in the Assembly Area, where they are inspected, assembled into units ready to be charged to the reactor, and flow tested. Fissile material in the form of fuel tubes is received in critically safe boxes, designed so that full or partial flooding would not produce criticality. The fuel tubes are unloaded and stored in special boron-concrete racks that are also critically safe with full or partial flooding. The boron content of the storage racks is measured on a periodic basis by a neutron absorption method.

Water in the Assembly Area is strictly controlled. The only water is in the closed loop system used for flow testing the assembled components. Hydrogenous material is not allowed to be brought into the Assembly Area; there are no extraneous pipes carrying water. If water should leak at the flow test station it would fall to the sub-floor beneath the station, and away from fissile material.

After the components are assembled one-by-one and flow tested, each is placed on a vertical hanger and placed in proper loading order in the final storage room. Spacing of the hangers is mechanically controlled to prevent clustering of the assemblies. If flooding should occur, criticality could not occur.

The Assembly Area is equipped with Nuclear Incident Monitors that warn personnel of an impending critical array. Personnel access to the Area is rigidly controlled by the SRP Security system.

Studies made of the nuclear safety of the Assembly Area indicate that a criticality accident could not happen. To summarize the reasons:

- Rigid geometrical spacing of incoming fissile material.
- Storage of fissile material in borated-concrete racks.
- Flow-testing of only one assembly at a time.
- No water outlets.
- Control of hydrogenous material in the Area.
- Nuclear Incident Monitors.
- Strict control of personnel access to the Area.

7.3.7 Disassembly Area

Irradiated fuel and target assemblies are discharged and stored under water for a period of time sufficient to allow certain fission products to decay to low levels before the assemblies are disassembled and shipped to the Separations Area for processing.

The assemblies are stored in a vertical position on hangers for the first part of the decay period. The hanger spacing is mechanically controlled top and bottom by metal spacers to prevent the assemblies from clustering in the basin. After the assemblies are placed on hangers and moved into storage rows, the ends of the rows are locked to prevent further movement.

During vertical storage the tops of the assemblies are under 15 to 20 feet of water. This depth of water provides sufficient shielding to protect personnel from the radiation from the discharged assemblies, and would also protect personnel against irradiation from an accidental criticality event.

The Disassembly Area is equipped with Nuclear Incident Monitors that alarm at low levels of radiation. Hazards in operation of the Disassembly Area are:

- Dropped fuel assemblies.
- Decrease in level of basin water.
- Raising an irradiated assembly out of the basin.
- Inadvertent criticality.

One dropped fuel assembly poses no problem. Several assemblies dropped on top of each other could conceivably produce a critical array, but the probability of producing the array is small.

Basin water level is monitored. A slight decrease in level produces visual and audible alarms in the reactor control room. There are no drains in the basin. The level may be lowered three feet in an emergency to provide cooling or flooding of reactor areas without increasing the radiation level in the Disassembly Area to an unwanted level.

It is possible to raise an irradiated assembly from the basin with hoists, ropes, or tools that are normally used in moving and positioning the assemblies. The Nuclear Incident Monitors provide alarms for this incident.

Criticality of irradiated fuel assemblies could occur if five or more assemblies were allowed to cluster into a critical configuration. However, fuel assembly hangers have permanently

installed blocking devices that prevent the hanging assemblies from clustering. If criticality should ever occur, the shielding provided by the basin water would protect operating personnel from radiation. No offsite exposure would be expected to occur.

7.4 ACCIDENT ANALYSIS

All reactor accidents share the common problem of too much power for too little cooling. Accident analysis can be grouped into three broad classes.

- 1) Reactivity addition (equivalent to removal of neutron absorber) that increases reactor power or power in a local region of the reactor (Section 7.4.1).
- 2) Flow reduction, caused by loss of pumping power, reduction of circulation, or loss of coolant, that reduces the cooling capacity of the reactor or individual heat-producing assemblies (Section 7.4.2).
- 3) Non-nuclear types of accidents that are not directly related to rapid changes in the reactor conditions (Section 7.4.4).

For all of the accidents analyzed, reactor power, power distributions, and temperatures are limited so that if the accident should happen, the reactor would be shut down by the primary or redundant shutdown systems before:

- Fuel cladding is breached, or the
- Reactor tank is damaged, or the
- Confinement system is breached.

The primary method for limitation is to prevent the coolant temperatures from exceeding the saturation temperature (T_{sat}). If T_{sat} is not exceeded, there will be no core damage or radioactive releases from a power increase or flow reduction. If all shutdown and emergency cooling mechanisms should fail, fuel melting or other damage would occur to the reactor system, and radionuclides would be released. Environmental effects for a wide range of these hypothetical releases are given in Section 7.5.

7.4.1 Reactivity Addition

Reactivity addition accidents are caused by removing neutron absorbing material from the reactor, or moving neutron absorbers, such as partial rods, to increase local power generation. Each of the following accidents is analyzed by discussing the assumptions made, expected frequency, results of the accidents, the pertinent scram circuits, and the analysis that is made.

7.4.1.1 Single Control Rod Withdrawal

Assumptions

- Reactor is operating at full power at operating limits.
- Control rod withdrawn is adjacent to hottest assembly in the reactor.
- Withdrawal is at the maximum rate possible (0.123 ft/sec requiring two minutes to move from the full-in to the full-out position).
- The withdrawn rod is near the edge of the reactor, thus causing a radial power tilt as well as local and reactor power increases.

Frequency

- Unwanted control rod motion has occurred about twice a year at SRP since 1977; half of the motions have been withdrawals.

Results

- Reactor and hottest assembly powers would increase as follows:

$$\begin{aligned}\text{Reactor Power: } P(t)/P(0) &= 1 + R \cdot (dk/dt) \cdot t \\ \text{Hottest Assembly: } P_H(t)/P_H(0) &= 1 + (A+R) \cdot (dk/dt) \cdot t,\end{aligned}$$

where $R = 120$, $A = \sim 500$, $dk/dt = 3 \times 10^{-5}$ k/sec, and k is the dimensionless neutron multiplication factor. Reactor power increases almost linearly at a rate of 0.4% per second, while the hottest assembly power increases at about 1.9% per second.

Scram Instruments

- Primary: Assembly coolant temperature monitor in the hottest assembly.
- Secondary: Nearby assembly coolant temperature monitors; high-level flux monitors.

Analysis

- The accident is analyzed for every reactor charge to establish normal operating limits, and is analyzed generically to establish confinement protection limits. The operating limit on assembly coolant flow and coolant temperatures is set so that a reactor scram would prevent the coolant from reaching the saturation temperature. Under this condition there would be no damage to fuel or reactor, and radioactivity would not be released to the environment.

7.4.1.2 Partial Control Rod Movement

Assumptions

- The partial rod is centered in the reactor at its position of maximum absorption.
- The rod drives in or out at the maximum speed of 0.123 ft/sec.
- The partial rod is in a control cluster near the side of the reactor, thus causing radial power tilting.
- Axial power distribution changes as well as radial power distribution.

Frequency

- Same as unwanted control rod motion (Section 7.4.1.1).

Scram Instruments

- Same as for Section 7.4.1.1.

Results

- Reactor and local power increases are less than or equal to those caused by unwanted full rod withdrawal.

Analysis

- Same as for full rod withdrawal (Section 7.4.1.1).

7.4.1.3 Gang Rod Withdrawal

Groups of control rods called gangs are moved together in normal reactor operation. Gang I consists of the inner 19 clusters of control rods, Gang II the next ring of 18 control clusters, and Gang III the outer ring of 24 clusters.

7.4.1.3.1 At Full Power

Assumptions

- Reactor is at full power operating at limits.
- A gang of control rods moves out continuously at maximum speed.
- Radial power perturbation cannot occur.

Frequency

- Unwanted continuous gang withdrawal has not occurred at SRP in 115 reactor-years of operation. Incidents of a similar type have occurred, caused by spurious signals in the control computers, at a frequency of about 0.34/reactor/year. In one such incident in 1976, a spurious signal withdrew Gang I rods 0.2 feet in 15 seconds.

Results

- Reactor power and hottest assembly powers would increase at rates of

$$P(t)/P(0) = 1 + R \cdot (dk/dt) \cdot t$$

$$P_H(t)/P_H(0) = 1 + (A+R) \cdot (dk/dt) \cdot t$$

where $R = 120$, $A = 50$, and $k/\text{sec} = 10^{-4}$ k/sec for maximum values. Reactor power would increase at a rate of 1.2%/sec, while the hottest assembly power would increase at 1.7%/sec.

Scram Instruments

- Primary: Assembly coolant temperature monitors
- Secondary: High-level flux monitors (can be the primary instrument).

Analysis

- The gang-rod-withdrawal accident is analyzed for both Transient Protection Limits and Confinement Protection Limits. This accident is often the most restrictive in setting reactor operating limits. The operating limit, as stated in Section 7.4.1.1, is set to prevent damage to fuel and the reactor.

7.4.1.3.2 At Low Power

Assumptions

- Inadvertent gang withdrawal occurs three decades below full power (at 1 to 3 Mwt).
- The inventory of ^{135}Xe , which has a very large neutron cross section, is at or near maximum. (At full power, ^{135}Xe absorbs about 3% of all neutrons produced in the reactor, but when the reactor is shut down, the inventory of ^{135}Xe increases by decay of ^{131}I to several times its full power inventory. If the reactor were restarted with a large inventory of ^{135}Xe , its

burnup would add reactivity that could exceed that caused by control rod withdrawal, Figure 7.4-1.)

- Temperature coefficients do not provide negative feedback to prevent a rapid power rise.

Frequency

- Same as given in Section 7.4.1.3.1.

Results

- Reactor power would increase at rates greater than for gang withdrawal at full power, because of the ^{135}Xe burnup.

Scram Instruments

- Primary: High-level flux monitors and period (rate of flux increase) monitors.
- Secondary: Assembly coolant temperature monitors at about 50% full power.

Analysis

- The accident is analyzed for each type of charge. For certain high-level flux charges, restrictions are placed on the time for xenon to decay before the reactor can be restarted.

7.4.1.4 Control Rod Melting

Assumptions

- If control rod melting is possible for the reactor charge design being analyzed:
 - Control rod heating and melting occur adiabatically.
 - The neutron-absorbing material disappears from the reactor as soon as melting occurs.
 - Partially inserted rods are severed at the midplane by melting, allowing the lower part to drop in (Figure 7.4-2).
 - The control rods melt in clusters on the outside of the reactor.

Figure 7.4-1. Relative Concentration of ^{135}Xe After Shutdown

Figure 7.4-2. Reactivity Transient for Melting of Partially Inserted Control Rod

Frequency

- Control rods have never melted in SRP reactors. There have been two cases where the control rod housing has been unseated, thus permitting little or no cooling for the rods. The rods were not damaged.

Results

- Power increases are similar to single rod withdrawal accidents, although the rate of reactivity addition is different.

Scram Instruments

- Assembly effluent temperature monitors around the affected control cluster.

Analysis

- For a septifoil with no forced flow (unseated), control rod melting would begin with film-boiling burnout at a heat flux of 95 kW/ft². Typical maximum heat flux values for current charges are 53 to 69 kW/ft². The control rod melting accident is not considered in establishing limits if the maximum heat flux in the charge is less than the value calculated for control rod melting.

7.4.1.5 Assembly Melting

7.4.1.5.1 Loss of Target

Assumptions

- An abrupt reduction in coolant flow occurs in a high power target.
- The target assembly melts whether the reactor is shut down immediately or not.
- The target material disappears from the reactor as soon as the target melts, which increases reactivity. Two reactivity effects are shown in Figure 7.4-3.

Frequency

- No target assembly has melted at SRP. Reductions in coolant flow have been observed, but all reductions have been slow enough to allow a reactor shutdown before melting occurred in the target assembly.

Figure 7.4-3. Approximate Reactivity Transients for Melting Target Assemblies

Results

- If a high-power target assembly should melt, reactivity would be added at a rate greater than that for control rod or gang rod withdrawal. The course of the accident would be trivial if the safety rod scram system performed as designed (Figure 7.4-4). If the safety rod scram should fail, target melting could begin before the automatic backup systems would respond.

Scram Instruments

- The flow monitor for the afflicted target assembly would be the first scram instrument to respond. The secondary circuit would be the assembly coolant temperature monitor.

Analysis

- Loss-of-target accidents are not considered in deriving transient protection limits, because the postulated abrupt loss of a target is not considered to be credible. More realistic reductions of flow to individual assemblies are considered in establishing operating limits (Section 7.4.2.4 - Flow Reduction in a Single Assembly). However, the loss-of-target accident is considered in establishing confinement protection limits. Reactor power limits are set so that if the safety rod system fails, shutdown from the ABS-S/C would prevent overpressurization, or damage, to the activity confinement system.

7.4.1.5.2 Loss of Fuel

Assumptions

- The assumption is made that a sudden, abrupt loss of flow occurs to a fuel assembly. The fuel assembly melts, and some of the molten debris from the uranium-aluminum alloy fuel may be entrained and reach the moderator, where it would then be exposed to a higher neutron flux than in its usual pre-melt condition. The exposure would cause a temporary increase in reactivity, until the debris is swept from the reactor core. Simultaneously, steam voids formed in the molecules around the fuel particles would decrease reactivity.

Frequency

- Fuel melting has never occurred in the SRP reactors. Cladding failures have occurred, which have released fission products to the moderator, but gross melting of a fuel assembly has not occurred.

Figure 7.4-4. Assembly Power Transients for Loss of Target

Results

- Calculations to assess this accident indicate that the primary and backup shutdown systems provide adequate protection for this accident. By adequate protection it is meant that 1) the reactor tank is not overpressurized, and 2) the confinement system is not damaged.

Scram Instruments

- The primary scram instrument is the assembly flow monitor. Secondary scram instruments are the High-Level Flux Monitors and assembly temperature monitors.

Analysis

- This analysis is one of the more complicated types of accident analyses. Deficiencies have been noted in both the theoretical model and the fundamental data needed for this complex problem. Investigation of this type of accident is continuing.

7.4.1.6 Reloading Error

Assumptions

- The reactor is shut down and the charge-discharge operation is in progress in a mixed-lattice charge. It is assumed that an error is made when irradiated targets are discharged from adjacent positions without charging fresh targets to these positions. Instead, and in spite of mechanical interlocks, fuel assemblies are charged to these positions in a second error, which adds reactivity. If the reactivity increment is large enough, the reactor could be made supercritical.

Frequency

- Replacement of a target assembly with a fuel assembly has not occurred at SRP.

Results

- The result of the postulated accident could be fuel melting and radioactivity release to the reactor building. The scram system is ineffective because the safety and control rods are

already in the reactor. The Supplementary Safety System is much less effective because of the reduced moderator and coolant circulation rate required during charge-discharge operations. The neutron flux changes caused by reloading errors are highly localized (Figure 7.4-5) and therefore the two fission counters external to the reactor core may not detect the error.

Scram Instruments

- Scram instruments are not effective, as described above. The most effective means of decreasing the effect would be to reverse the reloading step that made the reactor supercritical.

Analysis

- Each reactor charge is analyzed to search for the worst possible reloading error. The charge is redesigned if the reactivity increase exceeds a conservative criterion. Hardware design prevents charging a fuel assembly to a target position in the mixed-lattice charge. An improved monitoring system, consisting of six internal fission chambers, has been designed and tested, and will be installed beginning in FY 82 in all SRP reactors (including L-Reactor).

7.4.2 Flow Reduction

7.4.2.1 Loss of D₂O Coolant Pumps

Assumptions

- It is assumed that AC power to the six D₂O coolant pumps is lost simultaneously. The DC motors to the pumps continue to supply power and would maintain flow at 29% of full flow (Figure 7.4-6). Flywheels between the pumps and motors slow the flow decay transient.

Frequency

- Loss of all offsite AC power has occurred once at SRP. The on-site AC power generation is insufficient for simultaneous operation of all SRP reactors. Thus it is assumed that loss of AC power could occur for any reactor.

Results

- As the flow decreases, fuel and target assembly effluent temperatures rise (Figure 7.4-7). The increased water temperature produces a negative reactivity, which causes reactor power to drop slightly in the first two seconds.

Figure 7.4-5. Typical Flux Response to Reloading Accident in Which Fuel is Placed in a Target Position

Figure 7.4-6. Flow Reduction for Loss of AC Power to D₂O Pump Motors

Figure 7.4-7. Power and Temperature Transients for Loss of AC Power to D₂O Pumps

Scram Instruments

- The primary scram results from the two plenum pressure scram instruments. These are backed up almost immediately by the assembly coolant flow monitor.

Analysis

- The accident analysis is used to set both operating and confinement protection limits. For a typical reactor (Figure 7.4-7), the safety rod scram would limit the maximum coolant temperature to a value at least 7°C lower than the saturation temperature. If the safety rods are ineffective, the ABS would limit coolant temperatures to about 5°C less than the saturation temperature.

7.4.2.2 Loss of H₂O Pumps

Assumptions

- Electrical power is lost to the pumps supplying H₂O directly to the reactor heat exchangers. The H₂O flow decreases as shown in Figure 7.4-8, to the 25% value sustained by gravity flow. Gravity flow is assured by the difference in elevation of the cooling water basin and the heat exchangers at -20 ft.

Frequency

- Loss of electrical power has occurred once at SRP.

Results

- As a result of the decrease in H₂O flow, the temperature of the D₂O leaving the heat exchangers and entering the reactor would increase. The D₂O outlet and fuel assembly effluent temperatures would also increase (Figure 7.4-9). At the same time, reactor power would decrease because of the negative temperature coefficient of the reactor charges. The fuel coolant temperatures change more slowly than for a loss of D₂O pump power (compare Figure 7.4-9 with Figure 7.4-7).

Scram Instruments

- The primary scram instruments are the twelve heat exchanger flow monitors. Secondary instruments are the two H₂O header flow monitors and the fuel assembly effluent temperature monitors.

Figure 7.4-8. Flow Reduction for Loss of AC Power to H₂O Pump Motors

Figure 7.4-9. Temperature Transients for Loss of Power to H₂O Pumps

Analysis

- The accident is not used to establish reactor operating limits because the transients are slow compared to other flow reduction accidents. As can be seen in Figure 7.4-9, the temperature of the maximum assembly would be 19°C below the saturation temperature (coolant boiling) at shutdown with the ABS-S/C. The accident is used in establishing confinement protection limits.

7.4.2.3 Loss of Both D₂O and H₂O Pumps

This accident has been studied as an extreme extension of the accidents discussed in Sections 7.4.2.1 and 7.4.2.2. Analysis shows that the accident of D₂O flow reduction increases coolant temperatures so much more quickly than H₂O flow reduction that the two accidents are essentially independent. In the event of loss of both D₂O and H₂O pumps, coolant temperatures increase at the same rate as for loss of D₂O pumps only. Thus, the combined case is not considered in establishing operating or confinement protection limits.

7.4.2.4 Pump Shaft Break

Assumptions

- It is assumed that a pump drive shaft breaks between the D₂O pump impeller and the flywheel when the reactor is at full power. The impeller is left free to rotate, which allows a reversal of flow through the pump.

Frequency

- The accident has not occurred at SRP. Over 115 reactor-years of operation, and over 600 pump-years of operation, have been accumulated. Pump shafts have been inspected during periodic overhaul of the pumps at a frequency of about twice per year (49 inspections from 1961 to 1981).

Results

- If a shaft breaks, the fluid momentum drops to zero (and reverses) much more quickly than if a D₂O pump should lose power (because of the energy stored in the flywheel). The resulting flow changes in the reactor are asymmetric -- the fuel and target assemblies in the affected coolant sector have a greater flow reduction than other assemblies in the reactor. The expected flow reductions, which have been normalized to

test measurements made in the reactor, are shown in Figure 7.4-10. Some assembly flows reduce to 75% of normal in two seconds, while average assembly flows reduce to slightly greater than 80% normal. Net flow in the reactor decreases, but flow in the other five coolant loops increases about 6%.

Scram Instruments

- The primary scram instruments are the plenum pressure monitors, followed by the assembly flow monitors.

Analysis

- Analysis of the pump shaft break accident is used in deriving operating and confinement protection limits. As shown in Figure 7.4-11, the safety rod scram would prevent the assembly coolant temperatures from reaching the saturation temperature.
- Analysis of the case in which the broken pump shaft freezes and prevents the impeller from turning has been compared with the analysis in which the impeller is left free to rotate. The latter case produces the more restrictive limits.
- As seen in Figure 7.4-11 (and later in Figure 7.4-12) the maximum assembly temperature exceeds T_{sat} if the safety rods fail to drop. Reactor limits are set such that if this happens the steam generated does not produce a force great enough to lift the plenum (700,000 pounds in L-Reactor). The steam generation lasts for a time too short to cause any assemblies to melt.

7.4.2.5 Rotovalve Closure

Assumptions

- Rotovalves are installed in the six external loops of the D_2O circulation system between each of the twelve heat exchangers and the reactor plenum. During normal, full-power operation, the rotovalves are fully open. During maintenance work, the rotovalves are fully closed to prevent loss of D_2O . It is assumed that the two rotovalves in each of two external loops close simultaneously when the reactor is at full power.

Frequency

- The postulated accident has not occurred at SRP. However, on one occasion the two rotovalves in one external loop closed simultaneously at full power; and spontaneous closure of a single rotovalve has occurred six times in 27 reactor-years of operation.

Figure 7.4-10. Flow Reduction for Pump Shaft Break

Figure 7.4-11. Power and Temperature Changes Following Pump Shaft Break

Figure 7.4-12. Flow Reduction for Rotovalve Closure in Two External Loops

Results

- The flow reduction calculated for simultaneous closure of the four rotovalves is shown in Figure 7.4-13. Flow in the minimum flow assembly after two seconds is about 97% of normal, compared with 75% of normal flow at two seconds for a pump shaft break accident (Figure 7.4-10). The difference between the maximum expected assembly effluent temperature and the saturation temperature is large (Figure 7.4-12) compared with the difference for a pump shaft break accident.

Scram Instruments

- The primary scram instruments are the plenum pressure monitors and the assembly flow monitors.

Analysis

- Rotovalve closure incidents are not used to set operating or confinement protection limits because this incident always yields higher limits than the pump shaft break incident.

7.4.2.6 Flow Reduction in a Single Assembly

Assumptions

- It is assumed that a gradual reduction in flow occurs to a single coolant channel within an assembly. This could be caused by the swelling that accompanies a cladding failure in a uranium fuel or target assembly.

Frequency

- Fuel failures accompanied by flow reduction have occurred at SRP. Two fuel failures have occurred in the last three years of operation of three reactors.

Results

- Assembly flow gradually decreases, while assembly channel effluent temperatures gradually increase.

Scram Instruments

- The assembly coolant flow monitor would be the first to scram the reactor. The scram setpoint for the monitor is required to be at the point that would prevent coolant boiling in the hot channel. The assembly effluent temperature monitors are also set to prevent boiling in the hottest channel.

Figure 7.4-13. Power and Temperature Changes Following Rotovale Closure

Analysis

- This slow flow reduction incident is used to determine operating limits for the reactor.

7.4.2.7 Loss of Control Rod Cooling

Assumptions

- Flow reduction or blockage in the header supplying cooling to the control rods, or in the individual septifoil housing the control rods is unlikely because there are strainers in the headers and because heat exchangers with much smaller flow passages are upstream. Instead of a flow blockage, it is assumed that the septifoil housing is unseated in the reactor, thus reducing the flow to zero.

Frequency

- Header flow reductions have never occurred, but there have been two cases of septifoils being unseated (and undetected) for long periods of time. Control rods were not damaged.

Results

- Control rod temperatures increase, but damage or melting does not occur (see Section 7.4.1.4).

Scram Instruments

- Reduction in header flow would cause a reactor shutdown within two seconds.

Analysis

- See Section 7.4.1.4.

7.4.2.8 Loss of Blanket Gas Pressure

Assumptions

- A blanket gas leak reduces the blanket gas pressure linearly from 5 psig to zero psig in two seconds.

Frequency

- Slow leaks of blanket gas have occurred, but not a sudden rapid drop in pressure.

Results

- Loss of blanket gas pressure would reduce the saturation temperatures in the reactor and cause evolution of the helium gas dissolved in the D_2O . Other secondary results follow. Cavitation may occur in the external cooling loops, which would reduce reactor coolant flow and increase coolant temperatures. The gaseous helium would appear as bubbles in the D_2O , which would cause a negative reactivity effect and drive reactor power down. The lower power would produce a positive reactivity feedback and the power would rise again. The transients expected for a sudden loss of blanket gas pressure are shown in Figure 7.4-14. A safety rod scram would occur after one second. Figure 7.4-15 shows the power and temperature oscillation for a particular charge if the scram did not occur.* However, the ABS/SC would shut down the reactor after 2.5 seconds, so that realistically, no oscillation would occur. Oscillations in currently operating charges would be smaller than indicated in Figure 7.4-15.

Scram Instruments

- The primary and secondary scram instruments are the two blanket gas pressure monitors and the assembly effluent temperature monitors.

Analysis

- Analysis of this accident is used to set normal operating limits. The assembly coolant temperature monitor is required to have its scram setpoint set low enough to ensure that the saturation temperature of the channel exit is not exceeded at a blanket gas pressure of 4 psig (normal operating pressure is 5 psig).

7.4.2.9 Loss of Coolant Accident

Assumptions

- It is postulated that a leak occurs somewhere in the D_2O coolant system when the reactor is at power. There are two classes of leaks: credible and hypothetical. It is assumed that a hypothetical, very fast leak rate occurs.

Frequency

- Small leaks from seals, flanges, and valves occasionally occur. The D_2O makeup system can replace D_2O at rates up to 4 gpm. No leak rates at SRP have reached 10 gpm.

* The transients for currently operating charges would not oscillate as much as shown in Figure 7.4-15.

Figure 7.4-14. Possible Transients for Sudden Loss of Blanket Gas Pressure

Figure 7.4-15. Power and Temperature Transients from Helium Bubbles Caused by Sudden Loss of Blanket Gas Pressure

Results

- If a leak rate greater than 4 gpm should occur, the moderator level in the reactor tank, the blanket gas pressure, and the plenum pressure would all decrease. The response would be:
 1. Shut down the reactor.
 2. Isolate the leak as much as possible.
 3. Activate the Emergency Cooling System, if needed, to replace the lost D₂O with H₂O.
 4. Maintain circulation to cool the fuel and target assemblies. One other result of a large leak — the release of radioactivity to the reactor building and the environment — will be discussed in following sections.

Scram Instruments

- The scram instruments that would be activated are the moderator level, blanket gas pressure, or plenum pressure circuits, followed by the individual assembly flow and temperature monitors.

Analysis

- A large effort has been expended on the analysis of credible and hypothetical leaks. An Emergency Cooling System (ECS) supplied from four separate independent sources of water can be activated manually or by logic circuits connected to the reactor scram instruments. Analysis shows that no fuel melting would occur for any credible loss-of-coolant accident. Of the credible accidents, the most likely would be a break in one of the smaller pipes in the auxiliary cooling systems. An example would be a break in a 6-inch pipe supplying D₂O coolant to the septifoil system. The leak rate from this system would be 3700 gpm; no fuel damage would occur after the ECS was actuated.
- The analysis is also made for hypothetical maximum leak rates — an abrupt, double-ended break of a large pipe that causes a leak of 75,000 gpm accompanied by other circumstances that render two of three ECS supply systems ineffective. The worst of the accidents analyzed is a break in a plenum inlet line that also serves as one of the lines that would supply emergency H₂O coolant. The accident is not considered credible in the SRP system of stainless steel pipe operating at relatively low pressures of ~100 psi. For a large leak (75,000), the ECS would mitigate the accident, but up to 1% core damage could result.

- Flow and pressure transients during the first second after the hypothetical pipe break are shown in Figure 7.4-16. Shutdown would begin about one second after the pipe break. The reactor power change is shown in Figure 7.4-17. Analysis of the accident indicates that fuel damage does not occur in this one-second interval. The longer term flow transient is shown in Figure 7.4-18. The factors that enter into the analysis are: reactor power, power distribution, reactor flow, flow distribution, ratio of fission product decay power to normal operating power level, the ECS supply rate, and finally the degree of fuel damage as a function of assembly flow and power. Reactor power is limited to a value that would produce less than 1% core damage if this hypothetical maximum leak rate should occur.

7.4.2.10 Loss of D₂O Circulation

Assumptions

- It is assumed that a complete loss of D₂O circulation occurs by loss of pumping power or some obstruction. Loss of pumping power could occur if all electrical power were lost and the motor room were flooded so as to stop the DC motors. Obstructions could occur if all rotovalves were closed, or if the D₂O became frozen.
- The loss of circulation would cause a reactor scram, but the ECS system would have to be activated to prevent melting fuel from the remaining decay heat. The addition of H₂O from the ECS would force a moderator-H₂O mixture out of the three pressure relief systems in the reactor tank.

Frequency

- The assumed accident has never occurred at SRP.

Results

- Radioactive moderator is released to the building through the pressure relief ports. Some fuel melting could occur.

Scram Instruments

- The reactor is shut down. The ECS is activated through redundant logic circuits.

Figure 7.4-16. Flow and Pressure Transients During First Second of Maximum Rate LOCA

Figure 7.4-17. Reactor Power Transient for Safety Rod Scram

Figure 7.4-18. Flow Transient for Maximum-Rate Loss of Coolant

Analysis

- The pre-accident reactor power is adjusted to limit fuel melting to 1% of the reactor core. In this sense, the loss-of-circulation accident is considered in deriving reactor power limits. The analysis of this accident is also used to define function specifications for the operation of the ECS.
- Emergency sump pumps and dams are provided to prevent flooding of the motor room. Operating procedures specify recirculating effluent H₂O to the 25-million-gallon inlet basins if the river water temperature should drop to 5°C. The D₂O freezing point is 4°C, and on one occasion (over 28 years of operation), the temperature of the Savannah River came close to this value.
- Detailed analysis of this accident shows that the reactor power that would limit fuel damage to 1% is higher than the reactor power prescribed by other limits. Thus, no melting would occur, but radioactive moderator would be released to the reactor building and the environment.

7.4.2.11 Loss of Cooling During and After Discharge

Assumptions

- Irradiated fuel and target assemblies are discharged in air and transported by crane to the discharge canal. If the crane becomes disabled, emergency cooling would be required to prevent melting and release of fission products. It is assumed that the crane becomes disabled, or that an assembly is dropped to the reactor room floor.

Frequency

- The emergency cooling systems have always worked when required. In about 300,000 assembly discharge operations, there have been several instances in which the discharge operation was interrupted and emergency cooling was required. Although no fission products have been released during discharge operations, an antimony-beryllium source rod once melted while being held in air for an extended period of time with no cooling. About 100,000 curies of antimony and tellurium isotopes were released to the reactor room.

Results

- If emergency cooling to the discharge machine should fail at the same time a discharge machine interruption occurs, melting of fuel could take place.

Scram Instruments

- Reactor scram instruments are not effective in this accident.

Analysis

- Discharge operations are delayed after reactor shutdown until the hottest assembly can be cooled in the discharge machine with the minimum emergency crane coolant flow. Redundant cooling sources and coolant delivery paths are provided. Five sources of water are available to the discharge machine from four independent systems -- primary D₂O, secondary D₂O, primary H₂O, and secondary H₂O. Each source has independent hoses, pipes, and actuation valves. Primary H₂O cooling is started automatically as soon as the irradiated assembly is withdrawn from the reactor and the water pan swings under the assembly. If primary H₂O flow stops, switching to the secondary source is automatic. The switching can also be done manually.
- A reactor room spray system is available if an assembly is dropped onto the floor or the top of the reactor. The spray system pumps run continuously during discharge operation. Actuation of the system is manual.

7.4.3 Summary of Reactor Accident Analysis

Operating and confinement protection limits are calculated for each reactor charge for eight postulated reactivity addition accidents and eleven postulated flow reduction accidents. Table 7.4-1 presents a summary of the analyses.

7.4.4 Non-nuclear Hazards

7.4.4.1 Toxic Gas Release

In past operations, the effects of toxic gas releases have been analyzed, and provisions made for shutdown, building evacuation, and remote control of coolant flows, pumps, and valves. The two toxic gases considered were the chlorine gas used to prevent biofouling of reactor heat exchangers, and H₂S gas used in the heavy water production area. Two recent changes in plant operation have reduced the hazards from these gases.

- L-Reactor will use sodium hypochlorite as the cooling water biocide instead of chlorine. Sodium hypochlorite (NaOCl) has no significant safety hazard, and will provide the same biological protection as chlorine.

TABLE 7.4-1

Summary Table — Analysis of Postulated Reactor Accidents

No.	Accident Description	Condition of Reactor	Has Incident Occurred at SRP?	Expected Frequency Per Year (3 Reactors)	Main Effect	Scram Systems		Used to Establish	
						Primary	Secondary	Operating Limits (Safety Rods)	Confinement Protec. Limits (ABS-S/C)
Reactivity Addition Accidents									
1.	Single Rod Withdrawal	Full power	Yes	1	Increasing assembly power	(1)	(2)	Yes	Generically
2.	Partial Rod Insertion	Full power	Yes	1	Increasing assembly power	(1)	(2)	Yes	Generically
3a.	Gang Rod Withdrawal	Full power	No	0	Increase reactor, assembly power	(1)	(2)	Yes (usually limiting)	Yes
3b.	Gang Rod Withdrawal	Low power	No	0	Rapid power rise	(2)	(1)	No (limits Xe conc.)	No
4.	Control Rod Melting	Full power	No	0	Increasing assembly power	(1)	(2)	No	No
5.	Target Melting	Full power	No	0	Increased reactivity	(4)	(1),(2)	Yes	Yes
6.	Fuel Melting	Full power	No	0	Increased reactivity	(4)	(1),(2)	(5)	(5)
7.	Reloading Error	Shutdown — charge-discharge	No	0	Increased reactivity	(6)	(7)	No	No
Flow Reduction Accidents									
8.	Loss of D ₂ O Coolant Pump Power	Full power	No	0	Increased assembly coolant temperature	(8)	(4)	Yes	Yes
9.	Loss of H ₂ O Pump Power	Full power	No	0	Increased reactor inlet temperature	(9)	(10),(1)	No	Yes
10.	Loss of Both D ₂ O and H ₂ O Pump Power	Full power	No	0	Same as No. 8	(8)	(4)	No	No
11.	Pump Shaft Break	Full power	No	0	Increased assembly	(8),(4)	(1)	Yes	Yes

(1), (2), etc. -- see page 7-75.

TABLE 7.4-1 (Continued)

No.	Accident Description	Condition of Reactor	Has Incident Occurred at SRP?	Expected Frequency Per Year (3 Reactors)	Main Effect	Scram Systems		Used to Establish	Confinement
						Primary	Secondary	Operating Limits (Safety Rods)	Protec. Limits (ABS-S/C)
Flow Reduction Accidents (Contd)									
12.	Rotovalve Closure	Full power	No (11)	0	Increased assembly temperature	(8),(4)	(1)	No	No
13.	Flow Reduction in Single Assembly	Full power	Yes	~0.6	Increased assembly temperature	(4)	(1)	Yes	No
14.	Loss of Control Rod Cooling	Full power	Yes	~0.02	Increased control rod temperature	(12)	None	No	No
15.	Loss of Blanket Gas Pressure	Full power	Yes	0.2	Decreased saturation temperature	(13)	(1)	Yes	No
16.	Loss of Coolant (Leak)	Full power	No	0	Decreased moderator level; release of radioactivity	(14)	(13),(8)	Yes	No
17.	Loss of D ₂ O Circulation	Shutdown	No	0	Increased assembly temperature	(15)	None	Yes	No
18.	Loss of Cooling During or After Discharge	Discharge operations	No	0	Possible melting of fuel	None	None	Yes	No
<div><div>(1) Assembly Effluent Temperature Monitor (600) (2) High Level Flux Monitors (4) (2) Period Meters (2) (4) Assembly Flow Monitors (300 target, 300 Fuel) (5) Under Study</div><div>(6) Reverse reloading step (7) Supplementary Safety System (8) Plenum Pressure Monitors (2) (9) Heat Exchanger Flow Monitors (12) (10) H₂O Header Flow Monitors (2)</div><div>(11) Two rotovalves closed in one system only one time (12) Septifoil Header Low Flow (13) Blanket Gas Pressure Monitors (2) (14) Moderator Low Level (1) (15) Manual or Automatic Action of Emergency Coolant System</div></div>									

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

Thus, an analysis of the effects of toxic gas release is not necessary for L-Reactor operation.

7.4.4.2 Organic Matter

The secondary H_2O cooling system is a once-through system that draws water from the Savannah River. It is, therefore, subject to buildup of organic material as conditions promote growth of microorganisms or deposition of vegetable debris. Such a buildup poses no special problem to the safety of a reactor under normal operating conditions. The predictable results of a buildup are reduction in coolant flow (as organic matter obstructs flow passages) and reduction in heat exchanger efficiency (since the organic matter has low thermal conductivity). These effects are apparent from routine monitoring of process variables, thus attracting attention and prompting remedial action.

The buildup of organic matter can pose a serious threat to reactor safety under emergency conditions. Material can build up in the piping of the emergency cooling system without being detected, because there is neither flow nor heat transfer in these pipes under normal operating conditions. If the need for emergency cooling should arise, the debris could be flushed into the reactor and inhibit flow in fuel coolant channels. The general solution to this problem is periodic inspection and cleaning of the unused piping.

The possibility of biofouling of a coolant system was well known before the startup of the first SRP reactor. The chlorination process cited in the preceding section was intended to control the problem by inhibiting the growth of bacteria in the secondary cooling system. But accumulations of organic matter by some mechanisms not anticipated have been observed during the past decade.

The most persistent of the new mechanisms is infestation by the asiatic clam, Corbicula manillensis. Analysis of the problem indicated that the organism would pass through the debris screens when it was in the larval state (smaller than one mm), attach itself to some solid surface until it grew to about six mm, and then break loose. The Savannah River was the original source of the larvae at SRP, but colonies surviving in the 186 basins became secondary sources. Both basins and piping (including the normally unused piping of the ECS) are now cleaned at least annually.

Another unanticipated mechanism has been observed on one occasion. A heavy concentration of vegetation (mostly pine straw and leaves) appeared in the supply of water from the river. This debris would be more effective than other organic matter in stopping coolant flow. A special strainer was designed to withstand a large accumulation of debris before inhibiting flow significantly and to let even debris-laden water pass if the strainer became plugged.

Two other isolated incidents were 1) a buildup of a filamentous fungus slime and 2) accumulation of midge fly larvae and pupae. Each of these cases required extraordinary cleaning of the 190 pump screens and a temporary increase in chlorination at the Savannah River pumphouses. Another general lesson learned from these experiences is not to suspend chlorination of H_2O during prolonged shutdowns when the H_2O is not needed to cool the reactors. Such interludes enable extraordinary growth and accumulation of organic matter.

7.5 RADIOLOGICAL CONSEQUENCES OF REACTOR ACCIDENTS

7.5.1 Introduction

Routine reactor operations are designed to control effluent releases to their lowest practical level within technological and economic constraints. Despite the care taken to avoid failures or operating errors that potentially could lead to safety problems, anticipation of such occurrences during the service life of the reactor facilities is prudent. Therefore, protection for the operating staff, the public, and the plantsite is provided by reliable protective devices and systems, designed to ensure that such incidents will be prevented, arrested, or accommodated safely. The requirements for these protection systems are based on a spectrum of occurrences and accidents which the plant design must safely accommodate.

The occurrences considered range from relatively minor events that result in essentially no risk to the public (releases of hazardous materials within the criteria for routine operation), to accident situations with a potential for serious consequences, but which are unlikely to occur.

The range of accidents considered was discussed in Sections 7.2, 7.3, and 7.4. This section discusses how released radioactivity may affect the public. The sources of a radioactivity release are discussed first. Then the calculational techniques and finally the results of the calculations are presented.

7.5.2 Sources of Radioactive Release

The hypothesized SRP reactor accidents described here cover a spectrum of events leading to release of radioactivity. Four specific accidents are discussed which give a range of consequences. These accidents are: a moderator spill; a discharge mishap in which an irradiated assembly is dropped and melts; a hypothetical loss of coolant accident in which 10% of the reactor core melts — a value ten times as high as the 1% melting that would be expected if only one of the three top addition systems of the Emergency Cooling System is operative; and a misloading accident during charge-discharge operations, in which seven fuel assemblies form a critical mass and melt.

The effects of each accident are compared with the criterion given in 10 CFR 100⁴ for power and testing reactors. This criterion is that the exclusion area (area in which activities may be controlled) be of such a size that "an individual located at any point on its boundary for two hours immediately following

onset of the postulated fission product release would not receive a total radiation dose to the whole body in excess of 25 rem, or a total radiation dose in excess of 300 rem to the thyroid from iodine exposure." The fission product release is from such accidents that "have generally been assumed to result in substantial meltdown of the core with subsequent release of appreciable quantities of fission products."⁴ It is considered that the 10% core meltdown accident satisfies the definition of "substantial meltdown," being ten times the calculated result that would occur with multiple failures of reactor shutdown and/or emergency cooling systems.

The sources of radioactivity considered in this section are tritium in the D₂O moderator and fission products in the fuel and targets. Potential offsite doses from nonfission product isotopes (⁶⁰Co, ²³⁹Pu, etc.) are considered in Section 7.5.5.1.

7.5.2.1 Radioactivity Release From a Moderator Spill

This report uses a conservative and limiting value of five million (MCi) curies of tritium as being present in the moderator of each reactor. This is 30 to 40% higher than present actual values for operating SRP reactors. This tritium could be partially released to the confinement system following ECS 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.

It is unlikely that the full moderator inventory of tritium would evaporate and diffuse into the confinement system following any accident because the moderator would flow first into the 60,000-gallon tank and then to the 500,000-gallon tank of the liquid activity confinement system. It is estimated that about 3% of the tritium would evaporate during the two-hour period after the postulated accident. It is assumed that this amount (165,000 curies) is released from the stack during the two-hour period specified in 10 CFR 100.

7.5.2.2 Radioactivity Release From Core Melting

If any fuel or target assemblies melt, fission products become available for release. Depending on the type of assemblies melting and other circumstances, the radioactivity released would include noble gases (Xe, Kr), iodine, tritium, and radioactive particulates (fission products, ⁶⁰Co, ²³⁹Pu, etc.). The concentration of these isotopes in the core is a function of reactor power (taken as 3000 MW). Most of these isotopes decay rapidly

following shutdown; and depending on the expected accident sequence, some isotopes may not contribute significantly to potential offsite doses. Figure 7.5-1 shows the source of noble gases (at 3000 MW) and Table 7.5-1 gives the full-core equilibrium iodine inventory. The radioactive particulates include several different isotopes and would be captured by the HEPA filters. The amount of particulates that would penetrate the filters would not contribute significantly to the offsite dose.^{5,6}

7.5.2.2.1 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. The fission products in the assembly would have decayed significantly between shutdown of the reactor and the discharge operation. Fourteen hours of decay of fission products are assumed as the minimum time to satisfy the discharge constraints discussed in Section 7.4.2.11. A single assembly would contain 0.39% of the full core inventory before decay.

The reactor room emergency spray system would be used to cool a hot assembly in some discharge mishaps and prevent melting. If melting occurred, the spray water would keep much of the iodine and particulates from becoming airborne. The effect of particulates at the site boundary is negligible. No credit is taken for iodine confinement within the assembly, however, and 50% of the iodine and 100% of the noble gases available for release are assumed to escape the assembly and become airborne within the confinement system. The iodine that reaches the carbon filter bed is assumed to be all elemental iodine because of the high airflow and rapid transport of iodine to the carbon beds.⁶

7.5.2.2.2 Melting of Seven Assemblies Caused by a Misloading

Criticality could result from a misloading event (Section 7.4.1.6). As many as seven assemblies could melt following this accident. The melting could release fission products and tritium into the moderator. For purposes of analysis, it is assumed that 50% of the iodine and all the noble gases and tritium become airborne. Prior to 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 is assumed that the fission product content of the seven assemblies is the equilibrium concentration at full power. Two cases are considered: melting of seven assemblies in a tritium-producing charge, or melting seven assemblies in a mixed-lattice charge.

Figure 7.5-1. Gamma Decay Energy of Noble Gases

TABLE 7.5-1

Iodine Inventory of Core at Full Power

<u>Isotope</u>	<u>Amount in Core (MCi at 3000MW)</u>
^{131}I	76
^{132}I	114
^{133}I	169
^{134}I	197
^{135}I	154

7.5.2.2.3 Postulated Core Melt

The amount of radioactivity released would be 10% of the noble gases shown in Figure 7.5-1 and 10% of the iodine given in Table 7.5-1. Fifty percent of the released iodine would be airborne. The iodine would be trapped on the carbon filters and some of the iodine would desorb later and be released from the stack (see Section 7.5.3.1).

7.5.3 Release of Radioactivity

In the moderator spill accident, tritium is released to the confinement system and discharged from the 200-foot stack. The release is assumed to occur over a two-hour period. Only a small part of the tritium would actually be released; the rest would remain in solution in the two (60,000-gallon and 0.5-million-gallon) holding tanks. It is conservatively assumed that 3.3% of the tritium evaporates and exits as water vapor.

For the other three accidents, assemblies are assumed to melt. The amount of fission products released is proportional to the fraction of the core that melts. Noble gases and iodine are assumed to be released into the process room. Gases vented to the blanket gas system would eventually be released into the confinement system. It is estimated that 1% of the particulates (fission products, Pu isotopes, etc.) would be released into the building, and half of that would reach the filters.^{5,6} The iodine released to the reactor room and 99% of the remaining particulates would be captured by the activity confinement system. The reactor room spray system could remove much of the airborne iodine and particulates before they left the process room, but this is not considered in the accident analysis.

Following a postulated melting accident, all noble gases are assumed to be released from the 200-foot stack. As discussed above, 99% of the airborne particulates are assumed to be captured on the HEPA filters which is well in line with filter efficiency test results. For iodine, it is assumed that 99.95% of it is trapped on the carbon beds and that 0.05% of it bypasses the filter (the 0.05% value is based on filter efficiency tests). In comparison with other doses, the released solids are considered insignificant.⁵ As indicated in the sub-section below (Section 7.5.3.1), some of the iodine trapped on the carbon beds would be desorbed as the result of the high radiation field generated by the decay of radioactive iodine. These desorption rates are used to calculate potential offsite doses. The remaining iodine would be held in the 60,000-gallon and 0.5-million-gallon tanks or in the reactor or reactor building. An insignificant fraction of this iodine would be converted to organic iodine compounds and then volatilize.⁶ The tanks are vented back through the activity confinement system, so no unfiltered radioiodine compounds would be released.

7.5.3.1 Response of the Confinement System to an Iodine Release

The response of the airborne activity confinement system (AACS) to a postulated severe iodine release has been evaluated for two conditions: minimum acceptable operating conditions, and adverse accident conditions. The release postulated is 50% of the equilibrium iodine inventory reaching the filter train.

In evaluating the minimum acceptable operating conditions, it was assumed that:

1. Only one exhaust fan and three filter compartments are online instead of the normal set of two fans and four filter compartments.
2. All carbon filters are at the end of the maximum service life-time.
3. The HEPA filters and demisters in the filter compartments are fouled enough to cause the maximum flow resistance allowed.

In evaluating the adverse accident conditions, it was assumed that:

1. Iodine loading is severely skewed among the filter compartments.
2. HEPA filters are blinded by smoke or steam, thereby reducing the airflow through the filters and enhancing thermal desorption of iodine.
3. Failure of fans and incorrect positioning of dampers.

The evaluation showed that the AACS can tolerate component failures and still perform its intended function. Very improbable combinations of minimum acceptable operating conditions, adverse accident conditions, and/or system failure would be required to defeat the intended performance of the system. For example, the first 5 hours after an accident that deposits iodine on the carbon filters is the most critical period for the AACS, because thermal desorption is most likely then. During this early critical period, failure of fans or misoperation of dampers is very unlikely. After 5 hours, the temperature of the carbon beds begins to decrease as the radioactive decay of the iodine occurs.

Typical desorption curves for iodine on SRP carbon beds are shown in Figure 7.5-2. The desorption rate of iodine from the carbon filter is 0.056% for the first two hours.

7.5.3.2 Reliability of the Airborne Activity Confinement System

The L-Reactor Airborne Activity Confinement System (AACS) has been described in Section 3.3.5.9. This section describes the reliability features of the AACS. The AACS is a passive system of filters that is online at all times during reactor operation and during charge-discharge operations. No operator action is required to make it operative. The following requirements must be met by the AACS before operation is allowed. Each requirement is supported by a series of required actions (inspections, monitoring, and tests) that assure the requirements are met.

Requirements

1. The filter compartment housing must withstand the pressure surge caused by the maximum credible steam explosion.

Figure 7.5-2. Iodine Retention Tests in Radiation Field of 15 Million Rads $^{60}\text{Co/hr}$
(Average age of carbon filters on SRP reactors is 15 months)

2. Carbon filters must remove 99.95% of the halogen activity in the air exhausted from the reactor building.
3. Particulate filters must remove 99% of particulates of 0.3 micron and above in the air exhausted.
4. Moisture separators must remove 99% of the entrained liquid droplets in the air exhausted.
5. The exhaust fans must continuously exhaust a minimum of 40,000 cubic feet per minute from the process areas of the reactor building.
6. The M damper must open when required to direct air from below-grade process areas to the filters.
7. The N damper must close when required to prevent air from below-grade process areas going directly to the stack.
8. The incident switch must initiate automatic equipment changes (de-energize supply fans, open and close dampers) when required.
9. The exhaust stack must withstand the maximum credible earthquake for the area.
10. Adequate water supply to the Confinement Heat Removal (CHR) system (Sections 7.3.5.8 and 7.3.5.4) from the disassembly basin must be maintained.
11. The integrity of the CHR system equipment must be verified periodically.
12. Periodic functional tests must demonstrate CHR equipment operability.
13. Operating procedures must specify operability requirements of the CHR system.
14. Personnel must be trained to respond correctly to the CHR console alarms.

Redundancy

- Only one of the three exhaust fans is required to supply the 40,000 cubic-feet-per-minute airflow.
- Only one of the two diesel generators is required to supply power to the exhaust fans if normal power is lost.

History

The AACS has been required only once during SRP operation (during the source rod melting incident — Section 7.4.2.11). The AACS worked as designed and prevented the release of radioactivity from the reactor building.

Limitations

- The ACS does not remove tritium or noble gases.
- The filter compartments and the area around them would have extremely high radiation levels following an accident. Their removal and disposal would have to be done with remote equipment.

7.5.4 Calculation of Offsite Dose

This section specifies the techniques used to calculate off-site doses resulting from hypothetical reactor accidents. The methods discussed are used for analysis of all accidents, including the moderator spill and fuel melting accidents.

7.5.4.1 Calculational Method and Criteria

There are three procedures necessary to compute the maximum offsite dose. First, the source of radioactivity must be specified. Specifying the source designates the release rate and isotope type. Second, the transport of the isotope by the wind must be computed. The calculational procedure and pertinent meteorological data determine the transport of activity. Third, the amount of radioactivity absorbed by an individual at the plant boundary must be computed. This calculation requires specifying a standard man, breathing rates, and parameters related to absorption of energy from a particular isotope.

Individual body characteristics, time of exposure, and wind behavior are parameters used in calculating the maximum individual dose at the boundary. In an actual accident, the WIND computer system of SRP would predict the release path and indicate appropriate action to minimize exposure to people offsite.⁷ Evacuation procedures would reduce the actual dose to an individual.⁸

The NRC criteria provide guidelines for siting a reactor in a manner that reduces risk to the public to as low as is reasonably

practical. In addition to this broad stipulation, the NRC specifies that the maximum dose to an individual at the plant boundary should not exceed 25 rem to the whole body and 300 rem to the thyroid after an accident.⁴ SRP reactors meet these criteria for all of the accidents described here.

7.5.4.2 Source Treatment

The release of radioactivity is assumed to spread as a Gaussian plume, and the irradiation of an individual is treated as a time-integrated calculation. Two-hour duration of the release and of the meteorology is assumed; this implies the subject is irradiated for a two-hour period after the release. Measurements at the SRP site show that the probability of wind persistence for a two-hour period is only about 20%.⁹ Slow (2 to 4 m/sec, or ~4.5 to 9.0 mph) stable winds associated with the slow diffusion rate would transport the atmospheric releases to the plant boundary in about one hour. The source term for iodine is the amount that would desorb in the first two hours following the incident.

7.5.4.3 Transport of Release

The transport of iodine and noble gases is calculated according to methods suggested by Nuclear Regulatory Guides.* SRP has seven towers located in the operating areas from which to gather meteorological data, as well as one instrumented TV tower located near the plant boundary (Figure 2.4-1). Atmospheric stability, which is used in the calculations, is determined from the observed magnitude of the standard deviation of wind azimuth and classified according to values given in Reference 11.

The transport calculations yield the relative concentrations, χ/Q , which are the downwind concentrations of an isotope in Ci/m³ for a unit release of 1 Ci/sec at the stack. Calculations are made for the relative concentration at the 50-percentile value of meteorological conditions, which is the value that indicates a higher concentration could occur 50% of the time, and a lower concentration the rest of the time.

* It is recognized that other methods for calculating transport have been proposed, namely, Regulatory Guide 1.145.¹⁰ These methods are under study at SRP.⁹

7.5.4.4 Dose Conversion

The transport of the radioactive release to the plant boundary is based on the above described techniques. At the boundary, the release is assumed to irradiate a standard man to determine the maximum dose received. The calculational methods and parameters are consistent with SRP standard techniques, which are based on recommendations by the International Commission on Radiological Protection.¹² For iodine and tritium, a standard man and breathing rate are used to calculate an inhalation dose. The dose conversion factor considers skin absorption, as well as inhalation in the case of tritium. The dose from noble gases assumes the subject is immersed in a semi-infinite cloud. The irradiation continues for a two-hour period.

The details of the calculation of absorbed dose and the biological dose equivalent from the noble gases, tritium, and iodine are included in References 13 and 14.

7.5.5 Results of Calculations

The bases and assumptions for both the radioactive source terms and the methods for computing the transport to the plant boundary are described in Sections 7.5.3 and 7.5.4, respectively. The results of the calculations are given in Table 7.5-2. The results in the table are given in order of increasing severity.

The radiation doses in Table 7.5-2, which are calculated for 50% meteorological conditions, are all considerably less than the 10 CFR 100⁴ guideline values for site suitability determinations for power and testing reactors. For the postulated loss-of-coolant accident at the 10% core melting level the dose is 4% of the guideline whole body dose, and 2.6% of the guideline value for the thyroid dose.

The core damage accident assumes that a massive double-ended pipe break occurs. The break is assumed to be in one of the plenum inlet lines used by the ECS system, so that one of the ECS addition systems is incapacitated. It is further assumed that a valve does not open in one of the remaining ECS systems and that one DC pump motor is off. Thus, only one of the three ECS addition systems is assumed to work as designed. The reactors are operated at power levels that limit core damage to less than 1%. Thus, the postulated core damage considered here is about ten times the damage that could reasonably be expected. Nevertheless, the doses (Table 7.5-2) are below the 10 CFR 100⁴ guidelines.

TABLE 7.5-2

Calculated Radiation Dose to a Person at the SRP Site Boundary
During the Two-Hour Exposure Period Following an Accident

Accident	Calculated Dose, rem	
	Whole Body	Thyroid
Guideline values for reactor siting in 10 CFR 100 ⁴	25	300
Moderator (D ₂ O) spill	0.005	0
Discharge Mishap (one fuel assembly melts)	0.04	0.3
Misloading Criticality (seven fuel assemblies melt)		
Tritium-producer charge	0.14	1.0
Mixed lattice charge	0.22	2.0
Loss of coolant (LOCA) with two top addition systems inoperative (two times expected core damage), 2% core melt*	0.2	1.5
Postulated 10% core melt accident	1.0	7.6

7.5.5.1 Nonfission Product Isotopes

The potential offsite dose from nonfission product isotopes (e.g., ^{60}Co , ^{210}Po , and ^{238}Pu) that may be present in large quantities in the mixed-lattice charges, has also been considered. Few, if any, of these isotopes will be present in sufficient concentrations to generate sufficient heat to melt the target. Hence, major releases of the product materials in mixed-lattice charges would be expected to occur only in conjunction with a major reactor accident, i.e., greater than a 2% core melt.

For calculational purposes, it is assumed that in an accident the fractional release of the nonfission product isotopes to the building environment, transport in the reactor building, and removal by the activity confinement system will be the same as the behavior of particulate fission products discussed above; namely, 1% of the inventory is released to the building, 50% of the released fraction is deposited in the building before reaching the filter compartments, and 99% of the remainder is collected by the compartments. The assumed net release fraction is thus 5×10^{-5} .

To provide an estimate of the relative magnitude of the potential offsite effects of several isotopes, full-charge inventories of several possible products were calculated. The inventories are based on the production capability in a single reactor (except ^{238}Pu inventory, which is based on the availability of intermediates as feed material). Lesser amounts would be present in mixed lattices involving the production of several isotopes simultaneously.

The quantity of each isotope that might be inhaled by a receptor at the plant boundary is based on a fractional release of 5×10^{-5} for all isotopes, the overall site χ/Q at the 50th percentile level, and a breathing rate of $3.47 \times 10^{-4} \text{ m}^3/\text{sec}$. The calculated amount inhaled is given in Table 7.5-3. This quantity, in micro-curies, is compared with the Annual Limit on Intake (ALI), as calculated in ICRP-30¹⁵ for an adult limited to 5 rem per year (for an accident the limit would be 25 rem). Fallout, deposition, and decay in transit to the plant boundary are neglected. As given in Table 7.5-3, all comparisons show that the amount inhaled is less than the Annual Intake Limit.

TABLE 7.5-3

Potential Offsite Doses from Nonfission Product Isotopes*

<u>Isotope</u>	<u>Amount Inhaled** at Plant Boundary, μCi</u>	<u>ALI, μCi†</u>	<u>Fraction of ALI</u>
^{60}Co	2.7	190	0.01
^{210}Po	0.09	0.54	0.17
^{233}U	6×10^{-6}	0.81	7×10^{-6}
^{238}Pu	.005	0.0054	0.9
^{239}Pu	1.2×10^{-4}	0.0054	0.02
^{244}Cm	.003	0.011	0.3

* These numbers generally are based on a reactor charge producing a single product. If two or more products are being produced simultaneously in the same reactor, the maximum inventory of any one would be lower.

** Based on a release fraction of 5×10^{-5} , overall site χ/Q at 50-percentile, breathing rate of $3.47 \times 10^{-4} \text{ m}^3/\text{sec}$.

† Annual Limit on Intake for Inhalation, from Reference 15.

7.5.6 Risk Evaluation

The dose values given in Table 7.5-2 are the consequences that would result at the site boundary. Other consequences would also occur — reactor damage, worker exposure, building contamination, cleanup costs, loss of production — but these are not environmentally related consequences. However, for each of the accidents to happen requires a sequence of events which can only occur if multiple failures occur. The following discussion centers on estimates of the probability for each of the accidents discussed above.

7.5.6.1 Moderator Spill

A sizeable moderator spill has occurred once at SRP during the early stages of operation. At the time of the spill, the moderator contained very little tritium. Since over 100 years of reactor operation has occurred at SRP, this experience suggests that the probability of a spill is about 0.01 per reactor year. In addition, a judgement estimate of the probability for spilling all of the moderator instead of only part is also 0.01. The overall estimated probability is, thus, 0.0001, or 10^{-4} per reactor year. The risk associated with a moderator spill — consequence times probability — is 0.0005 millirem per reactor year.

7.5.6.2 Discharge Mishap

Over 300,000 fuel or target assemblies have been discharged without failure of cooling water or the holding mechanism in the discharge machine. No assembly has been dropped. Melting did occur in one element during this time, in a source rod, because of procedural error, and not because of mechanical or cooling water failure. The source rod incident is treated as a separate incident apart from fuel and target discharge. The estimated probability for melting during discharge, based on studies at SRP, indicates that this probability is equal to or less than 10^{-4} per reactor year.

7.5.6.3 Misloading Error Leading to Criticality

The probability of a misloading error occurring during charge-discharge operations has been estimated as 3×10^{-6} per reactor year. The estimate is based on fault tree analysis combined with the expected number of unit operations per year. A misloading error leading to criticality can occur in only a limited number of

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 must have a probability of less than 3×10^{-6} , or about 10^{-7} per reactor year.

7.5.6.4 Core Melt

Literature search on pipe breaks indicate probabilities on the order of 3×10^{-5} per year for massive failures. The probability of partial failure of the ECS system, leading to 1% core melting, has been estimated to be 3×10^{-2} . Thus, the probability of failure leading to 1% core melting would be about 10^{-6} per reactor year. The probability of the accident progressing to 2% core melting would be less than 10^{-6} .

7.5.6.5 Results

Risks of the postulated accidents are tabulated in Table 7.5-4. The risks range from less than 1×10^{-5} millirem per year to 4×10^{-3} millirem per year. All values are very much less than risk that could be associated with natural radiation of 100 to 120 millirem per year.

7.5.7 Consequences of a Hypothetical Moderator Release

One final, hypothetical (and noncredible) accident is analyzed. It is assumed that the entire inventory of reactor coolant and moderator (55,000 gallons) is spilled and transported to the soil portion of the 50-million-gallon emergency basin. From there it seeps into the ground and is transported to the nearest stream at the rate of one foot per day — the normal ground water flow rate. The radiation dose to all age groups from drinking water, sport and commercial fishing, saltwater invertebrates, and recreation is then calculated with the SRP version of the code LADTAP-II.¹⁶

The moderator inventory of radioactivity is given in Column 3 of Table 7.5-5. The final column in this table gives the amount of radionuclides that reach the river.

In calculating the radiation dose, it is assumed that the river flow is at a low value (6,100 cubic feet per second) and that the 50-mile population is 781,000.

TABLE 7.5-4

Risk Evaluation of Accidents

<u>Accident</u>	<u>Estimated Probability, y^{-1}</u>	<u>Risk, mrem/year (Whole Body)</u>
Moderator Spill	10^{-4}	5×10^{-4}
Discharge Mishap	10^{-4}	4×10^{-3}
Misloading Criticality	10^{-7}	$1-2 \times 10^{-5}$
Loss-of-Coolant, 2% Core Melt	$<10^{-6}$	$<2 \times 10^{-4}$
Natural Radiation	1	100-120

TABLE 7.5-5

Moderator Radioactivity Reaching River in Hypothetical Accident

<u>Radionuclide</u>	<u>Curies/ml</u>	<u>Curies in Basin</u>	<u>Half-Life</u>	<u>K_D*</u>	<u>Curies to River</u>
³ H	1.8 x 10 ⁻²	3.8 x 10 ⁶	12.33 y	0	3.0 x 10 ⁻⁶
²⁴ Na	3.1 x 10 ⁻²	6.5 x 10 ⁶	15 h	0	~0
⁵¹ Cr	4.0 x 10 ⁻⁴	8.4 x 10 ⁴	28 d	0	4 x 10 ⁻¹³
⁹¹ Sr	1.4 x 10 ⁻³	2.9 x 10 ⁵	9.5 h	100	~0
⁹² Sr	1.4 x 10 ⁻³	2.9 x 10 ⁵	2.7 h	100	~0
⁹⁵ Zr-Nb	1 x 10 ⁻⁴	2.1 x 10 ⁴	64 d	0	6 x 10 ⁻⁴
¹³¹ I	5 x 10 ⁻⁵	1 x 10 ⁴	8 d	0	~0
¹⁴⁰ Ba	6.3 x 10 ⁻⁴	1.3 x 10 ⁵	12.8 d	0	~0
¹⁴¹ Ce	9 x 10 ⁻⁵	1.9 x 10 ⁴	32 d	0	3 x 10 ⁻¹¹
¹⁴³ Ce	2.5 x 10 ⁻⁴	5.2 x 10 ⁴	33 h	0	0
²³⁵ U	<5 x 10 ⁻⁷	1 x 10 ²	1.6 x 10 ⁵ y	60	100**
²³⁸ Np	<5 x 10 ⁻⁷	1 x 10 ²	2.1 d	1400	0
²³⁹ Np	1.7 x 10 ⁻³	3.6 x 10 ⁵	2.4 d	1400	0

* K_D values selected as conservative from a wide range of references and measurements. If no data was available, a K_D value of zero was used.

** Water treatment plants will normally remove uranium.

The accident is considered not to be credible because:

- The spilled moderator first goes to a 60,000-gallon tank. This tank is designed to contain the first 60,000 gallons, without the water being purged to the outside.
- Water in excess of 60,000 gallons is automatically diverted to a 500,000-gallon-tank that sits in the bottom of the 50-million gallon emergency basin. Piping to this tank is so designed - that water in excess of 500,000 gallons is automatically diverted to the 50-million-gallon emergency basin without the water in the tank being purged to the basin.
- The two tanks are vented to the activity confinement system.

Results of the LADTAP-II calculations are given in Table 7.5-6. The largest body dose would be 60 millirem to a child, or about half of the annual dose from cosmic and terrestrial radiation. Body dose to the population is 1,540 man-rem, compared with about 94,000 man-rem expected from natural radiation to a projected 50-mile population of 781,000.

TABLE 7.5-6

Dose Estimates for Hypothetical Moderator Release Accident

	Organ Dose Commitment							
	<u>Skin</u>	<u>Bone</u>	<u>Liver</u>	<u>Body</u>	<u>Thyroid</u>	<u>Kidney</u>	<u>Lung</u>	<u>G.I.-LLI</u>
<u>Max. Individual, mrem</u>								
Adult	0.19	11.4	42.9	43.6	42.9	45.5	42.9	44.0
Teen	0.364	11.5	30.6	31.3	30.6	33.2	30.6	31.4
Child	0.076	32.7	57.1	59.1	57.1	62.5	57.1	57.9
Infant	-	28.1	55.4	57.5	55.4	61.3	55.4	55.9
<u>Population, man-rem</u>								
Port Wentworth	-	157	617	627	617	654	617	632
Beaufort-Jasper	-	309	893	912	893	956	893	913
Fish-sport	-	1.71	2.47	2.58	2.47	2.84	2.47	2.60
Fish-commercial	-	0.006	0.009	0.009	0.009	0.010	0.009	0.009
Salt Water Invert	-	0.03	0.009	0.011	0.009	0.015	0.009	0.011
Recreation	1.09	-	-	0.87	0.87	-	-	-
Total	1.1	470	1510	1540	1510	1610	1510	1550

7.6 TRANSPORTATION ACCIDENTS INVOLVING RADIOACTIVE MATERIALS

The cumulative risks from accidents in Ci/yr for a single reactor are estimated to be about 2×10^{-3} Ci β - γ /yr, 2×10^{-5} Ci α /yr, and 3×10^{-2} Ci tritium per year as shown in Table 7.6-1.

The radiological risks for these Ci/yr values were calculated using the GASPAR code defined in NRC Regulatory Guide 1.109¹³ as modified for accidental releases. The calculated total body radiological risk to the population is 1.1 man-rem/yr and to the maximally exposed member of the population is 0.017 mrem/yr (Table 7.6-2).

7.7 EMERGENCY RESPONSE

The Emergency Response Plan for L Area will include specific policies and procedures to minimize injuries and property damage caused by accidents, natural disasters, or deliberate damage in the 100 Areas. The plan will deal with sheltering or evacuation, nuclear incidents, civil defense readiness, missile or air attack, rescue plan, natural disasters and alerts, bomb threats, offplant accidents, and forced entry or terrorist attack.

If an emergency occurs which affects L Area, another area of the offsite population, the Area Emergency Coordinator (ranking Reactor Department supervisor on shift) will declare an area emergency and notify the Emergency Operating Center (EOC). The EOC supervisor will consult with Health Protection (HP), evaluate the conditions, and relay emergency information through EOC to all other Area Emergency Coordinators. The Area Emergency Coordinator is responsible for coordinating and directing area-wide emergency response activities and for keeping the HP EOC supervisor advised on problems within his area. The HP Shift Supervisor is responsible for supervising and directing activities outside the incident area. The ranking member on shift of each department in the area maintains close contact with the Area Emergency Coordinator. Each department follows its own procedures.

The EOC is the center of all activity during a major emergency. It is located in the basement of the main administration building (703-A) and consists of a patrol and communications room, a staff room, and an operations center. There is also an emergency operating station in each of the 100 Areas, in Building 751-A, and an offsite station in Aiken, SC.

The EOC is staffed by DOE-SR and Du Pont management personnel, a trained shift crew, an HP supervisor, and the Reactor Department Shift Supervisor from Building 105-K. The primary duties of the center are to:

TABLE 7.6-1

Annual Risk During Transportation for a Reactor Area

Shipping Operation	Risk, Ci/yr		
	β - γ	α	T
Irradiated Fuel	$\sim 1 \times 10^{-6}$	$\sim 1 \times 10^{-9}$	$\sim 2 \times 10^{-4}$
Unirradiated Fuel		Very Small	
100-Area Sample Trucks	-	-	2×10^{-2}
Scrap Metal		Extremely Small	
Solid Wastes	$< 1 \times 10^{-6}$	$< 1 \times 10^{-9}$	
Moderator Shipments	-	-	3×10^{-3}
Unshielded Trailer Shipments	$\sim 2 \times 10^{-3}$	$\sim 2 \times 10^{-5}$	-
Deionizers			
Reactor Basin	$\sim 1 \times 10^{-6}$	$\sim 1 \times 10^{-9}$	
Purification		Very Small	
Totals	$\sim 2 \times 10^{-3}$	$\sim 2 \times 10^{-5}$	$< 3 \times 10^{-2}$

TABLE 7.6-2

Radiological Risk from Potential Transportation Accidents

	Dose Commitment						
	Total Body	Bone	Lung	Liver	Thyroid	Kidney	G.I. Tract
Maximum Individual, mrem	1.66×10^{-2}	5.31×10^{-1}	5.29×10^{-2}	6.07×10^{-2}	8.29×10^{-5}	4.61×10^{-2}	7.33×10^{-4}
Population, man-rem	1.12×10^0	3.55×10^1	2.68×10^0	3.96×10^0	9.52×10^{-3}	3.01×10^0	4.93×10^{-2}

1. Protect onsite and offsite personnel.
2. Develop information on conditions inside and outside the incident area.
3. Display this condition to the staff.
4. Initiate offsite warning messages in the absence of the DOE-SR manager or alternate.
5. Advise Area Coordinators in other areas whether to take cover or evacuate.
6. Select evacuation routes (if needed).
7. Control caravans.
8. Arrange for decontamination and clearance of evacuated personnel.
9. Arrange for medical assistance and direct handling of injured personnel.

Warnings or advisories to the public regarding emergencies or incidents resulting from Savannah River Plant operations will be released by the DOE-SR Manager or his successor in command. The EOC supervisor assumes this responsibility if DOE personnel cannot be reached in 15 minutes, and immediate notifications of the public are necessary.

7.8 REFERENCES

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5. R. E. Cooper, and B. C. Rusche, The SRL Meteorological Program and Off-Site Dose Calculations, DP-1163, SRL-DuPont Co., (September, 1968).
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9. M. M. Pendergst and J. C. Huang. A Computer Code to Assess Accidental Pollutant Releases. DP-1552 (July 1980).
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12. Report of ICRP Committee II on Permissible Dose for Internal Radiation (1959) with Bibliography for Biological, Mathematical and Physical Data, Health Physics, 3, (1960).

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13. NRC Regulatory Guide 1.109, Calculation of Annual Doses to Man from Routine Release of Reactor Effluents for the Purpose of Evaluating Compliance with 10 CFR Part 50, Appendix I (October 1977).
14. D. C. Kocher, Dose Rate Conversion Factors for External Exposure to Photon and Electron Radiation from Radionuclide Occurring in Routine Releases from Nuclear Fuel Cycle Facilities, Health Physics, 38, (4), pp. 543-621 (April 1980).
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8. SOCIOECONOMIC SUMMARY

8.1 INTRODUCTION

Primary socioeconomic benefits resulting from the reactivation and operation of L-Area Reactor will be the creation of a small number of new permanent jobs for area residents and a few persons from outside the region. Other short-term benefits to communities around SRP will be the creation of jobs by L-Area construction activities in addition to the SRP construction base force of about 1100 to 2600 during 1982 and 1983 (Figure 8.1-1). SRP payrolls will be increased by about 4% during construction and by about 6% during operation of L-Area Reactor as compared to present payrolls (June 1981). Incremental population growth as a result of these new L-Area jobs will be small. Socioeconomic studies recently completed for the proposed Defense Waste Processing Facility (DWPF) project little or negligible socioeconomic impacts for the SRP region in the coming years as a result of the DWPF.¹ These studies support the projections of even smaller incremental benefits or costs to the region resulting from this reactor project.

8.2 CONSTRUCTION ACTIVITIES

The projected total construction manpower requirements for L-Area startup construction activities and the base construction work force required through calendar year (CY) 1984 are shown on Figure 8.1-1. The base work force required for Assigned Maintenance Orders (AMOs), General Plant Projects (GPPs), and upgrading of facilities is forecast to decrease in CY 1982 and then increase in CY 1983 and 1984. The construction manpower forecast for L Area coupled with the base work force forecast for SRP results in a fairly uniform construction manpower demand with a peak in CY 1982 followed by a slight decline and then a gradual increase through CY 1983. The base force projection would include manpower for installing waste management facilities required by L-Area operation.

Figure 8.2-1 shows the additional manpower requirements of the proposed Naval Reactor Fuel Material Facility (FMF) and DWPF construction activities if these activities are authorized for 1983. L-Area construction activities will be decreasing as construction of these facilities begins. Further, the types of construction workers required for early phases of FMF and DWPF will be completely different from those working in L Area. Therefore, L-Area construction activities will have little effect on the SRP construction labor pool in the region through CY 1983.

FIGURE 8.1-1 Estimated Construction Manpower for L-Area and SRP Base Construction Work Force

FIGURE 8.2-1 Estimated Construction Manpower for SRP Proposed Programs

The scheduling of construction for installation of Units No. 1 and No. 2 at the Vogtle Nuclear Plant could interact with L-Area construction activities. The average work force at the Vogtle project is expected to be about 5100 in CY 1982 and 1983 and to decline slightly in CY 1984. If Vogtle construction activities draw some SRP construction employees, SRP may need to seek additional skilled craft construction employees that may not necessarily reside in the region. Resultant socioeconomic effects attributed to L-Area construction are expected to be quite small compared to those that would be caused by Vogtle construction activities.

8.3 OPERATIONS

The operations work force for L Area is expected to peak at about 400 employees during startup and then decrease to a sustained work force of about 350 employees (Figure 8.3-1).

In order to prepare components for L Area, the 300-Area facilities will also have to expand operations, thus, requiring about 80 additional employees (Figure 8.3-1). The reprocessing of reactor fuel from L Area will require a further 80 employees in the 200 Separations Areas.

The majority of this incremental increase to the SRP operations manpower pool will be new hires from the region surrounding the SRP site. Studies for the Draft EIS for the DWPF indicated that recruitment of employees for various types of jobs required for L Area may result in up to 10% of this incremental work force being recruited from outside the local region.¹ Potential new residents would be mostly professional personnel who would be expected to reside in the Aiken, North Augusta, or Augusta urban areas, resulting in imperceptible socioeconomic impacts. The wages of the other personnel hired in the region to permit staffing of L Area and related operations are expected to increase slightly financial benefits of SRP to the surrounding communities when compared to the impact of the 9100 persons currently employed on the SRP site.

FIGURE 8.3-1 Incremental Increase in SRP Operating Manpower as Impacted by L-Area Startup

8.4 REFERENCE

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9. ALTERNATIVE MITIGATION MEASURES FOR L-AREA OPERATIONS

This chapter discusses potential cooling alternatives for L Reactor. Most of these alternatives could not be implemented before the planned restart date of October 1983. However, a number of the alternatives could be considered for implementation after reactor restart.

9.1 ALTERNATIVE COOLING FOR L-REACTOR THERMAL EFFLUENT

The primary goal of alternative cooling is to reduce or eliminate impacts of thermal discharge to Steel Creek and the Savannah River. In addition to potential direct benefits to the wetlands of the Steel Creek area, some of the alternatives could have additional advantages, such as reduction in impingement and entrainment at the river pumphouses, lower pumping costs, and less reliance on the Savannah River as a source of cooling water.

Ten alternatives for cooling L-Reactor thermal effluent are given in Table 9.1-1. These ten alternatives can be divided into two general types:

- Once-through cooling alternatives
- Recirculating cooling alternatives.

Although this list of alternatives is not all inclusive, it does include a reasonable and representative range. Costs and rankings (Section 9.1.2) are also based upon the best information available to date and are subject to revision.

9.1.1 Description of Alternatives

9.1.1.1 Once-Through Cooling Alternatives

9.1.1.1.1 Direct Discharge to Steel Creek

The planned action is to discharge the cooling water from L Reactor to Steel Creek with the flow eventually reaching the Savannah River at the mouth of Steel Creek. Impacts to the wetlands and floodplains of Steel Creek and the Savannah River swamp are discussed in Section 5.2.1.1. The thermal plume in the Savannah River will expand (Section 5.2.1.2), and impingement

TABLE 9.1-1

Alternatives for Cooling L-Reactor Thermal Effluent

I. Once-Through Cooling Alternatives

1. Direct discharge of L-Reactor effluent to Steel Creek, planned action
2. Spray cooling in L-Reactor effluent canal prior to discharge to Steel Creek
3. Rubble dams and small nonrecirculating lakes in Steel Creek
4. Dam and a 500-acre nonrecirculating lake in Steel Creek
5. Penstock and canal to divert effluent from Steel Creek to Pen Branch
6. Dam and canal to divert effluent from Steel Creek to Pen Branch

II. Recirculating Cooling Alternatives

1. Pumphouses, penstock, and canal to recirculate effluent through PAR Pond
2. Thirteen-hundred acre pond on Steel Creek for recirculating effluent (L Pond)
3. Twenty-seven hundred acre pond on Steel Creek and Pen Branch for recirculating K and L effluents (KAL Pond)
4. Forced draft cooling towers in the vicinity of L Area for recirculating effluent

and entrainment at the Savannah River pumphouses will increase (Section 5.2.2). Cesium-137 will be remobilized and transported offsite into the Savannah River and/or Creek Plantation Swamp (Section 5.1.1.3). SRP reactor operations will become more dependent on the Savannah River as a source of cooling water.

9.1.1.1.2 Spray Cooling

A gravity-powered system installed in the L-Area thermal canal (Figure 9.1-1) would operate like a conventional spray pond with the following exceptions:

- No reservoir is required.
- No pumphouse, pit, and associated electrical services are needed.
- No pumping costs are associated with the system.

The spray system would dissipate a portion of cooling water heat into the atmosphere. Under ideal conditions, cooling water temperature would decrease about 15°C. Additional cooling would occur as the effluent flows through Steel Creek and the Savannah River swamp to the Savannah River.

The spray system would be coupled to the present 72-inch L-Area effluent pipe via a valve box. A 72-inch steel penstock would be used to transport the water downstream about 600 feet (Figure 9.1-1). At this point, the penstock would branch, diverting the water into a system of two parallel trunks running down the effluent canal. The trunk lines would be 1600 feet long and would use ramp-bottom, hollow-cone spray nozzles, each having a flow of 79 gpm at a pressure of 15 psig.

From both a design and a meteorological standpoint, the proposed system should perform satisfactorily. However, the cooling efficiency of the system would be less than design conditions for periods during the summer because of the canal location and the light, variable winds in the SRP area. Preferably, a spray canal should be oriented with its long axis perpendicular to the prevailing summer winds to optimize ambient airflow across the spray nozzles. However, the L-Area effluent canal lies in a north-south direction and could not take full advantage of air and water thermal exchange since the prevailing wind during the summer months is from the South. In addition, winds are frequently light or calm with speeds less than 5 mph. Under summer conditions, the proposed spray system would provide little additional cooling (<5°C) prior to discharge to Steel Creek.

A.

B.

FIGURE 9.1-1. Conceptual Layout (A) and Location (B) of a Spray Canal in the Present L-Area Canal

Temperature profiles of Steel Creek and the swamp, assuming temperature decreases of 5, 10, and 15°C in the canal, are shown in Figure 9.1-2. Under summer conditions, very little additional cooling takes place with the spray canal compared to direct discharge (Figure 9.1-2 and Table 9.1-2). Under April conditions, lower temperatures were obtained for both direct discharge and for spray cooling.

Spray cooling provides little, if any, mitigation when compared to direct discharge. The water temperature at the mouth of Steel Creek would be essentially the same for direct discharge and spray cooling. With no significant thermal reduction and no flow decrease, a spray system offers essentially no mitigation for loss of floodplain habitat for waterfowl and the American alligator in the Steel Creek area. Cesium transport offsite and impingement and entrainment at the Savannah River pumps would not be mitigated.

Capital costs for a spray system would be about 5 million dollars with a construction schedule of about two years. Operating costs would be about 5.3 million dollars (primarily river water pumping costs). No reduction in reactor production would be expected.

9.1.1.1.3 Small Lake(s) on Steel Creek

Two types of lake systems on Steel Creek could be used to mitigate the thermal impact of L-Area effluent on the lower reaches of the creek and the swamp. One system utilizes several small dams (rubble dams) to create a series of small lakes, and the other system uses one large dam and one lake.

9.1.1.1.3.1 Rubble Dams

A series of rubble dams on Steel Creek could provide pooling of water with increased surface area and decreased velocity for enhanced cooling in the stream. The dams could be created by dumping large stone or broken concrete at accessible locations in Steel Creek. The dams would be five to eight feet high and could be solid or porous, but better results could be expected with solid dams. With solid dams, sediment would collect upstream of the dam, and water spilling over would increase the effectiveness of the system by increasing the exposure of the hot water to air.

FIGURE 9.1-2. Temperature Profiles for Steel Creek Assuming Three Levels of Performance by a Spray Canal in the L-Area Thermal Canal Under Summer Conditions
 A. 5°C Drop B. 10°C Drop C. 15°C Drop

TABLE 9.1-2

Comparison of Spray Cooling* with Direct Discharge

<u>Conditions</u>	<u>Temperature, °C</u>		
	<u>Road A-14**</u>	<u>Road A†</u>	<u>River Mouth††</u>
2000 MW (Summer)			
Direct Discharge	58	56	37
Spray Canal	55	52	37
2000 MW (April)			
Direct Discharge	50	47	28
Spray Canal	48	45	27
2400 MW (Summer)			
Direct Discharge	63	59	38
Spray Canal	59	56	38
2400 MW (April)			
Direct Discharge	55	51	29
Spray Canal	53	48	29

* Assuming a 5°C temperature drop from spray cooling at the L-Area effluent canal, most likely summer performance.

** About 17,500 feet downstream of the discharge point.

† About 25,000 feet downstream of the discharge point.

†† About 43,500 feet downstream of the discharge point.

Locations of the dams would be selected to minimize relocation of existing roads, powerlines, and cables and to maximize the potential for cooling in the upper reaches of Steel Creek (Figure 9.1-3). About 400 acres of surface area could reduce the stream temperature to about 41°C at Road A under summer conditions (Figure 9.1-4 and Table 9.1-3). Under April conditions, a temperature of about 38°C is achieved at Road A with only 150 acres of surface area (Figure 9.1-5).

This alternative cooling system would provide limited use of Steel Creek by aquatic organisms. Some thermally tolerant aquatic plants would survive in the delta area. The system offers no thermal mitigation for the endangered species, American alligator, above Road A. Some aquatic life forms would be expected to survive below Road A; however, rubble dams and small lakes on Steel Creek would impact additional floodplain along the creek. The effect of rubble dams on cesium transport is not known, but mitigation is expected to be minimal. Dams would allow the water to pool and sediment should settle; thus, providing a collecting place for cesium, but permanent control of cesium cannot be assured. Impingement and entrainment would not be mitigated. Recovery of archeological resources may be necessary.

The capital costs are estimated to be 3 to 5 million dollars. These costs include several small dams, grubbing and clearing, and relocation of power lines, and cables. Operating costs are about 5.3 million dollars primarily for pumping costs for water from the Savannah River. Reactor production is unaffected. The construction schedule is about two years. An Army Corps-of-Engineers dredge and fill permit¹ and DOE wetlands assessment² would be required (Section 9.1.3).

9.1.1.1.3.2 500-Acre Lake on Steel Creek

A lake with a surface area of 400 to 500 acres either as one lake or a series of small lakes located in the Steel Creek floodplain would reduce the water temperature to about 40°C at SRP Road A under summer conditions. The topography along Steel Creek lends itself to the construction of one lake (Figure 9.1-6). Temperature profiles show that a three-stage, 500-acre lake would give acceptable cooling performance when combined with the L-Area effluent canal (Figure 9.1-7). The lake would be physically separated with overflow baffles into three sections of about equal

FIGURE 9.1-3. Possible Layout for a Series of Small Rubble Dams and Cooling Lakes on Steel Creek

FIGURE 9.1-4. Relationship Between Number of Acres of Small Lakes on Steel Creek and Water Temperature, Summer Conditions, 2400 MW

TABLE 9.1-3

Comparison of Small Lakes* with Direct Discharge

<u>Conditions</u>	<u>Temperature, °C</u>	
	<u>Road A</u>	<u>River Mouth</u>
2000 MW (Summer)		
Direct Discharge	56	37
Small Lakes	34	29
2000 MW (April)		
Direct Discharge	47	28
Small Lakes	29	24
2400 MW (Summer)		
Direct Discharge	59	38
Small Lakes	41	35
2400 MW (April)		
Direct Discharge	51	29
Small Lakes	29	25

* Assuming 400 acres of effective cooling surface.

FIGURE 9.1-5. Relationship Between Number of Acres of Small Lakes on Steel Creek and Water Temperature, April Conditions, 2400 MW

FIGURE 9.1-7. Expected Cooling Performance of a 500-Acre Lake on Steel Creek Under Summer Conditions

area to enhance its cooling efficiency. The overflow baffles would prevent short circuiting of hot water and maximize use of the surface area. The final baffle would be an underflow baffle to provide discharge of water from several feet below the pond surface. This arrangement minimizes diurnal temperature variation and provides additional cooling capacity during hot weather.

Figure 9.1-7 shows the temperature reductions achieved by various portions of the system. August 1959 meteorological conditions (worst case) gave 37.6°C, and the July 1980 conditions gave 35.6°C in Steel Creek entering the swamp. However, the modeling results are very sensitive to wind. Figure 9.1-8 shows the results of modeling the worst-case conditions over a range of wind speeds from 0 to 10 mph for the effluent from the pond. A 10-mph reduction in wind speed increased pond temperature by 7.5°C.

The system achieves a temperature of <38°C under summer conditions as Steel Creek enters the swamp. The temperature profile is essentially the same as that for rubble dams. A temperature of about 40°C is achieved at SRP Road A, which would provide for limited use of Steel Creek and the Steel Creek delta by aquatic organisms. With reduced temperatures, some vascular aquatic plants would survive in the delta area; however, extensive open "mud flats" could occur.

This system offers no mitigation for the American alligator above the dam, because temperatures would exceed the lethal limits for the American alligator.³ Some vegetation would survive where the creek enters the swamp because of reduced temperature. The extent to which the lake and remaining vegetation in the delta area would restrict cesium transport offsite is not known. Impingement and entrainment would not be mitigated. Recovery of archeological resources would be required.

Capital costs are estimated to be 14 million dollars. This cost includes an earthen dam, the necessary grubbing and clearing, and relocation of the 115-kV electric lines and supervisory control cable. The construction schedule is about two years. Operating costs are about 5.3 million dollars (pumping costs from the Savannah River). Reactor production is not affected. An Army Corps-of-Engineers dredge and fill permit¹ and a DOE wetlands assessment² will be required (Section 9.1.3).

FIGURE 9.1-8. Effect of Wind Speed on Effluent Temperature from a Proposed 500-Acre Cooling Lake on Steel Creek (August 1959 Conditions)

9.1.1.1.4 Diversions to Pen Branch

L-Area thermal effluent could be diverted to Pen Branch to mitigate the impacts of L-Reactor operation on Steel Creek. Much of Pen Branch already receives thermal effluent from K Reactor. Diversion would prevent or reduce additional movement of cesium offsite. Two diversion alternatives have been evaluated.

9.1.1.1.4.1 Penstock and Canal Diversion

Cooling effluent from L Reactor would be diverted by means of an 84-inch underground pipe beginning at the 904-L Building in L Area. The pipe would convey the flow in a northwesterly direction about 2300 feet to the north side of SRP Road 7 where it would discharge into an open canal (Figure 9.1-9, Option A). The water would flow through the canal about 2000 feet to Pen Branch. No pumping would be required in the pipe or canal portions of the system.

This diversion would avoid wetlands destruction, endangered species impacts, and offsite cesium transport from Steel Creek. However, wetlands impacts to the Pen Branch system would be extensive. About 3.5 miles of stream and floodplain which have not been impacted previously by SRP operations would be impacted by thermal effluents ranging from 55°C to 70°C. The delta area of Pen Branch in the Savannah River floodplain could expand from about 90 acres to about 300 acres with total tree kill expected in an additional 200 acres. Intermediate impacts due to increased flooding in two to three additional square miles of the Savannah River floodplain would be expected. Temperatures at the mouth of Steel Creek are likely to range 3 to 4°C higher than direct discharge down Steel Creek from L Area, both in the spring and summer months (Figures 9.1-10 and 9.1-11). Impingement and entrainment at the river pumps would not be mitigated.

Capital costs are about 6 million dollars, and annual operating costs are about 5.3 million dollars (primarily pumping cost from the Savannah River). Construction time required is about two years. Structural improvements may be required at bridges crossing Pen Branch. Reactor production would be unaffected. An NPDES Permit modification^{4,5} and a DOE wetlands assessment² would be required (Section 9.2.3). Archeological resource recovery may be required.

The only significant advantage of this alternative over direct discharge to Steel Creek appears to be the mitigation of offsite cesium movement.

FIGURE 9.1-9. Two Diversion Alternatives of L Reactor Cooling Effluent to Pen Branch
 (A) Penstock and Canal Diversion
 (B) Lake and Canal Diversion

FIGURE 9.1-10. Temperatures Along Pen Branch from Penstock and Canal Diversion of L Reactor Cooling Water Effluent, 2000 MW
 (A) Summer Conditions
 (B) Spring Conditions (April)

FIGURE 9.1-11. Temperatures Along Pen Branch from Penstock and Canal Diversion of L Reactor Cooling Water Effluent, 2400 MW

- (A) Summer Conditions
- (B) Spring Conditions (April)

9.1.1.1.4.2 Lake and Canal Diversion

This diversion to Pen Branch would require an earthen dam in Steel Creek about 6000 feet below the L-Area effluent canal (Figure 9.1-9, Option B). The dam would form a small lake (60 acres) to provide additional cooling. A 4000-ft canal would divert the flow from the lake to Pen Branch. No pumping would be required.

Steel Creek would be relatively unimpacted below the dam. The current annual flow would be reduced by about 50% below the dam so that the Steel Creek floodplain would be drier, and the present shrub revegetation would be expected to proceed faster. Cesium transport via Steel Creek would be mitigated, but some cesium-137 would be redistributed to the Pen Branch system. About 7.7 Ci of Cesium-137 has been estimated as being present in the area which would be covered by the lake. About 1.5 miles of formerly unimpacted stream and floodplain along Pen Branch would be impacted. Other wetland impacts in the Savannah River floodplain would be similar to the Penstock and Canal Diversion (Section 9.1.1.1.4.1). Cesium transport offsite would be reduced, but some cesium would be redistributed to Pen Branch and the Savannah River floodplain. Impingement and entrainment at the river pumps would be the same as with direct discharge. Structural improvements may be required at bridges crossing Pen Branch. Archeological resources would have to be recovered in the vicinity of the canal from the Ashley Plantation site.

The temperature profile shows that the small lake immediately reduces the temperature of the L-Reactor effluent (Figures 9.1-12 and 9.1-13). Where the K-Reactor effluent joins the L-Area Reactor effluent at the junction of Pen Branch and Indian Grove, there is no significant difference in the temperature of the separate flows. Because of the large volume of flow, the temperature of the combined effluents decreases slowly from the entrance to the Savannah River swamp to the mouth of Steel Creek. At the river mouth the combined K and L effluent is about 2 to 4°C higher than effluent with separate K and L discharges.

Figure 9.1-14 shows that the small lake and canal provide lower temperatures than the penstock and canal division. The difference becomes less pronounced in the lower reaches of the creek and the swamp. In both systems, the water temperature at the mouth of Steel Creek is higher than that with direct discharge.

Capital costs are about 4 million dollars, and annual operating costs are about 5.3 million dollars (primarily pumping cost from the Savannah River). Construction time is about two years. Reactor production would be unaffected. An Army Corps-of-Engineers

FIGURE 9.1-12. Temperatures Along Pen Branch from Small Lake and Canal Diversion of L Reactor Cooling Water Effluent, 2000 MW
 (A) Summer Conditions
 (B) Spring Conditions (April)

FIGURE 9.1-13. Temperatures Along Pen Branch from Small Lake and Canal Diversion of L Reactor Cooling Water Effluent, 2400 MW
 (A) Summer Conditions
 (B) Spring Conditions (April)

FIGURE 9.1-14. Temperatures Along Pen Branch Comparing the Performance of the Two Diversion Alternatives from L Area to Pen Branch
 (A) Summer Conditions, 2000 MW
 (B) Summer Conditions, 2400 MW

dredge and fill permit,¹ an NPDES permit modification,^{4,5} and a DOE wetlands assessment² would be required. Archeological resource recovery would be required.

9.1.1.2 Recirculation Alternatives

Several recirculation systems were evaluated as alternatives to once-through cooling. The alternatives examined include recirculation through:

- PAR Pond
- L-Pond
- KAL Pond
- Mechanical draft cooling towers.

9.1.1.2.1 Recirculation Through PAR Pond

Prior to June 1964, P and R Reactors were cooled by recirculating cooling water through PAR Pond. With R Reactor shut down, L Reactor could be cooled by installing a system of pumphouses, penstock, and canals at PAR Pond (Figure 9.1-15).

A new line would be installed to carry the thermal effluent from L Area to a point near the former R Reactor outfall. The existing P-Area pumphouse and lines could be used to return cooling water to L Reactor. A new intake structure and pumphouse would be needed to supply P Reactor and could be located either near the existing P-Reactor pumphouse or farther south on PAR Pond as shown in Figure 9.1-15. New penstock (water pipelines) would be required from PAR Pond to P Area in either case.

Use of PAR Pond would avoid impacts to Steel Creek and would reduce use of Savannah River water for cooling. Impingement and entrainment at the river pumps and thermal discharge to the Savannah River would remain essentially unchanged from present levels.

Doubling the volume of thermal effluent to PAR Pond would impact the use of Ponds A and B, and the "cold arm" of PAR Pond by

FIGURE 9.1-15. Alternative Recirculation of Cooling Water from L Reactor to PAR Pond. A and B Represent Possible New Supplemental Lines for P Reactor.

waterfowl and the American alligator (Figure 9.1-16).³ Additional thermal input could also enhance populations of Aeromonas bacteria with the potential to reduce fish, amphibian, turtle and alligator populations.⁶ Installation of penstock would require about 11 miles of right-of-way (200 acres) in upland habitats consisting principally of pine stands.

Capital costs would be about 47 million dollars, and operating costs would be about 4.3 million dollars. Production loss would be about 2 to 4% based upon P Reactor experience. Construction time would be three to four years. NPDES permit modification^{4,5} and a wetlands assessment² would be needed.

9.1.1.2.2 Recirculation Through L Pond

A lake of about 1300 acres would be constructed in Steel Creek upstream of SRP Road A (Figure 9.1-17). A large earthen dam would be constructed above Road A, and a smaller dam would be needed to contain the lake at the 200-foot contour. A pumphouse and intake structure would be located to ensure maximum cooling and to minimize production losses.

This cooling system would convert about 1300 acres of Steel Creek floodplains, bottomland hardwood forests, and upland pine stands into an aquatic habitat. That portion of Steel Creek and its floodplain and delta below the dam would remain essentially unimpacted; therefore, suitable habitat for vegetation and wildlife would remain below the lake. The lake itself would generally be unsuitable for aquatic life because more than 50% of it would remain above 35°C for most of the year. Backwater areas would support some waterfowl, amphibians, reptiles, and fish as observed in the PAR Pond system.⁷⁻¹³

Cesium remobilized in the lake would be filtered and retained in the lower Steel Creek area with movement offsite unlikely.^{14,15} Impingement and entrainment would be reduced at the Savannah River pumphouses. Archeological resource recovery would be needed. Thermal releases to the Savannah River would remain at present levels. More local fogging could occur around the lake than occurs around PAR Pond because of the generally higher temperature in L Pond.

Capital costs would be 72 million dollars. Operating costs would be about 2.9 million dollars with reduced pumping cost from the Savannah River. Construction time would be about three years. A production loss of about 2 to 4% could occur. An Army Corps-of-Engineers dredge and fill permit¹ and DOE wetlands assessment² would be needed.

FIGURE 9.1-16. The PAR Pond Cooling System (R Reactor is no longer active.)

FIGURE 9.1-17. L Pond for Recirculation of Cooling Water for L Reactor

9.1.1.2.3 K and L Cooling Pond (KAL Pond)

A lake of up to 2700 acres would be constructed in Steel Creek and Pen Branch by building two earthen dams just above SRP Road A (Figure 9.1-18). The two lakes would be connected by digging a ten-foot deep channel, 0.2 mile long. The necessary pump-houses, penstock, and waterlines would be constructed to provide K and L Reactors with recirculated cooling water from the lake and to supply makeup water from the Savannah River. The reactors will use the existing effluent canals to return the water to KAL Pond. L-Reactor effluent would be returned to the Steel Creek arm ("L Pond"), and K-Reactor effluent would be returned to the Pen Branch arm of ("K Pond"). Construction of KAL Pond would require relocation of some onsite roads, powerlines, the K to L steamline, and control cables.

KAL Pond would impact about 2700 acres including floodplains, bottomland hardwood forests, and upland pine stands. One of the upland pine stands was formerly used by red-cockaded woodpeckers. That portion of the Steel Creek floodplain below the dam would remain essentially unimpacted. The area below the Pen Branch dam would begin to recover from current thermal impacts and would provide suitable wildlife habitat. Any cesium remobilized in the L Pond of KAL Pond would be redistributed in the Pen Branch system. However, the downstream portions of Steel Creek and Pen Branch would "filter" this cesium and retain it on the SRP site.^{14,15} Backwater areas would support some wildlife.⁷⁻¹³

Recirculation, by using KAL Pond, would reduce impingement and entrainment at the Savannah River pump-houses, reduce thermal releases to the river, and reduce dependency on the river as a source of cooling water. Archeological resource recovery would be needed.

Capital costs would be about twice that of L Pond or about 130-140 million dollars. The construction schedule is about four years. Operating costs would be about 2 million dollars. Some reduction in operating costs is realized because pumping from the river is decreased. A production loss of about 2 to 4% would occur for both K and L Reactors. An Army Corps-of-Engineers dredge and fill permit¹ and a DOE wetlands assessment² would be required.

9.1.1.2.4 Forced Draft Cooling Towers

Cooling towers could be constructed to handle the heat load of L Reactor. Mechanical draft cooling towers would be sized to return water within 8°C of the wet-bulb temperature (summer conditions). The cooling towers would be located as close as practical

FIGURE 9.1-18. Proposed KAL Pond Cooling Alternative

to the reactor building to minimize pumping costs without impacting other L-Area operations.

Cooling towers would avoid thermal impact to Steel Creek and the Savannah River. Cesium transport would be mitigated. The volume of river water required (makeup water) would be greatly reduced; therefore, impingement and entrainment at the Savannah River pumphouses would be essentially unchanged from present operations. Discharge of blowdown from the cooling tower to site streams (either Pen Branch or Steel Creek) would have minimal effects.

Terrestrial impacts to the L-Area vicinity would occur. Twenty to 30 acres would be needed for construction in upland pine stands. Drift could cause local fogging and occasional icing conditions in the winter, but these effects would be minimal and restricted to onsite effects. SRP soils are easily leached; therefore, drift and salt deposition may reduce productivity in surrounding pine stands, although these are expected to be minor.

Capital costs for cooling towers for L-Reactor would be about 39 million dollars with operating costs of about 1.7 million dollars. Construction schedule is 2 to 3 years. Production loss would be about 3 to 5%. A modification of the SRP NPDES permit would be needed for the blowdown released to SRP streams.^{3,4}

9.1.2 Comparison and Ranking of Cooling Water Alternatives

Table 9.1-4 lists the principal criteria which were used to evaluate the cooling alternatives. Criteria 1 through 5 could generally be considered as "nonenvironmental criteria," emphasizing timing, cost, and operational factors. Criteria 6 through 11 could be considered as "environmental criteria," emphasizing cesium transport, wetlands impacts, endangered species, Savannah River impacts, and other factors. Each alternative was evaluated with respect to these criteria. Several factors, such as local fogging, fugitive dust, and socioeconomic factors were considered to be of minimal impact and, therefore, not included in the evaluation.

As shown in Table 9.1-5, none of the alternative cooling options could be implemented prior to startup in October 1983 other than the planned action. The once-through cooling alternatives would require less time to implement; whereas, the recirculation alternatives would need an additional one to two years to implement.

TABLE 9.1-4

Criteria for Assessing L-Area Cooling Alternatives

I. Nonenvironmental Criteria

1. Construction schedule should not delay startup in October 1983
2. Capital costs as low as possible consistent with benefits
3. Operating costs as low as possible consistent with benefits
4. Production loss of weapons material as low as possible
5. Adequate or increased availability of cooling water supply

II. Environmental Criteria

6. Cesium transport from Steel Creek as low as possible
7. Minimal wetlands impacts
8. Minimal impact on endangered species
9. Minimal aquatic impacts on the Savannah River from thermal discharges and impingement and entrainment
10. Minimal terrestrial impacts
11. Acceptable archeological impacts

TABLE 9.1-5

**Minimum Number of Years Required to Construct Cooling
Alternatives for L-Area Effluent**

<u>Alternative</u>	<u>Minimum Years Required</u>	<u>Meets Startup Date of October 1983</u>
I. Once-Through Alternatives		
Direct Discharge	1	Yes
Spray Cooling	2	No
Rubble Dams	2	No
Dam and 500-Acre Lake	2	No
Penstock and Canal Diversion	2	No
Dam and Canal Diversion	2	No
II. Recirculating Alternatives		
PAR Pond	3 to 4	No
L Pond	3	No
KAL Pond	4	No
Forced Draft Cooling Towers	2 to 3	No

The alternatives fall into two groups based upon capital and operating costs (Table 9.1-6). The once-through cooling options have lower capital costs, but higher operating costs. Capital costs for the recirculating alternatives are higher because facilities would have to be relocated, and dams, new pipelines, and pumphouses constructed. Operational costs for recirculation alternatives are generally lower because less energy is required to recirculate the effluent compared to pumping cooling water from the Savannah River.

Production losses are zero with the once-through alternatives and range from 2 to 8% with the recirculation alternatives (Table 9.1-7). The once-through alternatives require 180,000 gpm (~400 cfs) of additional cooling water from the Savannah River above present SRP usage (Table 9.1-8). The PAR Pond, L Pond, and cooling tower alternatives would require an additional 10,000 to 20,000 gallons of makeup water from the Savannah River above present SRP usage. Installation of KAL Pond would reduce present SRP water use by about 160,000 gpm.

Generally, the recirculation alternatives have less environmental impact than the once-through alternatives. However, the proposed alternatives for new cooling lakes and the diversions to Pen Branch will affect formerly "unimpacted" habitat, and some environmental "trade-offs" are involved.

Four of the once-through cooling alternatives have the greatest potential for moving cesium-137 contamination offsite. The diversion alternative and the recirculation alternatives reduce the potential for offsite cesium transport.

Wetlands impacts would be expected with all of the alternatives except with the forced draft cooling towers (Table 9.1-9). Direct discharge, spray cooling, rubble dams, and the 500-acre lake would impact 1100 to 1200 acres of wetlands over a 20-year operational period. This includes 140-150 acres of future impact to the Steel Creek delta area expected from present delta growth rates at SRP.¹⁶ The diversion would likewise impact 800 to 1000 acres of wetlands. The recirculation lake alternatives would impact smaller areas of wetlands. KAL Pond would have an added benefit of allowing the lower portion of Pen Branch and its delta to recover. Endangered species, especially the American alligator, would receive the most impact from the once-through options and least from the cooling tower alternative. Impingement and entrainment and thermal impacts on the Savannah River are greatest with the once-through alternatives and least with recirculation alternatives (Table 9.1-8). Terrestrial impacts are confined to SRP and are greater with the new lakes (Table 9.1-10). Archeological impacts, likewise, are greater with the new lakes (Table 9.1-11).

TABLE 9.1-6

**Estimated Capital and Operating Costs
for Cooling Alternatives for L-Area Effluent**

<u>Alternative</u>	<u>Cost in Millions of Dollars</u>	
	<u>Capital Cost</u>	<u>Operating Cost, Annual</u>
I. Once-Through Alternatives		
Direct Discharge	1.0	5.3
Spray Cooling	5.0	5.3
Rubble Dams	3.0 to 5.0	5.3
Dam and 500-Acre Lake	14.0	5.3
Penstock and Canal Diversion	6.0	5.3
Dam and Canal Diversion	4.0	5.3
II. Recirculating Alternatives		
PAR Pond	47	4.3
L Pond	72	2.9
KAL Pond	130-140	1.9
Forced Draft Cooling Towers	39	1.7

TABLE 9.1-7

Estimate of Percent of Production Loss with L-Area Cooling Water Alternatives

<u>Alternatives</u>	<u>Percentage of Production Loss</u>
I. Once-Through Alternatives	
Direct Discharge	0
Spray Cooling	0
Rubble Dams	0
Dam and 500-Acre Lake	0
Penstock and Canal Diversion	0
Dam and Canal Diversion	0
II. Recirculation Alternatives	
PAR Pond	2-4
L Pond	2-4
KAL Pond	4-8*
Forced Draft Cooling Towers	3-5

* Total for two reactors, K and L.

TABLE 9.1-8

Estimate of Increase or Decrease in SRP Cooling Water Use from the Savannah River with Cooling Water Alternatives (+ increase, - decrease)

<u>Alternatives</u>	<u>Change, gpm</u>
I. Once-Through Alternatives	
Direct Discharge	+180,000
Spray Cooling	+180,000
Rubble Dams	+180,000
Dam and 500-Acre Lake	+180,000
Penstock and Canal Diversion	+180,000
Dam and Canal Diversion	+180,000
II. Recirculation Alternatives	
PAR Pond	+ 10,000
L Pond	+ 10,000
KAL Pond	-160,000
Forced Draft Cooling Towers	+ 15,000

TABLE 9.1-9

Estimate of Acres of SRP Wetlands Impacted by L-Area Cooling Water Alternatives

Alternatives	Location and Acres of Wetlands Impacted							PAR Pond	Recovered Wetlands	Total
	Steel Creek Floodplain	Steel Creek Delta	Steel Creek Delta Growth*	Pen Branch Floodplain	Pen Branch Delta	Pen Branch Delta Growth*				
I. Once-Through Alternatives										
Direct Discharge	725	285	145	0	0	0	0	0	1155	
Spray Cooling	725	285	145	0	0	0	0	0	1155	
Rubble Dams	745	285	145	0	0	0	0	0	1175	
Dam and 500-Acre Lake	785	285	145	0	0	0	0	0	1215	
Penstock and Canal Diversion	0	0	0	340	200	400	0	0	940	
Dam and Canal Diversion	60	0	0	180	200	400	0	0	840	
II. Recirculation Alternatives										
PAR Pond	0	0	0	0	0	0	400-500	0	400-500	
L Pond	230	0	0	0	0	0	0	0	230	
KAL Pond	230	0	0	515	0	0	0	630	115	
Forced Draft Cooling Towers	0	0	0	0	0	0	0	0	0	

* Assumes growth rate of present SRP delta areas given in Reference 16.

TABLE 9.1-10

Estimate of Acres of Upland Terrestrial Habitat Impacted by
Cooling Water Alternatives for L-Area Restart

<u>Alternatives</u>	<u>Potential Acres Impacted</u>
I. Once-Through Alternatives	
Direct Discharge	~0
Spray Cooling	~0
Rubble Dams	~0
Dam and 500-Acre Lake	270
Penstock and Canal Diversion	10
Dam and Canal Diversion	10
II. Recirculation Alternatives	
PAR Pond	135
L Pond	1070
KAL Pond	2210
Forced Draft Cooling Towers	50

TABLE 9.1-11

Estimate of Number of Archeological Sites Potentially Impacted by
Cooling Water Alternatives for L-Area Restart

<u>Alternatives</u>	<u>Number of Known Sites</u>	<u>Estimated Number of Sites</u>
I. Once-Through Alternatives		
Direct Discharge	18	18
Spray Cooling	18	18
Rubble Dams	18	18
Dam and 500-Acre Lake	18	18
Penstock and Canal Diversion	18	28
Dam and Canal Diversion	23	30
II. Recirculation Alternatives		
PAR Pond	4	8
L Pond	23	40
KAL Pond	29	48
Forced Draft Cooling Towers	0	<5

9.1.3 Regulatory Requirements for Alternative Cooling Options

The use of alternative cooling for L Reactor would trigger additional regulatory requirements besides those already needed for restart. Most of the added regulatory actions will involve only minor updates or modifications of approvals already needed for L Reactor as now planned (Table 9.1-12). However, some cooling options will require a major additional commitment of time and resources and may complicate approval of compliance efforts already underway. From a regulatory standpoint, cooling towers are most attractive and the dam and canal diversion to Pen Branch is least desirable.

Only one additional regulatory approval, not already required for L Restart, would be needed for some of the cooling options (Table 9.1-12). A Corps-of-Engineers (COE) dredge and fill permit¹ would be required for cooling alternatives that would dam, dredge, or place fill material in Steel Creek. Section 404 of the Clean Water Act⁴ authorizes the Corps to protect and regulate activities (such as dams) affecting navigable waters, their main tributaries and adjacent wetlands. COE permit program places a strong emphasis on minimizing, or avoiding altogether, wetland impacts.

The COE permit application is reviewed by several federal and state agencies with environmental interests, and released for public comment over 30 days. From 2 to 4 months is usually needed for approval, but controversial actions could take up to a year or more.

TABLE 9.1-12

Regulatory Requirements for Alternative Cooling Beyond Those Being Planned for Direct Discharge

Alternatives	COE* Dredge and Fill Permit	SCDHEC-NPDES** Permit Modifications		DOE† Wetlands/ Floodplain Assessment	US FWS†† Endangered Species Consultation	Archeology Survey and Recovery	Clean Water Act Section 316 Surveys
		Discharge Point	Thermal Plume				
I. Once-Through Alternatives							
Spray Cooling		0	+	+			0
Rubble Dams	-		+	0			0
Dam and 500-Acre Lake	-	0	+	+		-	0
Penstock and Canal Diversion			-	-	-	0	0
Dam and Canal Diversion	-		-	-	-	-	0
II. Recirculation Alternatives							
PAR Pond		0	+	+	-	0	+
L Pond	-	0	+	+	0	-	+
KAL Pond	-	0	+	+	0	-	+
Forced Draft Cooling Towers		0	+	+	+		+

* Corps of Engineers.

** South Carolina Department of Health and Environmental Control.

† Department of Energy.

†† United States Fish and Wildlife Service.

+ Mitigation, simplifies regulatory requirements.

- Significant effort needed to update or revise compliance activities; could complicate regulatory approval.

0 Minor effort required.

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10. ENVIRONMENTAL COMPLIANCE PLAN

This chapter discusses how L-Area restart activities will interface with environmental laws and regulations pertaining to:

- Permit requirements
- Documentation, studies, notification and/or mitigating actions needed before startup
- DOE-SR plans to comply with the State and Federal requirements

Table 10.1-1 summarizes the regulatory compliance requirements for the L-Area restart.

10.1 NATIONAL ENVIRONMENTAL POLICY ACT (NEPA)

NEPA requires federal agencies to incorporate environmental considerations into decisions made on actions with the potential to significantly affect the environment.¹ To document the environmental decision-making associated with an agency action that could have a significant environmental impact, an Environmental Assessment (EA) or an Environmental Impact Statement (EIS) is prepared and circulated for public as well as federal, state, and local agency review. An EA is prepared when the environmental consequences of an action are either unknown or minor. The EA discusses the proposed action, its environmental impacts, and possible mitigation. An EA can either conclude "no significant impact" or that an EIS is needed. An EIS is a broader, more comprehensive analysis of both the action and environmental impacts. In addition, an EIS places greater emphasis on reasonable alternatives to the action and mitigation of the impacts. In response to the NEPA mandate, DOE has formulated guidelines to implement NEPA in agency decision-making.²

DOE is currently preparing an EA for the L-Reactor restart.

10.2 WATER

10.2.1 National Pollutant Discharge Elimination System (NPDES)

The NPDES permit system (40 CFR 122 et. seq.) established under the Federal Water Pollution Control Act (Clean Water Act) and amendments³ is the basic regulatory mechanism for water

TABLE 10.1-1

Regulatory Compliance for L-Area Reactor Startup

<u>Facility/Action</u>	<u>Requirement</u>	<u>Agency</u>	<u>Status</u>
NEPA	Environmental Documentation	DOE	Environmental Assessment in progress
Water			
Process-sewer outfalls	NPDES Permit Renewal	SCDHEC-IAWD	Included in SRP permit renewal 5/19/81
Cooling water intake and discharge	316(a) and 316(b) Review	SCDHEC-IAWD	Planned
Oil storage	Spill Prevention Containment and Control Plan (SPCC)	EPA/DHEC	Existing SRP-plan will be revised
Domestic drinking water wells	Permit to Construct	SCDHEC-WSD	Received
Domestic water treatment and distribution system	Permit to Construct	SCDHEC-WSD	Needed
Auxiliary Sanitary Sewage Treatment Plant	Permit to Construct	SCDHEC-IAWD	Needed
Domestic sanitary sewage treatment plant	Permit to Construct	SCDHEC-IAWD	Received
Air			
Oil-fired, temporary steam boiler	Operation Permit	SCDHEC-BAQC	Received
Emergency diesel generators	Operation Permits	SCDHEC-BAQC	Needed
F-, H- and M-Area process facilities	Operation Permit Amendments	SCDHEC-BAQC	Will be changed prior to startup
Asbestos	Notification	SCDHEC	Ongoing
Solid			
Domestic sanitary sewage sludge	Undefined	DOE	Exempt
Rubble	Undefined	DOE	Ongoing
Domestic wastes	Sanitary Landfill Permit	SCDHEC	SRP landfill permitted
Endangered Species	Biological Assessment	USFWS	In progress
Historic Preservation	Archeological Survey and Assessment	SC-HPO	In progress
Floodplain/Wetlands Impact	Assessment	DOE	In progress
Meteorological Tower	Notification	FAA	Planned, if constructed
NEPA - National Environmental Policy Act FAA - Federal Aviation Administration EPA - Environmental Protection Agency DOE - Department of Energy SCDHEC - Department of Health and Environmental Control IAWD - Industrial and Agricultural Wastewater Division WSD - Water Supply Division BAQC - Bureau of Air Quality Control USFWS - Fish and Wildlife Service SC-HPO - South Carolina Historic Preservation Officer			

pollution control. Under this program, the states subsequent to Federal approval are given the authority to establish effluent limitations and to issue discharge permits to "point source" discharges consistent with established water quality criteria.

EPA formally transferred NPDES permitting authority to the South Carolina Department of Health and Environmental Control (SCDHEC) effective September 26, 1980. SRP has applied for a renewal and consolidation of the current NPDES permits. This request would create one permit covering all point source discharges from the SRP.⁴

All L-Area outfalls with the potential for future use are included in the SRP NPDES permit renewal application. Present plans call for the majority of aqueous waste to be discharged through the L-Area process sewers to Steel Creek (Section 5.2).

The revised NPDES permit for SRP will contain effluent limitations for some pollutants and monitoring requirements for certain outfalls. Effluent limitations are based on EPA recommendations and the State of South Carolina Water Classification Standards System.⁵

Normally, Steel Creek, as part of the Savannah River watershed, would have the classification of its terminus, the Savannah River — a Class B stream. Class B waters are defined as suitable for

- Secondary contact recreation
- Drinking water supply after conventional treatment
- Fishing, survival, and propagation of fish and other fauna and flora
- Industrial and agricultural uses.

L-Area effluents will meet all standards for Class B waters except for temperature. However, SRP streams receiving reactor cooling water effluent have been exempted from Class B standards under the previous SRP NPDES permit. EPA chose to enforce temperature limitations for SRP streams receiving reactor effluents near their point of contact with the Savannah River. SRP has requested in the present NPDES permit application a larger mixing zone in the Savannah River at the mouth of Steel Creek than is allowed under the present permit. The increased size of the mixing zone would accommodate the thermal effluents from L-Area Reactor and K-Area Reactor.

Modifying an NPDES permit for an increase in thermal discharges is allowed under 316(a) of the Clean Water Act (40 CFR 423).³ To support a request for a 316(a) exemption, the permitting agency may require a 316(a) demonstration study; i.e., scientific documentation showing that the expected heated effluent and its interaction with other pollutants will not significantly impact the environment.⁶ DOE-SR has initiated a 316(a) study.

In order to provide sufficient cooling water for L-Area Reactor, withdrawal of water from the Savannah River will be increased about 40 to 50 percent (Section 5.2.2). Section 316(b) of the Clean Water Act requires that a study be made to determine if any adverse environmental impacts will result from the increased river water pumping.³ A 316(b) study examines the intake structure and/or operation and is used by the permitting agency to determine if the proposed action (in this case, an increase in intake flow) has adverse environmental impacts. An impingement and entrainment study completed by SRL in 1977 considered present intake flows for three reactors (P, K, and C). However, increased future withdrawals due to L-Area operations may be large enough to require a new study. As part of the regulatory compliance plan for L-Area startup, DOE-SR has initiated a new 316(b) assessment.

SRP has also requested a variance from SCDHEC to exceed the maximum suspended solids effluent limitations for short periods of time when the emergency cooling water basins (186-basins) in each reactor area are cleaned. Annually, these basins are flushed with Savannah River water to remove sediments that accumulate.

10.2.2 Spill Prevention Control and Countermeasure Plan (SPCC)

Under the Clean Water Act [§§ 311(j)(1)(c), 311(j)(2), and 501(a)],³ the Environmental Protection Agency requires a Spill Prevention Control and Countermeasure (SPCC) Plan for all facilities that handle oil in bulk quantities (40 CFR 112).⁷ An SPCC plan is not necessary if underground storage tank capacity at a site is 42,000 gallons or less and total above-ground storage capacity is 1320 gallons or less (no individual tank can be larger than 660 gal for this exemption to apply).

An SPCC plan should include a discussion of prior spill events, potential spill scenarios, containment/diversionary structures or equipment, e.g., dikes, curbing, culverts, and retention ponds, and contingency plans (§ 112.7).⁷ EPA does not require submission of SPCC plans; however, they do reserve the right to review these plans at any time [§ 112.3(c)].⁷

L Area will have two aboveground, diesel fuel storage tanks with capacities of 8000 and 3000 gallons. To comply with SPCC requirements, each tank needs a diked area that will contain up to the full contents of the tank. If a spill does occur and the containment structure leaks, the fuel from the 8000-gallon tank would flow 10 to 15 feet, and the fuel from the 3000-gallon tank would flow 150 to 200 feet before reaching a storm sewer. Oil entering the storm sewer could eventually reach Steel Creek. As part of SPCC plans for SRP, a specialized set of oil-spill-cleanup procedures will be developed to cope with potential spills.

10.2.3 Domestic Water Wells

Two wells already exist in L Area and have been certified for domestic use by SCDHEC. Two additional wells will be drilled to later supply the water needs in L Area. A "Permit to Construct Ground Water Wells" has been received from the Water Supply Division of SCDHEC and modifications to the existing drinking water system are underway.

10.2.4 Domestic Water Treatment and Distribution System

Untreated well water drawn from geological formations beneath SRP is generally unsuitable for domestic consumption or for use in service operations because of its low pH. Modifications to the existing water treatment facility will be constructed at the site of the original facility in L Area to neutralize and chlorinate the well water. A "Permit to Construct" the domestic water treatment plant and distribution facilities will be required from the Water Supply Division of SCDHEC. Current plans call for release of treatment plant effluent to the L-Area process sewer, which is included in the NPDES permit application.

10.2.5 Domestic Sanitary Sewage

Sanitary wastes generated in L Area during the early phases of construction will be handled by portable chemical toilets and an onsite septic tank (Section 4.2.1.3). Waste collected by the chemical toilets is disposed offsite.

A "Permit to Construct" application has been submitted to SCDHEC for a new sanitary waste water treatment plant for L Area. The plant is similar to other "package" treatment facilities now used on SRP. The facility will treat all domestic sewage produced during the later phases of construction and when the reactor is

operating (Section 4.2.1.3). Effluent from waste treatment operations is chlorinated and discharged into the L-Area process sewer which empties into Steel Creek. The present SRP NPDES Permit Application includes this sanitary discharge.

10.3 AIR POLLUTION PERMIT REQUIREMENTS

This section identifies actions associated with L-Area restart that may require SCDHEC air permits (construction and operation), permit revisions, and/or air monitoring.

Increased air emissions are expected from facilities supplying power to L Area (Section 5.3.2) and from facilities processing fuel and target materials from L-Area Reactor (Section 5.3.8). Some of these activities will require permit action; others will not.

10.3.1 L-Area Steam and Electric Supplies

10.3.1.1 Primary Sources

L-Area steam and electric power demands will require SRP power plants to burn more coal and to release additional pollutants (Section 5.3.2.1). Plants will be modified to increase coal combustion efficiency (e.g., D Area) and steam export ability (K Area). Most of these modifications will not increase air pollutant emissions, and no construction or operating permit review will be needed (South Carolina Air Pollution Control Regulations 61-62, Section II-A, Nov. 1, 1980).⁸

SCDHEC operating permits for SRP coal-fired power plants set an upper limit on air pollutant emissions based on the maximum generation capacity of the individual plant. Since SRP power plants usually operate below full power, annual air pollutant releases typically remain well under emission ceilings. Additional air emissions of SO_x, NO_x, TSP (total suspended particulates) and HC (hydrocarbons) resulting from L-Area power demand are expected to be small and will not cause total source releases to approach or exceed standards. A permit modification will not be required because there will be no change in the design capacity of any boilers.

10.3.1.2 Temporary Steam Supply

Before the K to L steamline is complete, a temporary oil-fired, package boiler will provide heat for L Area during the winter months. SCDHEC will require an operating permit for this facility.

10.3.1.3 Emergency Diesel Generators

L Area will have fourteen diesel generators providing emergency electrical power. Diesel generators are operated periodically for testing purposes. Yearly emissions from consumption of diesel fuel are low (Section 5.3.4).

SCDHEC air pollution regulations require both construction and operating permits for emergency diesel generators greater than 150 kW rated capacity. L Area will have three emergency diesels rated at more than 150 kW:

- 2 at - 1000 kW each
- 1 at - 536 kW

These generators are already in place and have been on standby since L-Area Reactor operations were suspended in 1968. The generators will need operating permits.

10.3.2 Process Facilities Affected

Additional processing of fuel and target materials from L-Reactor will increase F-, H-, and M-Area production rates by about 33 percent. Unlike SRP coal-fired power plant operating permits, SCDHEC bases stack emission limitations for process facilities on average rates. Therefore, if NO_x emissions were to increase by about one-third due to L-Area restart (Section 5.3.8), some facilities will need operating permit revisions. However, other program changes will have more of an effect on process areas NO_x emissions, increasing some and decreasing others regardless of L-Reactor demands. As a result, the process facility air permits scheduled for review by SCDHEC in 1982 will reflect NO_x emission changes brought about by both L-Reactor Restart and other projects. DOE has recently requested SCDHEC to base permit limitations for process facilities on design capacity (similar to the SRP coal-fired boilers) instead of average operating rates in order to accommodate air emissions from increased future processing.

10.3.3 Asbestos

As part of the renovation activities in L Area, all asbestos used in original insulation is being removed for safety and health reasons. Asbestos is regulated as a "hazardous air pollutant" under Section 112 - Clean Air Act.¹⁰ EPA regulations specify emissions standards, disposal practices and site selection.¹¹ Following these guidelines, SRP currently seals asbestos waste in plastic and buries the material in a pit near C Area (Section 4.3.5.2). Asbestos from insulation materials is not considered a

hazardous waste by SCDHEC under its Hazardous Waste Management Regulations,⁹ although it could be considered a solid waste. Permission has been obtained from SCDHEC to use the SRP asbestos disposal site, and SCDHEC has been provided information on SRP asbestos disposal activities for the past few years.

10.4 SOLID AND CHEMICAL WASTE DISPOSAL

L-Area restart activities will generate a variety of residuals defined as solid and chemical wastes under the South Carolina Hazardous Waste Management Act⁹ and the Resource Conservation and Recovery Act of 1976 (RCRA) (42 USC 6901).¹² Disposal will take place at SRP. DOE claims exemption from EPA and SCDHEC solid and hazardous waste regulations under Section 1006(a) of RCRA which states that:

"Nothing in this act shall be construed to apply to (or authorize any state, interstate, or local authority to regulate) any activity or substance which is subject to... the Atomic Energy Act of 1954 (42 USC 2011 and following) except to the extent that such application (or regulation) is not inconsistent with the requirements of such act(s)."¹²

The current DOE policy states that this provision in RCRA excludes all SRP radioactive and nonradioactive "solid" and "hazardous" waste from EPA and SCDHEC control. DOE is in the process of formulating its own guidelines for the management of nonradioactive solid and hazardous waste at SRP based on EPA and SCDHEC regulations. Consequently, SCDHEC permits would not be needed for either solid or hazardous nonradioactive waste disposal sites and activities.

10.4.1 Domestic Sanitary Sewage Sludge

Sewage sludge in L Area will be temporarily retained in the treatment facility until removed by tank-truck. The sludge is emptied into a basin near Central Shops. SCDHEC has inspected the site on several occasions. Samples of sludge have been analyzed for trace metals. The sludge is not a "hazardous" waste but is a "solid" waste under SCDHEC Solid Waste Management Regulations (No. 2, Section VI).¹³ Generally, solid waste must be disposed of in a "permitted" sanitary landfill; however, SCDHEC has the discretion to waive permit requirements on a case-by-case basis. So far, SCDHEC has not taken a position on whether to grant the SRP sewage sludge basin a "variance" or to require a formal permit. If a permit were eventually required, DOE will make the proper applications and comply with SCDHEC regulations.

10.4.2 Rubble

Broken concrete, asphalt, and other construction and renovation debris will be buried in a "rubble" pit near L Area (Section 4.3.5.2). These materials are considered "nonburnable" waste by Solid Waste Management Regulations (No. 2, Section IV),¹³ and a permit is needed for disposal activities. At present, SCDHEC has not required a formal permit for SRP rubble pits. However, SCDHEC has been notified of rubble pit use and has inspected the pits several times.

10.4.3 Domestic Wastes

Garbage from construction and operational activities is disposed in the SRP sanitary landfill. The landfill is designed and operated according to SCDHEC guidelines. SCDHEC issued a permit to SRP for the sanitary landfill effective August 22, 1980. The permit allows for expansion of the existing site from the current ten acres to a total of 32 acres. The larger site can easily accommodate the extra waste from L Area.

10.5 ENDANGERED SPECIES

10.5.1 Federally Listed Endangered Species

The Endangered Species Act prohibits the taking of any endangered species [16 USC 1538(a)(1)(B)].¹⁴ The statute defines "taking" as: "to harass, harm, pursue, hunt, wound... or to attempt to engage in any such conduct" [16 USC 1532 (14)].¹⁴ "Harass" is further defined by regulations as an intentional or negligent act or omission that significantly disrupts normal behavior patterns of the endangered species [50 CFR 17.3 (c)].¹⁴ Similarly, "harm" includes activity resulting in significant environmental modification or degradation of the endangered species habitat.

The act requires Federal agencies not only to protect endangered species subject to their actions but also to enhance the species recovery to a point where they are no longer endangered [2(c) and 3(3)].¹⁴

If an endangered or threatened species is likely to be adversely affected by a proposed action, then a "biological assessment" must be prepared [7(c)].¹⁴ The biological assessment should include identification of species and habitat; survey methods; project description, project impacts (primary, secondary, and cumulative); and efforts taken to eliminate or mitigate any adverse effects. If the assessment concludes that a

project "may affect" an endangered species or its habitat, "consultation" is required with the U. S. Fish and Wildlife Service (FWS). During the consultation period with FWS, no "irreversible or irretrievable commitment of resources" may take place that might foreclose "implementation of reasonable alternatives" designed to mitigate expected impacts on endangered or threatened species [§7(d)].¹⁴

10.5.1.1 American Alligator (Alligator mississippiensis)

A reproducing population of American Alligators inhabit the Steel Creek floodplain and delta area (Section 5.2.3.2). Thermal effluent from L-Area Reactor will make the habitat in the Steel Creek area unsuitable for alligators.

Extensive field studies are under way to 1) determine population status, 2) assess impacts, and 3) develop mitigation plans. Before operation of L-Area Reactor can proceed, DOE-SR will be required to complete a biological assessment and to carry out mitigation measures compatible with FWS recommendations in order to reduce impacts on the alligator population of Steel Creek.

10.5.1.2 Red-Cockaded Woodpecker (Picoides borealis)

Areas likely to be affected by L-Area restart were surveyed for the Red-Cockaded Woodpecker [e.g., the proposed route of the K- to L-Area steam line, the Steel Creek delta and floodplain, and the area surrounding the L-Area complex (see also Section 2.6.2.5.2)]. The survey concluded that Red-Cockaded Woodpeckers do not presently use these areas. No evidence of past colonization was discovered (Section 5.2.3.1). The FWS will be informed of these findings and further "consultation" with the agency regarding the Red-Cockaded Woodpecker and L-Area startup is unnecessary.

10.5.1.3 Wood Stork (Mycteria americana)

The Wood Stork has been proposed for inclusion in the Federal list of endangered species and is considered a threatened species by the State of South Carolina (Table 2.6-10). The Savannah River swamp bottomland is used by the Wood Stork during summer migration (Section 5.2.3.3). Thermal effluents from L-Area Reactor would destroy wading habitats in the Steel Creek delta area potentially used by the Wood Stork during these summer migrations.

Until the listing status of the Wood Stork is resolved, no formal "biological assessment" of this species is necessary. However, biological surveys, which would form the basis of a "biological assessment," are being conducted in case they are needed for "consultation" with FWS before L-Area startup.

10.5.2 Species of Special Concern to South Carolina

Several species of "special concern" to the State of South Carolina are found on SRP (Table 2.6-10). Limited access to the site and extensive reforestation have fostered wildlife preservation. As a result, SRP has become a sanctuary for many species in decline throughout the state and the southeast. Intensive biological surveys currently under way at SRP to assess L-Area startup impacts have detected the presence of several of these species.

There are no formal legal or regulatory requirements protecting these state species of "special concern." However, the State Wildlife and Marine Resources Department will be informed of survey results pertaining to such species.

10.6 FLOODPLAIN MANAGEMENT AND WETLANDS PROTECTION

10.6.1 Introduction

Executive Orders 11988 — "Floodplain Management" (May 24, 1977)¹⁵ and 11990 — "Protection of Wetlands" (May 24, 1977)¹⁶ require Federal agencies to incorporate floodplain and wetlands protection into their decision-making. DOE published regulations based on both Executive Orders (Compliance with Floodplain/Wetlands Environmental Review Requirements — 10 CFR 1022).¹⁷

10.6.2 DOE Policy on Floodplain and Wetlands Protection

DOE policy on floodplain and wetlands protection (§ 1022.3)¹⁷ is designed to:

- Avoid long- and short-term adverse impacts whenever a "practicable" alternative is available.
- Include floodplain management goals and wetlands protection considerations in its planning, regulatory, and decision-making processes.
- Restore and preserve natural and beneficial values provided by floodplains and wetlands.

- Minimize the destruction, loss or degradation of floodplains, and wetlands.
- Carefully evaluate the potential impacts of any DOE action affecting a floodplain or wetland.
- Identify, evaluate, and implement alternative actions which will avoid or mitigate adverse floodplain and wetlands impacts.
- Provide opportunity for early public review of any plans or proposals possibly affecting floodplains or wetlands.

DOE regulations define "minimize" as "to reduce to the smallest degree practicable" [§ 1022.4(m)].¹⁷ The regulations further describe "practicable" as "capable of being accomplished within existing constraints," for example, environmental, cost, technology, and time factors [§ 1022.4(p)].¹⁷ Both the Executive Orders and DOE regulations emphasize the importance of less-damaging alternatives and mitigation. If DOE finds that there is no "practicable" alternative to adversely impacting a floodplain and/or wetlands, the agency will "design or modify the selected action in order to minimize potential harm" [§ 1022.5 (b) and § 1022.15(a)].¹⁷

10.6.3 L-Area Reactor Restart Compliance

The decision to restart L-Area Reactor will impact about 1014 acres of floodplain and wetlands along Steel Creek and in the Savannah River Swamp (Section 5.2.1.1). Thermal effluents and increased stream flow will:

- Inundate both floodplain and wetlands areas
- Increase siltation, erosion, and sedimentation in Steel Creek and adjoining swampland
- Eliminate functioning wetlands and floodplain habitats for both endangered and nonendangered species (Section 5.2.1.3).

In order to comply with both Executive Orders and DOE regulations, DOE-SR must prepare a "Floodplain and Wetlands Assessment" (§ 1022.12)¹⁷ that:

- Describes the proposed action
- Discusses effects on floodplains and wetlands
- Considers alternatives

Approaches that can mitigate expected adverse effects and protect ecologically sensitive floodplain/wetlands areas must also be discussed in the alternatives section [§ 1022.12(a) (3)].¹⁷

10.6.4 Notification and Timing

If an EA or EIS were required for the startup, the floodplain and wetlands assessment is typically prepared concurrently and included in the NEPA document [§ 1022.12(b)].¹⁷ If no NEPA documentation is necessary, the assessment is issued separately [§ 1022.12(c)]¹⁷ before the proposed action commences [§ 1022.18(a)].¹⁷ A "Public Notice" will then be published in the Federal Register as soon as "practicable." The public has 15 days to comment before the agency issues a "statement of findings" on a floodplain and wetlands action [§§ 1022.14 and 1022.18(a)].¹⁷

10.7 HISTORIC PRESERVATION

The Historic Preservation Act of 1966 [16 USC 470(f)]¹⁸ requires Federal agencies with jurisdiction over a Federal "undertaking" to consult with the appropriate state historic preservation officer before the project commences (56 CFR 800).¹⁸ The act emphasizes the protection of properties that might be eligible for inclusion in the National Register of Historic Places.

An archeological and historic survey of L Area and the Steel Creek floodplain was completed in February - March 1981, by the Institute of Archeology and Anthropology of the University of South Carolina (Section 2.2.4). One site was discovered that could meet the criteria of eligibility for the National Register. The survey results will be reviewed by the South Carolina State Historic Preservation Officer for concurrence with the survey findings and assessment.

10.8 FAA NOTIFICATION

SRP may construct a 200-ft (61-meter) meteorological tower in L Area. The tower would provide information on local meteorological conditions and function as part of the WIND System of SRP (Section 4.2.2.3). The Federal Aviation Administration (FAA) requires notification for all new structures 200 ft in elevation or higher. DOE will make the necessary notification.

10.9 REFERENCES

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18. Preparation of Environmental Statements: Guidelines for Discussion of Cultural (Historic, Archeological, Architectural) Resources. Prepared by the National Park Service, Department of the Interior, Washington, DC (1974).

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APPENDIX A

RED-COCKADED WOODPECKER SURVEY

Eco-Inventory Studies, Inc.

Box 1896

Mississippi State, MS 39762

31 Mar. 1981

Dr. Rebecca Sharitz
Savannah River Ecology Laboratory
P.O. Drawer E
Aiken, SC

Dear Dr. Sharitz:

This letter and the attached maps are submitted to you as a report of our survey for the endangered Red-cockaded Woodpecker along the proposed route of a steam line between K and L reactor and in the pine forests surrounding L reactor. The maps detail the areas surveyed. We were able to eliminate the need for systematically walking through some areas on the basis of the small size of the stand and the young age of the trees. However, on 15, 16, and 17 March we did survey an estimated 336 acres on foot using transects such that an observer passed within 100 meters of any point in the area being surveyed. We found no sign of present or past use of the area by Red-cockaded Woodpeckers. Many trees between K and L reactors, particularly those close to the pond, are of a suitable size and age for the species. Their proximity to water and the associated hardwood component of the forest, however, make them less than optimum for future colonization by the woodpeckers. During the course of our survey we noticed Wood Duck boxes placed along the banks of the "hot" stream outflow. I would suggest that these be removed prior to allowing flow of hot water. There's no point in attracting Wood Ducks to what would be an unsuitable environment. While surveying for Red-cockaded Woodpeckers we observed the following other bird species in the area:

Downy Woodpecker
Red-bellied Woodpecker
Common Flicker
Pileated Woodpecker
Eastern Bluebird
American Robin
Hermit Thrush
Carolina Wren
Common Crow
Fish Crow

Dark-eyed Junco
Blue Jay
Mockingbird
Red-shouldered Hawk
Wood Duck
Red-tailed Hawk
Turkey Vulture
House Wren
Yellow-rumped Warbler
Carolina Chickadee

Rebecca Sharitz - p. 2

Tufted Titmouse
Common Grackle
Red-winged Blackbird
Belted Kingfisher
Mourning Dove
Eastern Meadowlark

Brown-headed Nuthatch
Field Sparrow
Rufous-sided Towhee
Brown-headed Cowbird
Bobwhite
Eastern Phoebe

If I can provide additional information, please let me know.

Sincerely,

A handwritten signature in dark ink, appearing to read "Jerome A. Jackson", with a horizontal line extending to the right.

Jerome A. Jackson
President

Within 300-400 meters on
each side of thermal canal for
h-Area in case timber is removed.

MAP A

R STAND MAP

LEGEND

STAND BOUNDARY

STAND NO - ACRES
FOR. TYPE - COND. CLASS

LIM LAND

A-5

MPARTMENT
40

SCALE 4" = 1 MILE

For a better figure of Dr. Jerome A Jackson's survey area, see
Figure 2.6-3.

APPENDIX B

METEOROLOGICAL METHOD FOR ROUTINE RELEASE OF RADIOACTIVITY

The Nuclear Regulatory Commission's computer program, XQDOQ,¹ was used to calculate the annual-average relative air concentration ($\frac{X}{Q}$) and deposition ($\frac{D}{Q}$) values for the dose assessment in Section 5.1.1.1. The XQDOQ code implements the meteorological assumptions and models in Section C (excluding Cla and Clb) of NRC Regulatory Guide 1.111.²

Table B-1 presents the joint frequency distribution that was used in the $\frac{X}{Q}$ and $\frac{D}{Q}$ calculations. These stability-wind rose statistics for 1976 and 1977 were derived from 15-minute average data at the 200-ft (62-meter) elevation on the television tower (Section 2.4). The stability class was determined from vertical temperature gradients between 33 ft and 300 ft according to NRC Regulatory Guide 1.23.³

Tables B-2 through B-5 present the calculated values of $\frac{X}{Q}$ and $\frac{D}{Q}$ by compass sector and radial increment as obtained from the XQDOQ code assuming a ground level release on flat terrain.* Tables B-2 through B-4 show the $\frac{X}{Q}$ values for the cases of (1) no radioactive decay and no plume depletion by deposition, (2) 2.26-day decay during plume transit and no plume depletion by deposition, and (3) 8.00-day decay and plume depletion by dry deposition, respectively. Table B-5 shows the $\frac{D}{Q}$ values associated with Case 3, above. The segment values at the bottom of each of these tables are utilized in determining the doses to the 50-mile population (Appendix C).

Table B-6 shows the $\frac{X}{Q}$ and $\frac{D}{Q}$ values at the nearest approach of of the residential population by compass sector with respect to the L-Area release point. The release parameters utilized in the XQDOQ-code calculations (Tables B-1 through B-6) are listed at the bottom of this table.

* Under this assumption, the $\frac{X}{Q}$ and $\frac{D}{Q}$ distribution is the same about each release point.

TABLE B-1

Joint Frequency Distribution for Data from the 62-Meter Level
on the Television Tower During 1976 and 1977

Stability Class	Wind Speed, meters/sec	Wind Direction																SUM
		N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	
A	0 to 2	0.01	0.01	0.02	0.03	0.02	0.04	0.04	0.05	0.06	0.05	0.08	0.07	0.04	0.05	0.03	0.01	0.60
	2 to 4	0.06	0.05	0.22	0.29	0.32	0.32	0.30	0.30	0.36	0.53	0.77	0.63	0.58	0.54	0.22	0.13	5.61
	4 to 6	0.06	0.08	0.22	0.46	0.43	0.17	0.15	0.25	0.22	0.44	0.65	0.56	0.60	0.45	0.30	0.13	5.16
	6 to 8	0.02	0.05	0.13	0.25	0.18	0.07	0.03	0.06	0.10	0.24	0.31	0.32	0.38	0.36	0.16	0.01	2.67
	8 to 12	0.0	0.01	0.02	0.08	0.02	0.01	0.01	0.06	0.06	0.06	0.13	0.11	0.35	0.42	0.10	0.0	1.42
	>12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.0	0.0	0.01	0.00	0.06	0.09	0.01	0.0	0.18
Total																		15.64
B	0 to 2	0.01	0.01	0.01	0.01	0.02	0.01	0.02	0.01	0.02	0.04	0.03	0.04	0.05	0.03	0.01	0.00	0.33
	2 to 4	0.04	0.05	0.09	0.09	0.12	0.08	0.08	0.07	0.09	0.13	0.15	0.16	0.16	0.13	0.08	0.07	1.58
	4 to 6	0.01	0.04	0.09	0.10	0.11	0.06	0.04	0.05	0.07	0.10	0.12	0.12	0.10	0.10	0.07	0.02	1.20
	6 to 8	0.01	0.01	0.03	0.04	0.02	0.01	0.01	0.02	0.04	0.03	0.05	0.09	0.04	0.05	0.05	0.00	0.50
	8 to 12	0.00	0.01	0.01	0.02	0.00	0.00	0.00	0.01	0.00	0.01	0.01	0.04	0.09	0.08	0.03	0.0	0.33
	>12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.0	0.00	0.01	0.0	0.02	0.01	0.00	0.0	0.5
Total																		3.99
C	0 to 2	0.01	0.01	0.01	0.03	0.02	0.03	0.04	0.02	0.03	0.03	0.04	0.05	0.04	0.04	0.01	0.01	0.41
	2 to 4	0.03	0.07	0.15	0.11	0.09	0.08	0.07	0.06	0.08	0.11	0.14	0.16	0.15	0.14	0.08	0.04	1.57
	4 to 6	0.02	0.03	0.11	0.10	0.10	0.07	0.02	0.05	0.10	0.08	0.11	0.11	0.10	0.07	0.07	0.04	1.19
	6 to 8	0.00	0.02	0.03	0.07	0.03	0.01	0.01	0.02	0.04	0.04	0.05	0.05	0.05	0.05	0.04	0.01	0.53
	8 to 12	0.0	0.04	0.00	0.01	0.00	0.01	0.0	0.02	0.01	0.01	0.02	0.02	0.08	0.06	0.02	0.0	0.30
	>12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.01	0.00	0.01	0.01	0.01	0.0	0.04
Total																		4.04
D	0 to 2	0.06	0.11	0.17	0.14	0.15	0.16	0.14	0.14	0.14	0.18	0.16	0.16	0.19	0.15	0.15	0.08	2.29
	2 to 4	0.13	0.27	0.54	0.40	0.39	0.31	0.28	0.27	0.31	0.42	0.55	0.51	0.44	0.38	0.33	0.29	5.81
	4 to 6	0.10	0.26	0.56	0.59	0.55	0.40	0.26	0.42	0.39	0.42	0.53	0.40	0.36	0.29	0.36	0.13	6.02
	6 to 8	0.06	0.13	0.24	0.44	0.19	0.20	0.14	0.25	0.24	0.22	0.22	0.25	0.25	0.32	0.24	0.05	3.43
	8 to 12	0.02	0.10	0.03	0.13	0.03	0.03	0.06	0.10	0.07	0.06	0.04	0.11	0.29	0.60	0.23	0.01	1.89
	>12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.0	0.01	0.05	0.12	0.03	0.00	0.21
Total																		19.65
E	0 to 2	0.05	0.08	0.13	0.16	0.19	0.18	0.15	0.14	0.15	0.18	0.19	0.16	0.16	0.14	0.14	0.11	2.31
	2 to 4	0.07	0.21	0.51	0.49	0.53	0.46	0.43	0.48	0.51	0.70	0.61	0.54	0.47	0.34	0.37	0.23	6.96
	4 to 6	0.15	0.39	0.65	0.85	0.81	0.84	0.99	1.29	1.33	1.53	1.09	0.92	0.84	0.75	0.59	0.41	13.46
	6 to 8	0.05	0.19	0.17	0.41	0.15	0.20	0.25	0.74	0.59	0.47	0.51	0.59	0.97	0.95	0.51	0.15	6.88
	8 to 12	0.0	0.05	0.0	0.04	0.01	0.01	0.06	0.13	0.04	0.13	0.27	0.14	0.30	0.77	0.15	0.01	2.12
	>12	0.0	0.0	0.00	0.0	0.00	0.0	0.0	0.0	0.00	0.0	0.00	0.01	0.01	0.03	0.01	0.00	0.08
Total																		31.81
F	0 to 2	0.03	0.02	0.06	0.06	0.10	0.08	0.08	0.06	0.06	0.08	0.11	0.08	0.08	0.07	0.05	0.04	1.07
	2 to 4	0.09	0.15	0.23	0.19	0.19	0.29	0.34	0.26	0.34	0.44	0.39	0.31	0.22	0.15	0.14	0.13	3.87
	4 to 6	0.11	0.20	0.37	0.54	0.44	0.60	0.44	0.52	0.84	0.94	0.79	0.73	0.67	0.41	0.34	0.15	8.10
	6 to 8	0.08	0.15	0.14	0.30	0.42	0.24	0.14	0.36	0.54	0.59	0.48	0.53	0.60	0.52	0.34	0.18	5.60
	8 to 12	0.00	0.01	0.01	0.01	0.04	0.00	0.01	0.03	0.03	0.02	0.11	0.10	0.07	0.06	0.02	0.02	0.55
	>12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.02	0.0	0.0	0.00	0.0	0.0	0.02
Total																		19.21
G	0 to 2	0.03	0.02	0.03	0.03	0.03	0.03	0.04	0.03	0.02	0.05	0.01	0.02	0.03	0.01	0.02	0.03	0.43
	2 to 4	0.03	0.02	0.08	0.08	0.08	0.10	0.08	0.10	0.09	0.11	0.10	0.08	0.10	0.06	0.08	0.03	1.21
	4 to 6	0.05	0.06	0.08	0.17	0.12	0.17	0.11	0.13	0.23	0.30	0.22	0.28	0.20	0.13	0.10	0.09	2.44
	6 to 8	0.01	0.04	0.04	0.14	0.22	0.09	0.04	0.07	0.15	0.14	0.10	0.08	0.09	0.08	0.05	0.09	1.45
	8 to 12	0.01	0.00	0.00	0.0	0.02	0.02	0.00	0.01	0.01	0.02	0.02	0.01	0.00	0.00	0.00	0.01	0.15
	>12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total																		5.88

TABLE B-2

Ground-Level Release — Flat Terrain
No Decay, Undepleted

ANNUAL AVERAGE CHI/Q (SEC/METER CUBED)				DISTANCE IN MILES								
SECTOR	0.250	0.500	0.750	1.000	1.500	2.000	2.500	3.000	3.500	4.000	4.500	
S	2.316E-06	6.699E-07	3.255E-07	2.005E-07	1.048E-07	6.732E-08	4.814E-08	3.677E-08	2.936E-08	2.421E-08	2.045E-08	
SSW	3.810E-06	1.110E-06	5.429E-07	3.341E-07	1.740E-07	1.113E-07	7.930E-08	6.036E-08	4.804E-08	3.950E-08	3.327E-08	
SW	6.659E-06	1.931E-06	9.433E-07	5.803E-07	3.022E-07	1.933E-07	1.377E-07	1.048E-07	8.345E-08	6.861E-08	5.780E-08	
WSW	7.799E-06	2.257E-06	1.100E-06	6.769E-07	3.532E-07	2.264E-07	1.616E-07	1.232E-07	9.824E-08	8.088E-08	6.822E-08	
W	7.891E-06	2.287E-06	1.115E-06	6.862E-07	3.585E-07	2.301E-07	1.644E-07	1.255E-07	1.001E-07	8.247E-08	6.960E-08	
WNW	7.643E-06	2.220E-06	1.084E-06	6.673E-07	3.489E-07	2.241E-07	1.602E-07	1.224E-07	9.766E-08	8.049E-08	6.796E-08	
NW	7.151E-06	2.079E-06	1.015E-06	6.251E-07	3.268E-07	2.099E-07	1.501E-07	1.146E-07	9.147E-08	7.539E-08	6.365E-08	
NNW	7.980E-06	2.322E-06	1.135E-06	6.991E-07	3.655E-07	2.347E-07	1.678E-07	1.281E-07	1.022E-07	8.420E-08	7.108E-08	
N	9.140E-06	2.656E-06	1.296E-06	7.982E-07	4.175E-07	2.683E-07	1.919E-07	1.466E-07	1.171E-07	9.651E-08	8.151E-08	
NNE	1.122E-05	3.252E-06	1.585E-06	9.761E-07	5.110E-07	3.286E-07	2.352E-07	1.798E-07	1.436E-07	1.185E-07	1.001E-07	
NE	1.025E-05	2.954E-06	1.437E-06	8.836E-07	4.618E-07	2.965E-07	2.119E-07	1.618E-07	1.291E-07	1.064E-07	8.982E-08	
ENE	9.394E-06	2.703E-06	1.314E-06	8.072E-07	4.215E-07	2.704E-07	1.932E-07	1.474E-07	1.176E-07	9.690E-08	8.179E-08	
E	9.254E-06	2.663E-06	1.295E-06	7.959E-07	4.154E-07	2.664E-07	1.903E-07	1.451E-07	1.158E-07	9.534E-08	8.045E-08	
ESE	7.780E-06	2.238E-06	1.090E-06	6.694E-07	3.488E-07	2.233E-07	1.592E-07	1.213E-07	9.663E-08	7.950E-08	6.701E-08	
SE	6.215E-06	1.802E-06	8.797E-07	5.412E-07	2.823E-07	1.809E-07	1.290E-07	9.832E-08	7.835E-08	6.447E-08	5.436E-08	
SSE	3.977E-06	1.156E-06	5.644E-07	3.477E-07	1.818E-07	1.167E-07	8.345E-08	6.371E-08	5.085E-08	4.190E-08	3.538E-08	

ANNUAL AVERAGE CHI/Q (SEC/METER CUBED)				DISTANCE IN MILES								
BEARING	5.000	7.500	10.000	15.000	20.000	25.000	30.000	35.000	40.000	45.000	50.000	
S	1.760E-08	9.982E-09	6.721E-09	3.885E-09	2.651E-09	1.976E-09	1.557E-09	1.274E-09	1.072E-09	9.209E-10	8.044E-10	
SSW	2.857E-08	1.603E-08	1.071E-08	6.120E-09	4.139E-09	3.064E-09	2.401E-09	1.955E-09	1.638E-09	1.402E-09	1.220E-09	
SW	4.964E-08	2.786E-08	1.862E-08	1.064E-08	7.200E-09	5.333E-09	4.180E-09	3.406E-09	2.854E-09	2.443E-09	2.127E-09	
WSW	5.866E-08	3.307E-08	2.217E-08	1.274E-08	8.648E-09	6.422E-09	5.044E-09	4.117E-09	3.456E-09	2.963E-09	2.583E-09	
W	5.988E-08	3.384E-08	2.273E-08	1.308E-08	8.890E-09	6.608E-09	5.193E-09	4.241E-09	3.561E-09	3.055E-09	2.664E-09	
WNW	5.848E-08	3.307E-08	2.222E-08	1.279E-08	8.699E-09	6.467E-09	5.084E-09	4.152E-09	3.487E-09	2.991E-09	2.608E-09	
NW	5.478E-08	3.099E-08	2.082E-08	1.199E-08	8.156E-09	6.064E-09	4.767E-09	3.893E-09	3.270E-09	2.805E-09	2.446E-09	
NNW	6.115E-08	3.454E-08	2.319E-08	1.333E-08	9.052E-09	6.722E-09	5.279E-09	4.308E-09	3.615E-09	3.099E-09	2.701E-09	
N	7.016E-08	3.972E-08	2.671E-08	1.540E-08	1.048E-08	7.793E-09	6.129E-09	5.007E-09	4.206E-09	3.608E-09	3.147E-09	
NNE	8.619E-08	4.888E-08	3.291E-08	1.901E-08	1.295E-08	9.642E-09	7.589E-09	6.204E-09	5.215E-09	4.476E-09	3.907E-09	
NE	7.729E-08	4.372E-08	2.938E-08	1.693E-08	1.152E-08	8.567E-09	6.738E-09	5.505E-09	4.624E-09	3.968E-09	3.461E-09	
ENE	7.038E-08	3.981E-08	2.676E-08	1.542E-08	1.050E-08	7.817E-09	6.150E-09	5.028E-09	4.225E-09	3.627E-09	3.165E-09	
E	6.921E-08	3.911E-08	2.627E-08	1.512E-08	1.029E-08	7.652E-09	6.017E-09	4.916E-09	4.130E-09	3.544E-09	3.091E-09	
ESE	5.759E-08	3.242E-08	2.171E-08	1.245E-08	8.444E-09	6.266E-09	4.918E-09	4.012E-09	3.365E-09	2.884E-09	2.513E-09	
SE	4.672E-08	2.630E-08	1.761E-08	1.009E-08	6.840E-09	5.072E-09	3.979E-09	3.245E-09	2.721E-09	2.331E-09	2.031E-09	
SSE	3.044E-08	1.721E-08	1.156E-08	6.658E-09	4.527E-09	3.365E-09	2.645E-09	2.160E-09	1.814E-09	1.556E-09	1.357E-09	

CHI/Q (SEC/METER CUBED) FOR EACH SEGMENT

DIRECTION FROM SITE	SEGMENT BOUNDARIES IN MILES									
	.5-1	1-2	2-3	3-4	4-5	5-10	10-20	20-30	30-40	40-50
S	3.465E-07	1.094E-07	4.871E-08	2.952E-08	2.051E-08	1.023E-08	3.967E-09	1.988E-09	1.278E-09	9.225E-10
SSW	5.760E-07	1.817E-07	8.026E-08	4.831E-08	3.338E-08	1.646E-08	6.260E-09	3.085E-09	1.961E-09	1.404E-09
SW	1.002E-06	3.156E-07	1.394E-07	8.391E-08	5.798E-08	2.859E-08	1.088E-08	5.370E-09	3.417E-09	2.448E-09
WSW	1.169E-06	3.688E-07	1.636E-07	9.877E-08	6.843E-08	3.391E-08	1.302E-08	6.465E-09	4.130E-09	2.968E-09
W	1.185E-06	3.743E-07	1.664E-07	1.006E-07	6.981E-08	3.469E-08	1.336E-08	6.651E-09	4.254E-09	3.060E-09
WNW	1.151E-06	3.642E-07	1.621E-07	9.817E-08	6.816E-08	3.389E-08	1.307E-08	6.509E-09	4.165E-09	2.996E-09
NW	1.078E-06	3.411E-07	1.518E-07	9.195E-08	6.384E-08	3.175E-08	1.225E-08	6.103E-09	3.905E-09	2.810E-09
NNW	1.205E-06	3.815E-07	1.697E-07	1.027E-07	7.129E-08	3.541E-08	1.362E-08	6.766E-09	4.321E-09	3.104E-09
N	1.377E-06	4.358E-07	1.942E-07	1.177E-07	8.175E-08	4.070E-08	1.573E-08	7.843E-09	5.022E-09	3.615E-09
NNE	1.685E-06	5.333E-07	2.379E-07	1.444E-07	1.004E-07	5.007E-08	1.941E-08	9.703E-09	6.223E-09	4.484E-09
NE	1.528E-06	4.821E-07	2.144E-07	1.298E-07	9.009E-08	4.481E-08	1.729E-08	8.622E-09	5.522E-09	3.975E-09
ENE	1.397E-06	4.401E-07	1.955E-07	1.182E-07	8.204E-08	4.080E-08	1.576E-08	7.866E-09	5.043E-09	3.633E-09
E	1.377E-06	4.337E-07	1.925E-07	1.164E-07	8.070E-08	4.009E-08	1.545E-08	7.701E-09	4.931E-09	3.550E-09
ESE	1.158E-06	3.643E-07	1.612E-07	9.715E-08	6.722E-08	3.325E-08	1.273E-08	6.307E-09	4.024E-09	2.889E-09
SE	9.341E-07	2.947E-07	1.306E-07	7.877E-08	5.452E-08	2.697E-08	1.032E-08	5.107E-09	3.255E-09	2.335E-09
SSE	5.996E-07	1.897E-07	8.443E-08	5.112E-08	3.548E-08	1.764E-08	6.800E-09	3.387E-09	2.167E-09	1.559E-09

TABLE B-3

Ground-Level Release — Flat Terrain
2.260 Day Decay, Undepleted

ANNUAL AVERAGE SECTOR	CHI/Q (SEC/METER CUBED)			DISTANCE IN MILES							
	0.250	0.500	0.750	1.000	1.500	2.000	2.500	3.000	3.500	4.000	4.500
S	2.314E-06	6.687E-07	3.247E-07	1.998E-07	1.043E-07	6.687E-08	4.774E-08	3.641E-08	2.902E-08	2.389E-08	2.014E-08
SSW	3.807E-06	1.108E-06	5.418E-07	3.332E-07	1.733E-07	1.107E-07	7.876E-08	5.987E-08	4.759E-08	3.907E-08	3.287E-08
SW	6.654E-06	1.929E-06	9.414E-07	5.787E-07	3.010E-07	1.923E-07	1.368E-07	1.040E-07	8.265E-08	6.786E-08	5.709E-08
WSW	7.794E-06	2.254E-06	1.098E-06	6.752E-07	3.519E-07	2.253E-07	1.606E-07	1.223E-07	9.738E-08	8.007E-08	6.746E-08
W	7.885E-06	2.284E-06	1.113E-06	6.843E-07	3.570E-07	2.288E-07	1.633E-07	1.244E-07	9.915E-08	8.157E-08	6.875E-08
WNW	7.637E-06	2.217E-06	1.081E-06	6.655E-07	3.475E-07	2.229E-07	1.592E-07	1.214E-07	9.675E-08	7.963E-08	6.714E-08
NW	7.146E-06	2.076E-06	1.013E-06	6.233E-07	3.254E-07	2.087E-07	1.490E-07	1.136E-07	9.056E-08	7.453E-08	6.284E-08
NNW	7.975E-06	2.319E-06	1.133E-06	6.974E-07	3.642E-07	2.336E-07	1.668E-07	1.271E-07	1.013E-07	8.340E-08	7.031E-08
N	9.135E-06	2.653E-06	1.294E-06	7.964E-07	4.161E-07	2.671E-07	1.908E-07	1.456E-07	1.162E-07	9.566E-08	8.070E-08
NNE	1.121E-05	3.248E-06	1.582E-06	9.737E-07	5.091E-07	3.270E-07	2.338E-07	1.785E-07	1.424E-07	1.173E-07	9.902E-08
NE	1.025E-05	2.950E-06	1.435E-06	8.814E-07	4.601E-07	2.951E-07	2.106E-07	1.606E-07	1.280E-07	1.054E-07	8.885E-08
ENE	9.388E-06	2.699E-06	1.311E-06	8.053E-07	4.200E-07	2.691E-07	1.920E-07	1.464E-07	1.166E-07	9.599E-08	8.093E-08
E	9.248E-06	2.660E-06	1.293E-06	7.939E-07	4.139E-07	2.651E-07	1.891E-07	1.441E-07	1.148E-07	9.443E-08	7.959E-08
ESE	7.775E-06	2.236E-06	1.088E-06	6.678E-07	3.476E-07	2.223E-07	1.583E-07	1.205E-07	9.585E-08	7.877E-08	6.632E-08
SE	6.211E-06	1.799E-06	8.780E-07	5.398E-07	2.812E-07	1.799E-07	1.282E-07	9.755E-08	7.763E-08	6.380E-08	5.372E-08
SSE	3.975E-06	1.155E-06	5.632E-07	3.467E-07	1.810E-07	1.161E-07	8.284E-08	6.315E-08	5.033E-08	4.142E-08	3.492E-08

ANNUAL AVERAGE BEARING	CHI/Q (SEC/METER CUBED)			DISTANCE IN MILES							
	5.000	7.500	10.000	15.000	20.000	25.000	30.000	35.000	40.000	45.000	50.000
S	1.731E-08	9.737E-09	6.503E-09	3.697E-09	2.482E-09	1.820E-09	1.411E-09	1.137E-09	9.415E-10	7.962E-10	6.847E-10
SSW	2.819E-08	1.571E-08	1.043E-08	5.880E-09	3.925E-09	2.869E-09	2.219E-09	1.784E-09	1.476E-09	1.247E-09	1.072E-09
SW	4.896E-08	2.729E-08	1.811E-08	1.021E-08	6.819E-09	4.983E-09	3.854E-09	3.099E-09	2.563E-09	2.166E-09	1.862E-09
WSW	5.793E-08	3.246E-08	2.163E-08	1.227E-08	8.233E-09	6.041E-09	4.689E-09	3.783E-09	3.138E-09	2.660E-09	2.292E-09
W	5.907E-08	3.316E-08	2.212E-08	1.256E-08	8.429E-09	6.185E-09	4.799E-09	3.870E-09	3.209E-09	2.718E-09	2.342E-09
WNW	5.770E-08	3.241E-08	2.163E-08	1.230E-08	8.255E-09	6.059E-09	4.704E-09	3.794E-09	3.147E-09	2.666E-09	2.297E-09
NW	5.400E-08	3.033E-08	2.024E-08	1.149E-08	7.709E-09	5.653E-09	4.383E-09	3.531E-09	2.926E-09	2.476E-09	2.131E-09
NNW	6.042E-08	3.393E-08	2.264E-08	1.287E-08	8.635E-09	6.338E-09	4.921E-09	3.970E-09	3.294E-09	2.792E-09	2.406E-09
N	6.938E-08	3.907E-08	2.613E-08	1.490E-08	1.003E-08	7.383E-09	5.746E-09	4.646E-09	3.862E-09	3.280E-09	2.832E-09
NNE	8.517E-08	4.803E-08	3.215E-08	1.835E-08	1.236E-08	9.099E-09	7.081E-09	5.725E-09	4.759E-09	4.040E-09	3.488E-09
NE	7.636E-08	4.294E-08	2.869E-08	1.634E-08	1.099E-08	8.082E-09	6.285E-09	5.078E-09	4.219E-09	3.580E-09	3.089E-09
ENE	6.955E-08	3.912E-08	2.614E-08	1.490E-08	1.003E-08	7.382E-09	5.745E-09	4.645E-09	3.861E-09	3.279E-09	2.831E-09
E	6.838E-08	3.842E-08	2.565E-08	1.460E-08	9.819E-09	7.220E-09	5.614E-09	4.536E-09	3.769E-09	3.199E-09	2.760E-09
ESE	5.693E-08	3.187E-08	2.122E-08	1.203E-08	8.072E-09	5.924E-09	4.600E-09	3.712E-09	3.081E-09	2.613E-09	2.253E-09
SE	4.611E-08	2.579E-08	1.716E-08	9.708E-09	6.498E-09	4.759E-09	3.687E-09	2.970E-09	2.460E-09	2.082E-09	1.792E-09
SSE	3.000E-08	1.684E-08	1.123E-08	6.376E-09	4.275E-09	3.134E-09	2.429E-09	1.957E-09	1.621E-09	1.372E-09	1.181E-09

CHI/Q (SEC/METER CUBED) FOR EACH SEGMENT

DIRECTION FROM SITE	SEGMENT BOUNDARIES IN MILES									
	.5-1	1-2	2-3	3-4	4-5	5-10	10-20	20-30	30-40	40-50
S	3.456E-07	1.089E-07	4.831E-08	2.918E-08	2.021E-08	9.983E-09	3.781E-09	1.833E-09	1.141E-09	7.979E-10
SSW	5.749E-07	1.810E-07	7.972E-08	4.785E-08	3.298E-08	1.614E-08	6.022E-09	2.891E-09	1.791E-09	1.250E-09
SW	9.996E-07	3.144E-07	1.385E-07	8.311E-08	5.727E-08	2.803E-08	1.046E-08	5.021E-09	3.111E-09	2.171E-09
WSW	1.167E-06	3.675E-07	1.625E-07	9.791E-08	6.767E-08	3.331E-08	1.256E-08	6.085E-09	3.796E-09	2.665E-09
W	1.183E-06	3.728E-07	1.652E-07	9.968E-08	6.896E-08	3.401E-08	1.285E-08	6.229E-09	3.884E-09	2.724E-09
WNW	1.149E-06	3.628E-07	1.610E-07	9.726E-08	6.734E-08	3.324E-08	1.258E-08	6.103E-09	3.807E-09	2.672E-09
NW	1.076E-06	3.397E-07	1.508E-07	9.104E-08	6.303E-08	3.111E-08	1.176E-08	5.693E-09	3.544E-09	2.481E-09
NNW	1.203E-06	3.802E-07	1.687E-07	1.019E-07	7.053E-08	3.480E-08	1.316E-08	6.383E-09	3.984E-09	2.798E-09
N	1.375E-06	4.344E-07	1.931E-07	1.168E-07	8.094E-08	4.005E-08	1.523E-08	7.435E-09	4.661E-09	3.287E-09
NNE	1.682E-06	5.314E-07	2.365E-07	1.432E-07	9.932E-08	4.922E-08	1.876E-08	9.162E-09	5.745E-09	4.049E-09
NE	1.525E-06	4.804E-07	2.131E-07	1.287E-07	8.912E-08	4.404E-08	1.671E-08	8.139E-09	5.095E-09	3.587E-09
ENE	1.395E-06	4.385E-07	1.943E-07	1.173E-07	8.118E-08	4.011E-08	1.523E-08	7.433E-09	4.660E-09	3.285E-09
E	1.375E-06	4.322E-07	1.914E-07	1.154E-07	7.984E-08	3.940E-08	1.493E-08	7.271E-09	4.552E-09	3.205E-09
ESE	1.156E-06	3.631E-07	1.602E-07	9.638E-08	6.653E-08	3.270E-08	1.231E-08	5.967E-09	3.725E-09	2.618E-09
SE	9.324E-07	2.936E-07	1.297E-07	7.805E-08	5.389E-08	2.647E-08	9.936E-09	4.794E-09	2.981E-09	2.087E-09
SSE	5.984E-07	1.889E-07	8.382E-08	5.060E-08	3.502E-08	1.727E-08	6.521E-09	3.156E-09	1.964E-09	1.375E-09

TABLE B-4

Ground-Level Release — Flat Terrain
8.000 Day Decay, Depleted

ANNUAL AVERAGE CHI/Q (SEC/METER CUBED) SECTOR	DISTANCE IN MILES										
	0.250	0.500	0.750	1.000	1.500	2.000	2.500	3.000	3.500	4.000	4.500
S	2.191E-06	6.114E-07	2.899E-07	1.753E-07	8.887E-08	5.564E-08	3.891E-08	2.913E-08	2.284E-08	1.851E-08	1.540E-08
SSW	3.605E-06	1.013E-06	4.835E-07	2.922E-07	1.476E-07	9.202E-08	6.411E-08	4.783E-08	3.739E-08	3.023E-08	2.507E-08
SW	6.301E-06	1.763E-06	8.402E-07	5.076E-07	2.564E-07	1.598E-07	1.114E-07	8.308E-08	6.494E-08	5.250E-08	4.355E-08
WSW	7.380E-06	2.060E-06	9.801E-07	5.921E-07	2.997E-07	1.872E-07	1.307E-07	9.768E-08	7.647E-08	6.191E-08	5.142E-08
W	7.466E-06	2.087E-06	9.930E-07	6.002E-07	3.041E-07	1.902E-07	1.329E-07	9.943E-08	7.790E-08	6.311E-08	5.244E-08
WNW	7.232E-06	2.027E-06	9.651E-07	5.837E-07	2.960E-07	1.853E-07	1.296E-07	9.696E-08	7.600E-08	6.160E-08	5.121E-08
NW	6.766E-06	1.898E-06	9.041E-07	5.467E-07	2.772E-07	1.735E-07	1.213E-07	9.080E-08	7.117E-08	5.769E-08	4.795E-08
NNW	7.551E-06	2.120E-06	1.011E-06	6.115E-07	3.101E-07	1.941E-07	1.357E-07	1.015E-07	7.955E-08	6.446E-08	5.358E-08
N	8.649E-06	2.425E-06	1.155E-06	6.982E-07	3.542E-07	2.219E-07	1.552E-07	1.162E-07	9.114E-08	7.390E-08	6.145E-08
NNE	1.061E-05	2.969E-06	1.412E-06	8.538E-07	4.335E-07	2.717E-07	1.902E-07	1.425E-07	1.118E-07	9.069E-08	7.545E-08
NE	9.703E-06	2.696E-06	1.280E-06	7.729E-07	3.918E-07	2.452E-07	1.714E-07	1.282E-07	1.005E-07	8.145E-08	6.770E-08
ENE	8.889E-06	2.467E-06	1.170E-06	7.061E-07	3.576E-07	2.236E-07	1.562E-07	1.169E-07	9.157E-08	7.419E-08	6.166E-08
E	8.756E-06	2.431E-06	1.154E-06	6.962E-07	3.524E-07	2.203E-07	1.539E-07	1.150E-07	9.011E-08	7.299E-08	6.064E-08
ESE	7.362E-06	2.043E-06	9.709E-07	5.856E-07	2.959E-07	1.847E-07	1.288E-07	9.617E-08	7.523E-08	6.087E-08	5.052E-08
SE	5.881E-06	1.645E-06	7.835E-07	4.734E-07	2.395E-07	1.495E-07	1.043E-07	7.792E-08	6.098E-08	4.934E-08	4.096E-08
SSE	3.764E-06	1.056E-06	5.027E-07	3.041E-07	1.542E-07	9.650E-08	6.746E-08	5.048E-08	3.956E-08	3.206E-08	2.665E-08

ANNUAL AVERAGE CHI/Q (SEC/METER CUBED) BEARING	DISTANCE IN MILES										
	5.000	7.500	10.000	15.000	20.000	25.000	30.000	35.000	40.000	45.000	50.000
S	1.306E-08	6.988E-09	4.473E-09	2.382E-09	1.519E-09	1.068E-09	7.984E-10	6.226E-10	5.007E-10	4.124E-10	3.460E-10
SSW	2.122E-08	1.124E-08	7.142E-09	3.762E-09	2.381E-09	1.664E-09	1.238E-09	9.615E-10	7.707E-10	6.329E-10	5.297E-10
SW	3.686E-08	1.953E-08	1.241E-08	6.539E-09	4.140E-09	2.894E-09	2.154E-09	1.673E-09	1.342E-09	1.102E-09	9.225E-10
WSW	4.357E-08	2.319E-08	1.479E-08	7.836E-09	4.980E-09	3.492E-09	2.605E-09	2.029E-09	1.630E-09	1.341E-09	1.124E-09
W	4.446E-08	2.372E-08	1.515E-08	8.040E-09	5.114E-09	3.588E-09	2.678E-09	2.086E-09	1.676E-09	1.379E-09	1.156E-09
WNW	4.342E-08	2.318E-08	1.481E-08	7.866E-09	5.005E-09	3.513E-09	2.622E-09	2.043E-09	1.642E-09	1.351E-09	1.133E-09
NW	4.067E-08	2.171E-08	1.388E-08	7.368E-09	4.687E-09	3.289E-09	2.454E-09	1.911E-09	1.536E-09	1.263E-09	1.059E-09
NNW	4.542E-08	2.423E-08	1.547E-08	8.206E-09	5.216E-09	3.657E-09	2.729E-09	2.125E-09	1.707E-09	1.404E-09	1.177E-09
N	5.213E-08	2.787E-08	1.783E-08	9.486E-09	6.044E-09	4.246E-09	3.173E-09	2.474E-09	1.990E-09	1.639E-09	1.376E-09
NNE	6.403E-08	3.429E-08	2.196E-08	1.170E-08	7.464E-09	5.248E-09	3.924E-09	3.061E-09	2.463E-09	2.029E-09	1.704E-09
NE	5.742E-08	3.067E-08	1.961E-08	1.042E-08	6.638E-09	4.662E-09	3.483E-09	2.716E-09	2.184E-09	1.799E-09	1.509E-09
ENE	5.228E-08	2.793E-08	1.786E-08	9.497E-09	6.054E-09	4.255E-09	3.181E-09	2.481E-09	1.996E-09	1.645E-09	1.381E-09
E	5.141E-08	2.743E-08	1.753E-08	9.311E-09	5.929E-09	4.164E-09	3.111E-09	2.425E-09	1.951E-09	1.606E-09	1.348E-09
ESE	4.279E-08	2.274E-08	1.449E-08	7.666E-09	4.868E-09	3.412E-09	2.544E-09	1.981E-09	1.591E-09	1.309E-09	1.097E-09
SE	3.469E-08	1.844E-08	1.174E-08	6.207E-09	3.937E-09	2.756E-09	2.053E-09	1.597E-09	1.282E-09	1.054E-09	8.825E-10
SSE	2.260E-08	1.206E-08	7.704E-09	4.089E-09	2.601E-09	1.824E-09	1.361E-09	1.060E-09	8.518E-10	7.008E-10	5.875E-10

CHI/Q (SEC/METER CUBED) FOR EACH SEGMENT

DIRECTION FROM SITE	SEGMENT BOUNDARIES IN MILES									
	.5-1	1-2	2-3	3-4	4-5	5-10	10-20	20-30	30-40	40-50
S	3.104E-07	9.331E-08	3.946E-08	2.299E-08	1.545E-08	7.220E-09	2.463E-09	1.080E-09	6.264E-10	4.140E-10
SSW	5.161E-07	1.550E-07	6.504E-08	3.764E-08	2.517E-08	1.164E-08	3.899E-09	1.685E-09	9.678E-10	6.355E-10
SW	8.974E-07	2.693E-07	1.130E-07	6.539E-08	4.372E-08	2.021E-08	6.778E-09	2.930E-09	1.684E-09	1.107E-09
WSW	1.048E-06	3.147E-07	1.326E-07	7.698E-08	5.162E-08	2.399E-08	8.113E-09	3.534E-09	2.042E-09	1.346E-09
W	1.062E-06	3.193E-07	1.348E-07	7.842E-08	5.265E-08	2.452E-08	8.320E-09	3.631E-09	2.099E-09	1.385E-09
WNW	1.032E-06	3.107E-07	1.314E-07	7.650E-08	5.140E-08	2.396E-08	8.138E-09	3.554E-09	2.056E-09	1.356E-09
NW	9.661E-07	2.910E-07	1.230E-07	7.164E-08	4.814E-08	2.244E-08	7.623E-09	3.328E-09	1.923E-09	1.268E-09
NNW	1.080E-06	3.255E-07	1.376E-07	8.008E-08	5.378E-08	2.505E-08	8.492E-09	3.701E-09	2.138E-09	1.410E-09
N	1.234E-06	3.719E-07	1.574E-07	9.174E-08	6.169E-08	2.880E-08	9.811E-09	4.296E-09	2.490E-09	1.646E-09
NNE	1.510E-06	4.550E-07	1.929E-07	1.125E-07	7.573E-08	3.542E-08	1.210E-08	5.309E-09	3.080E-09	2.037E-09
NE	1.369E-06	4.113E-07	1.738E-07	1.012E-07	6.797E-08	3.170E-08	1.078E-08	4.717E-09	2.732E-09	1.806E-09
ENE	1.252E-06	3.755E-07	1.585E-07	9.217E-08	6.190E-08	2.886E-08	9.325E-09	4.305E-09	2.497E-09	1.651E-09
E	1.234E-06	3.701E-07	1.561E-07	9.071E-08	6.088E-08	2.836E-08	9.634E-09	4.214E-09	2.440E-09	1.613E-09
ESE	1.038E-06	3.109E-07	1.306E-07	7.574E-08	5.072E-08	2.353E-08	7.939E-09	3.453E-09	1.993E-09	1.314E-09
SE	8.370E-07	2.515E-07	1.058E-07	6.139E-08	4.112E-08	1.907E-08	6.428E-09	2.790E-09	1.607E-09	1.058E-09
SSE	5.373E-07	1.619E-07	6.841E-08	3.982E-08	2.675E-08	1.247E-08	4.231E-09	1.846E-09	1.067E-09	7.036E-10

TABLE B-5

Ground-Level Release — Flat Terrain

***** RELATIVE DEPOSITION PER UNIT AREA (MXX-2) AT FIXED POINTS BY DOWNWIND SECTORS *****												
DIRECTION FROM SITE	DISTANCES IN MILES											
	0.25	0.50	0.75	1.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50	
S	8.170E-09	2.763E-09	1.419E-09	8.711E-10	4.343E-10	2.634E-10	1.781E-10	1.290E-10	9.812E-11	7.730E-11	6.258E-11	
SSW	1.722E-08	5.822E-09	2.989E-09	1.835E-09	9.151E-10	5.550E-10	3.752E-10	2.719E-10	2.068E-10	1.629E-10	1.319E-10	
SW	3.005E-08	1.016E-08	5.218E-09	3.204E-09	1.597E-09	9.688E-10	6.550E-10	4.747E-10	3.609E-10	2.843E-10	2.302E-10	
WSW	3.970E-08	1.342E-08	6.893E-09	4.232E-09	2.110E-09	1.280E-09	8.652E-10	6.270E-10	4.767E-10	3.756E-10	3.041E-10	
W	3.550E-08	1.200E-08	6.164E-09	3.785E-09	1.887E-09	1.144E-09	7.737E-10	5.607E-10	4.263E-10	3.359E-10	2.719E-10	
WNW	3.121E-08	1.055E-08	5.418E-09	3.327E-09	1.659E-09	1.006E-09	6.802E-10	4.929E-10	3.748E-10	2.953E-10	2.390E-10	
NW	2.814E-08	9.516E-09	4.886E-09	3.000E-09	1.496E-09	9.072E-10	6.134E-10	4.445E-10	3.380E-10	2.663E-10	2.156E-10	
NNW	3.812E-08	1.289E-08	6.618E-09	4.064E-09	2.026E-09	1.229E-09	8.308E-10	6.020E-10	4.578E-10	3.606E-10	2.920E-10	
N	4.267E-08	1.443E-08	7.408E-09	4.549E-09	2.268E-09	1.375E-09	9.299E-10	6.739E-10	5.124E-10	4.037E-10	3.268E-10	
NNE	5.158E-08	1.744E-08	8.956E-09	5.500E-09	2.742E-09	1.663E-09	1.124E-09	8.147E-10	6.195E-10	4.881E-10	3.951E-10	
NE	5.335E-08	1.804E-08	9.262E-09	5.687E-09	2.835E-09	1.720E-09	1.163E-09	8.425E-10	6.407E-10	5.047E-10	4.086E-10	
ENE	4.959E-08	1.677E-08	8.610E-09	5.287E-09	2.636E-09	1.599E-09	1.081E-09	7.832E-10	5.955E-10	4.692E-10	3.798E-10	
E	5.365E-08	1.814E-08	9.314E-09	5.719E-09	2.851E-09	1.729E-09	1.169E-09	8.473E-10	6.442E-10	5.076E-10	4.109E-10	
ESE	5.227E-08	1.767E-08	9.075E-09	5.572E-09	2.778E-09	1.685E-09	1.139E-09	8.255E-10	6.277E-10	4.945E-10	4.003E-10	
SE	3.215E-08	1.087E-08	5.582E-09	3.427E-09	1.709E-09	1.036E-09	7.006E-10	5.077E-10	3.861E-10	3.041E-10	2.462E-10	
SSE	1.566E-08	5.294E-09	2.718E-09	1.669E-09	8.322E-10	5.047E-10	3.412E-10	2.473E-10	1.880E-10	1.481E-10	1.199E-10	

***** RELATIVE DEPOSITION PER UNIT AREA (MXX-2) BY DOWNWIND SECTORS *****												
DIRECTION FROM SITE	DISTANCES IN MILES											
	5.00	7.50	10.00	15.00	20.00	25.00	30.00	35.00	40.00	45.00	50.00	
S	5.177E-11	2.537E-11	1.592E-11	8.045E-12	4.869E-12	3.265E-12	2.339E-12	1.757E-12	1.366E-12	1.091E-12	8.905E-13	
SSW	1.091E-10	5.345E-11	3.354E-11	1.695E-11	1.026E-11	6.880E-12	4.930E-12	3.702E-12	2.878E-12	2.299E-12	1.876E-12	
SW	1.904E-10	9.331E-11	5.855E-11	2.959E-11	1.791E-11	1.201E-11	8.605E-12	6.462E-12	5.024E-12	4.013E-12	3.276E-12	
WSW	2.515E-10	1.233E-10	7.734E-11	3.909E-11	2.366E-11	1.586E-11	1.137E-11	8.535E-12	6.636E-12	5.301E-12	4.327E-12	
W	2.249E-10	1.102E-10	6.916E-11	3.496E-11	2.116E-11	1.419E-11	1.016E-11	7.633E-12	5.935E-12	4.741E-12	3.869E-12	
WNW	1.977E-10	9.689E-11	6.080E-11	3.073E-11	1.860E-11	1.247E-11	8.935E-12	6.710E-12	5.217E-12	4.167E-12	3.401E-12	
NW	1.783E-10	8.738E-11	5.482E-11	2.771E-11	1.677E-11	1.125E-11	8.058E-12	6.051E-12	4.704E-12	3.758E-12	3.067E-12	
NNW	2.415E-10	1.183E-10	7.426E-11	3.753E-11	2.272E-11	1.523E-11	1.091E-11	8.195E-12	6.372E-12	5.090E-12	4.155E-12	
N	2.703E-10	1.325E-10	8.312E-11	4.201E-11	2.543E-11	1.705E-11	1.222E-11	9.173E-12	7.133E-12	5.698E-12	4.650E-12	
NNE	3.268E-10	1.602E-10	1.005E-10	5.079E-11	3.074E-11	2.061E-11	1.477E-11	1.109E-11	8.623E-12	6.888E-12	5.622E-12	
NE	3.380E-10	1.656E-10	1.039E-10	5.253E-11	3.179E-11	2.132E-11	1.527E-11	1.147E-11	8.918E-12	7.124E-12	5.815E-12	
ENE	3.142E-10	1.540E-10	9.660E-11	4.883E-11	2.955E-11	1.981E-11	1.420E-11	1.066E-11	8.290E-12	6.622E-12	5.405E-12	
E	3.399E-10	1.666E-10	1.045E-10	5.282E-11	3.197E-11	2.144E-11	1.536E-11	1.153E-11	8.968E-12	7.164E-12	5.847E-12	
ESE	3.312E-10	1.623E-10	1.013E-10	5.147E-11	3.115E-11	2.089E-11	1.497E-11	1.124E-11	8.738E-12	6.980E-12	5.697E-12	
SE	2.037E-10	9.981E-11	6.263E-11	3.165E-11	1.916E-11	1.285E-11	9.205E-12	6.912E-12	5.374E-12	4.293E-12	3.504E-12	
SSE	9.920E-11	4.861E-11	3.050E-11	1.542E-11	9.331E-12	6.256E-12	4.483E-12	3.366E-12	2.617E-12	2.091E-12	1.707E-12	

***** RELATIVE DEPOSITION PER UNIT AREA (MXX-2) BY DOWNWIND SECTORS *****												
DIRECTION FROM SITE	SEGMENT BOUNDARIES IN MILES											
	0-1	1-2	2-3	3-4	4-5	5-10	10-20	20-30	30-40	40-50		
S	1.474E-09	4.554E-10	1.812E-10	9.902E-11	6.294E-11	2.703E-11	8.383E-12	3.322E-12	1.774E-12	1.098E-12		
SSW	3.106E-09	9.596E-10	3.818E-10	2.087E-10	1.326E-10	5.696E-11	1.766E-11	7.001E-12	3.739E-12	2.314E-12		
SW	5.422E-09	1.675E-09	6.666E-10	3.642E-10	2.315E-10	9.944E-11	3.084E-11	1.222E-11	6.526E-12	4.040E-12		
WSW	7.162E-09	2.213E-09	8.804E-10	4.811E-10	3.058E-10	1.314E-10	4.073E-11	1.614E-11	8.621E-12	5.336E-12		
W	6.404E-09	1.979E-09	7.874E-10	4.303E-10	2.735E-10	1.175E-10	3.642E-11	1.444E-11	7.709E-12	4.772E-12		
WNW	5.630E-09	1.739E-09	6.921E-10	3.782E-10	2.404E-10	1.033E-10	3.202E-11	1.269E-11	6.777E-12	4.195E-12		
NW	5.077E-09	1.569E-09	6.242E-10	3.411E-10	2.168E-10	9.311E-11	2.887E-11	1.144E-11	6.111E-12	3.783E-12		
NNW	6.876E-09	2.124E-09	8.454E-10	4.620E-10	2.936E-10	1.261E-10	3.911E-11	1.550E-11	8.277E-12	5.123E-12		
N	7.697E-09	2.378E-09	9.463E-10	5.171E-10	3.287E-10	1.412E-10	4.378E-11	1.735E-11	9.265E-12	5.735E-12		
NNE	9.306E-09	2.875E-09	1.144E-09	6.252E-10	3.974E-10	1.707E-10	5.293E-11	2.098E-11	1.120E-11	6.934E-12		
NE	9.624E-09	2.973E-09	1.183E-09	6.466E-10	4.109E-10	1.765E-10	5.474E-11	2.169E-11	1.158E-11	7.170E-12		
ENE	8.946E-09	2.764E-09	1.100E-09	6.010E-10	3.820E-10	1.641E-10	5.088E-11	2.017E-11	1.077E-11	6.665E-12		
E	9.678E-09	2.990E-09	1.190E-09	6.502E-10	4.132E-10	1.775E-10	5.504E-11	2.182E-11	1.165E-11	7.211E-12		
ESE	9.429E-09	2.913E-09	1.159E-09	6.335E-10	4.026E-10	1.729E-10	5.363E-11	2.126E-11	1.135E-11	7.026E-12		
SE	5.799E-09	1.792E-09	7.130E-10	3.896E-10	2.476E-10	1.064E-10	3.298E-11	1.307E-11	6.981E-12	4.321E-12		
SSE	2.825E-09	8.727E-10	3.473E-10	1.898E-10	1.206E-10	5.181E-11	1.606E-11	6.367E-12	3.400E-12	2.104E-12		

TABLE B-6

Ground-Level Release — Flat Terrain
Specific Points of Interest

RELEASE ID	TYPE OF LOCATION	DIRECTION	DISTANCE		X/Q	X/Q	X/Q	D/Q
			(MILES)	(METERS)	(SEC/CUB.METER)	(SEC/CUB.METER)	(SEC/CUB.METER)	
					NO DECAY	2.260 DAY DECAY	8.000 DAY DECAY	
					UNDEPLETED	UNDEPLETED	DEPLETED	
C	L-STK TO SRP BZ	SSE	5.80	9334.	2.467E-08	2.426E-08	1.792E-08	7.585E-11
C	L-STK TO SRP BZ	SE	6.17	9930.	3.463E-08	3.407E-08	2.493E-08	1.392E-10
C	L-STK TO SRP BZ	ESE	6.92	11137.	3.630E-08	3.573E-08	2.580E-08	1.844E-10
C	L-STK TO SRP BZ	E	8.24	13261.	3.432E-08	3.365E-08	2.370E-08	1.432E-10
C	L-STK TO SRP BZ	ENE	8.79	14146.	3.195E-08	3.130E-08	2.182E-08	1.193E-10
C	L-STK TO SRP BZ	NE	10.54	16963.	2.734E-08	2.666E-08	1.807E-08	9.528E-11
C	L-STK TO SRP BZ	NNE	13.12	21115.	2.276E-08	2.207E-08	1.441E-08	6.384E-11
C	L-STK TO SRP BZ	N	12.86	20696.	1.895E-08	1.843E-08	1.206E-08	5.463E-11
C	L-STK TO SRP BZ	NNW	12.02	19344.	1.801E-08	1.751E-08	1.151E-08	5.469E-11
C	L-STK TO SRP BZ	NW	10.66	17156.	1.907E-08	1.851E-08	1.256E-08	4.933E-11
C	L-STK TO SRP BZ	WNW	9.73	15659.	2.307E-08	2.248E-08	1.546E-08	6.359E-11
C	L-STK TO SRP BZ	W	7.75	12472.	3.233E-08	3.166E-08	2.254E-08	1.046E-10
C	L-STK TO SRP BZ	WSW	8.13	13084.	2.955E-08	2.896E-08	2.045E-08	1.083E-10
C	L-STK TO SRP BZ	SW	7.83	12601.	2.622E-08	2.566E-08	1.825E-08	8.711E-11
C	L-STK TO SRP BZ	SSW	7.59	12215.	1.577E-08	1.545E-08	1.103E-08	5.245E-11
C	L-STK TO SRP BZ	S	6.01	9672.	1.359E-08	1.332E-08	9.810E-09	3.711E-11

VENT AND BUILDING PARAMETERS:

RELEASE HEIGHT (METERS) 0.0
DIAMETER (METERS) 0.0
EXIT VELOCITY (M/SEC) 0.0

REP. WIND HEIGHT (METERS) 10.0
BUILDING HEIGHT (METERS) 0.0
BLDG.MIN.CRS.SEC.AREA (SQ.METERS) 0.0
HEAT EMISSION RATE (CAL/SEC) 0.0

AT THE RELEASE HEIGHT:

VENT RELEASE MODE WIND SPEED (METERS/SEC)

ELEVATED	LESS THAN	0.0	
MIXED	BETWEEN	0.0	AND 0.0
GROUND LEVEL	ABOVE	0.0	

AT THE MEASURED WIND HEIGHT (62.0 METERS):

VENT RELEASE MODE WIND SPEED (METERS/SEC)

ELEVATED	LESS THAN	0.0	
MIXED	BETWEEN	0.0	AND 0.0
GROUND LEVEL	ABOVE	0.0	

WIND SPEED (METERS/SEC)

UNSTABLE/NEUTRAL CONDITIONS	
LESS THAN	0.0
BETWEEN	0.0 AND 0.0
ABOVE	0.0

REFERENCES FOR APPENDIX B

1. Sagendorf, J. F. and Goll, J. T., "XOQDOQ Program for the Meteorological Evaluation of Routine Effluent Releases at Nuclear Power Stations." NUREG-0324 (Draft), U.S. Nuclear Regulatory Commission, Washington, DC (September 1977).
2. "Methods for Estimating Atmospheric Transport and Dispersion of Gaseous Effluents in Routine Releases from Light-Water-Cooled Reactors." Regulatory Guide 1.111 (Rev. 1), U.S. Nuclear Regulatory Commission, Washington, DC (July 1977).
3. "Onsite Meteorological Programs." Regulatory Guide 1.23 (Safety Guide 23), U.S. Nuclear Regulatory Commission, Washington, DC.

APPENDIX C

DOSE METHODOLOGY FOR ROUTINE RELEASES OF RADIOACTIVITY TO ATMOSPHERE

The Nuclear Regulatory Commission's computer code, GASPAR,¹ has been utilized to calculate the potential annual doses from routine operations in Section 5.1.1.1. The GASPAR code implements the air-release dose models of NRC Regulatory Guide 1.109,² assuming an operating lifetime of 30 years (the default option in the code). The calculated annual dose may be regarded either as an average annual dose during the operating lifetime or a 15-year Environmental Dose Commitment³ per year of operation. The former interpretation, which is implied by the regulatory guide, has been used in Section 5.1.1.1.

The dose factor library used in these GASPAR-code calculations is that described in Appendix C of NUREG/CR-1276.⁴ For the inhalation and ingestion pathways, this incorporates the age-specific 50-year dose commitment factors of Hoennes and Soldat (NUREG-0172)⁴ with NRC-approved corrections in actinide factors.

For the doses to the 50-mile population, the input data to the GASPAR code has been indicated under Section 5.1.1.1.2 of the main text. More specifically, this consists of the data presented in Tables 5.1-1 and 5.1-3, and the compass-sector segment $\bar{X}$ and $\frac{D}{Q}$ values shown in Appendix B. In addition, the absolute humidity during the growing season was taken to be 11.7 g/m³, an average daytime value derived from Tables 2.4-2 and 2.4-3, which was also utilized in the individual dose calculations.

For the doses to the maximally-exposed individuals, the χ OQDOQ code (Appendix B) and the GASPAR code were combined in a computer procedure to determine the doses at the location of maximum whole-body dose rates (mrem/yr) along the SRP buffer-zone boundary (the SRP site inclusive of the shaded areas in Figure 2.1-2). The necessary $\bar{X}$ and $\frac{D}{Q}$ values for the multipoint releases were generated internal to the procedure and are too numerous to tabulate here. However, a subset of the $\bar{X}$ and $\frac{D}{Q}$ values for releases from L Area has been shown in Table B-6 of Appendix B. The other input data consists of that in Tables 5.1-1 and 5.1-2 of the main text.

REFERENCES FOR APPENDIX C

1. Eckerman, K. F., et al., "User's Guide to GASPAR Code." NUREG-0597, U.S. Nuclear Regulatory Commission, Washington, DC (June 1980).
2. "Calculation of Annual Doses to Man from Routine Releases of Reactor Effluents for the Purpose of Evaluating Compliance with 10 CFR 20, Appendix I." USNRC Regulatory Guide 1.109, Revision 1, U.S. Nuclear Regulatory Commission, Washington, DC (1977).
3. "Environmental Radiation Dose Commitment: An Application to the Nuclear Power Industry." EPA-520/4-73-002, U.S. Environmental Protection Agency, Washington, DC (February 1974).
4. D. B. Simpson and B. L. McGill. Users Manual for LADTAP II — A Computer Program for Calculating Radiation Exposure to Man from Routine Release of Nuclear Reactor Liquid Effluents. NUREG/CR-1276, ORNL/NUREG/TDMC-1, Oak Ridge National Laboratory, Oak Ridge, TN (1980).
5. Age Specific Radiation Dose Commitment Factors for a One-Year Chronic Intake. USNRC Report NUREG-0172, Battelle Pacific Northwest Laboratories, Richland, WA (1977).

APPENDIX D

MOVEMENT OF CESIUM-137 FROM STEEL CREEK

Part I: Transport

Part II: Cesium-137 Dose Estimates

Part III: Hot Water Desorption

Part IV: Creek Plantation Swamp — Background Radiation

PART I

I. TRANSPORT

I.1 Transport of Cesium-137 From Steel Creek

I.1.1 Cesium-137 Distribution in Steel Creek Sediment

Cesium-137 is strongly associated with sediments and suspended solids. The principal mechanisms for this association are cation exchange with clay minerals, chelation with naturally occurring organics and sorption. The intensity of this association is expressed using the concept of distribution coefficients, K_d . K_d is the ratio of the equilibrium concentrations in solid to solution phases on an equal weight basis. A distribution coefficient of 3960, measured for sediments from Four Mile and Steel Creeks, shows that cesium-137 has a strong affinity for sediments in these systems.¹

The cesium-137 concentration distributions in Steel Creek decrease with depth and about 55% or 78 Ci of the estimated inventory is in the upper 10 cm of sediment (Table 2.7-5).² The deposition pattern is complex and differences between sediment cores one meter apart can vary as much as 190%.² In the Savannah River wetlands below SRP, the Creek Plantation, 70% of the cesium-137 is in the upper 6 cm.³ The differences between Steel Creek and Creek Plantation are probably due to different types of depositing environments. The Creek Plantation is only flooded during the high stages of the river, and in these wetlands, the water velocities are slow, particle size is smaller, little scour or rework of the sediments occurs and deposition rates are less than in Steel Creek.

The cesium-137 decreases exponentially with depth in the SCL Bridge-Steel Creek delta region and is described by the equation, $Y = 615.4 \cdot X^{-1.2}$, where X is depth in cm and Y is in pCi/g.² This distribution was derived using average cesium-137 concentrations centered on the midpoint of the depth sampling interval, (Figure D-1 and Table D-1). The equation transforms to $\log(Y/615.4) = -1.2 \cdot \log X$ and will plot as a straight line on log-log paper with a slope of -1.2 (Figure D-1). This distribution indicates the highest cesium-137 concentrations are found in the surface sediments, and the concentration at the 1 cm depth may be as high as 615 pCi/g. Using a visual classification index for sediment size, the fine (silt and clay) and coarse (sand) fractions had cesium-137 concentrations of 170.5 and 18.1 pCi/g, respectively.² The fine fraction represents about 36% of the sediment but contains greater than 80% of the activity $(100 \cdot 170.5 \cdot 0.36)/(170.5 \cdot 0.36 + 18.1 \cdot 0.64)$.

FIGURE D-1. Cesium-137 Distribution with Sediment Depth

TABLE D-1

Distribution of Cesium-137 Inventory in Sediments of Steel Creek

<u>Depth Interval, cm</u>	<u>Mean Conc., pCi/gm</u>	<u>% of Total Cs-137 Inventory in Interval</u>	<u>Inventory in that Interval, Ci</u>
0-10	93.5	55	78
11-20	24.5	14	20
21-30	15.1	9	13
31-40	13.0	8	11
41-50	7.1	4	6
51-60	3.8	2	3
61-70	3.4	2	3
71-80	4.0	2	3
81-90	3.3	2	3
91-100	2.1	<u>1</u>	<u>2</u>
Total		100	142 *

* A 142 Ci Cs-137 inventory is calculated to be in the Steel Creek system below L Area. About 88.8% of the Steel Creek flood plain area is below the L Area outfall ($0.888 \times 160 = 142$ Ci).

I.2 Cesium-137 Concentration in Suspended Solids

Although no direct measurements have been made on the concentration of cesium-137 in suspended solids in Steel Creek, estimates of the cesium-137 concentration in suspended solids may be made from data on a P-Area water diversion and on distribution of cesium-137 in sediments in the SCL Bridge-Steel Creek delta region (Figure D-2).

Because of the strong association of cesium-137 with sediment, $K_d = 3960$, it may be assumed that the cesium-137 in a water sample is associated with the suspended solids.¹ Cesium-137 concentrations of 1200 ± 716 pCi/g were calculated using measured suspended solids and cesium-137 concentration data in Steel Creek water (Table D-2) from a P-Area cold water diversion.

The readily transportable fraction of sediment is the silt and clays and these make up about 36% of the sediment in the SCL Bridge-Steel Creek delta region (Figure D-2). By assuming that all of the cesium-137 in the 0-10 cm depth interval is only in this fraction, a suspended solids concentration of cesium-137 would be about 260 pCi/g ($93.5 \text{ pCi/g} \div 0.36 = 260 \text{ pCi/g}$). This estimate is slightly higher than the visually-sized fine sediment concentration of 170 pCi/g.

The 1200 pCi/g estimate for suspended sediments is assumed to be the most representative value for transport calculations because it represents what was transported by the stream and includes the soluble cesium-137 that is associated with the sediment transport.

I.3. Suspended Sediment Transport

The silt and clay fraction after it is resuspended is referred to as washload. The washload is distributed fairly uniformly from the surface to the bottom of the stream. The sand fraction, referred to as bedload, is transported near the bottom.^{4,5} The washload fraction is more likely to be transported offsite.

The relation between waterflow and washload is affected by many variables such as gradation of bed material, depth of transportable material, and other sediment and hydraulic variables.⁶ The coupling of these variables in modern transport models could give further insight into the transport process, but the use of models for the present study is limited by the lack of time to develop sufficient information on: coupling of bedload to washload models, parameterization of the aforementioned variables for the Steel Creek system, and a scenario to describe Steel Creek

FIGURE D-2. Steel Creek Area

TABLE D-2

Cesium-137 Concentration in Suspended Solids in Steel Creek*

Concentration of Suspended Solids, mg/L	Concentration of Cs-137, pCi/L	Concentration in Suspended Solids, pCi/gm
10	16	1600
54	25	463
34	21	618
19	12	632
18	10	556
6	19	3166
7	11	1571
7	10	1429
12	11	917
12	9	750
7	12	1714
12	21	1750
11	8	727
8	11	1375
14	10	714
Avg 1199 $\pm$ 716 pCi/gm		

* The cesium-137 and suspended solids concentration data were selected from data on the effect of a P-Area cold water discharge to Steel Creek, November 1980. Since only erosion sources of cesium-137 were to be used, only the data from Road B and below and during and after the diversion, 11/10-24/80, were considered. Only cesium-137 concentrations greater than 7 pCi/L were considered to be analytically reliable. One sample at Road A-14, 11/10/80, was not used because of sand contamination (80 mg/L, 14 pCi/L).

erosion following release of hot water. In addition and more importantly, no way exists to verify the model without actually releasing hot water at full flow to the creek.

Most studies have shown that the suspended sediment discharged or eroded in upper reaches of SRP streams is deposited prior to reaching the wetlands.⁷⁻⁹ Measurements on Four Mile and Pen Branch show that SRP reactor streams have suspended solids concentrations similar to the Savannah River except during the cleaning of 25-million-gallon cooling water basins and heavy rains. Measurements at the hot water outfalls were 7 and 5 mg/L and immediately above the swamp the concentrations were 3 and 5 mg/L, respectively. Environmental monitoring and other water quality data indicate that rarely do suspended solids concentrations exceed 150 mg/L in streams in South Carolina.¹⁰

I.4. Cesium-137 Transport by Suspended Sediments

It is assumed that sediment transport will follow a two-step process analogous to storm runoff: (1) initial resuspension of loosely held sediment and (2) a steady transport of suspended solids comparable to Savannah River concentrations, but whose cesium-137 concentrations have come in equilibrium with the concentration of cesium-137 in the Steel Creek sediments through a continuous process of deposition and resuspension.

Only one study could be identified that could be used to approximate the effects of L-Reactor startup on sediment cesium-137 transport could be identified. In November 1980, a study on the effects of a three-day diversion of 32,000 gpm of P-Area water to Steel Creek on the transport of cesium-137 concentrations were increased about a factor of 10 above the normal value of 5 mg/L due to stream bed erosion near P Area. These increased concentrations were reduced to background levels six miles downstream of P Area. No significant changes in cesium-137 concentrations were measured at the point where Steel Creek water flows into the Savannah River wetlands region.

The suspended solids to be transported offsite following L-Reactor startup were assumed to follow the suspended solids-time distribution measured at Road B in the November 1980, P-Area water diversion. The suspended solids concentration peaked at 54 mg/L the day of the diversion and decreased exponentially to a background level in about 11 days, Table D-3.

To calculate the total cesium-137 transport, the Road B data were fitted with an exponential function, then integrated to give the daily and 11-day cesium-137 releases. A correlation coefficient of 0.9 was calculated using an exponential representation of

TABLE D-3

Data Table and Equation Estimation for Suspended Solids Release During Startup. Based on Road B Data

Date	Days (X)	Suspended Solids* Concentration, mg/L (Y)	Calculated Value Using Equation Below, mg/L
Nov. 11	0	69	50
12	1	49	44
13	2	34	41
14**	3	33	37
17	6	19	27
20	9	21	20
24	13	16	13

* a) Data fitted with $y = ae^{-bx}$

Estimated coefficients $a = 46.66 \quad 1.15$
 $b = -0.10078 \pm 0.022$
 Correlation coefficient $cc = -0.90$

b) The values were increased by 15 mg/L to adjust for suspended solids load from the Savannah River.

** Diversion ended on November 13, 1980.

the data: $y = 46.6 e^{-0.10078X}$; where y equals suspended solids concentration in mg/L and x equals time in days.

To estimate the cesium-137 transport during the initial startup, the equation was integrated,

$$y = 463 \left[e^{-0.10078X_1} - e^{-0.10078X_2} \right]$$

Using a cesium-137 suspended solids concentration of 1200 pCi/g and a daily flow of 450 cfs (1.1×10^9 L/day), the transport was calculated to be about 0.46 Ci/12 days, Figure D-3, Table D-4. For the steady flow cesium-137 transport after the first 11 days, it is assumed that the suspended solids concentrations will be equal to that supplied to it from the Savannah River and that it will have equilibrated with the silt and clay sources in Steel Creek to a cesium-137 concentration of 1200 ± 716 pCi/g. The average concentration of suspended solids in the Savannah River in 1979 was 15 ± 8 mg/L.¹⁰ The average annual transport would be 7.2 ± 4.4 Ci/yr, (0.015 g/L $\cdot 4 \times 10^{11}$ L/yr $\cdot 1200 \pm 716$ pCi/g $\cdot 1 \times 10^{-12}$ Ci/pCi).

The cesium-137 transported annually that is associated with suspended solids would be about 7.7 Ci/yr ($7.2 + 0.46$ Ci from initial resuspension) for the first year and about 7.2 Ci/yr for the second year.

I.5. Desorptive Transport of Cesium-137 in Steel Creek

Hot water desorption of cesium-137 from the sediments will occur following L-Reactor startup. Beginning in early June 1976, and until the end of that month, about 40,000 gpm of hot water, approximately 70°C, was diverted to Steel Creek from P Area. Cesium-137 concentrations and cesium-137 transport increased at SC 5, about eight miles downstream, during this diversion (Figure D-4). The cesium-137 concentration at SC 5 peaked within two weeks after the start of the diversion and decreased exponentially to a background level in about three months. To estimate the hot water cesium-137 transport, the SC 5 data were fitted with an exponential function, then integrated to give monthly cesium-137 transport values.

A correlation coefficient of 0.94 was calculated using an exponential representation of the data: $Y = 41.15e^{-0.7436X}$, where X equals time in days and Y equals the cesium-137 concentration (Table D-5). To estimate the cesium-137 transport due to hot water effects, the above equation was integrated,

$$y = 55.3 \left[e^{-0.7436X_1} - e^{-0.7436X_2} \right] \text{ and a flow of } 1.1 \times 10^9$$

L/day was used. A laboratory experiment with sediments from Steel Creek confirmed that higher water temperatures extract more cesium-137 than ambient temperatures (Part III, this Appendix).

FIGURE D-3. Estimate of Cesium-137 Transport Offsite from Suspended Solids Following L-Reactor Startup

TABLE D-4
Estimated Cesium-137 Releases Due to Sediment Transport

<u>Day</u>	<u>Resuspension* Transport, Ci/day</u>
1	0.062
2	0.056
3	0.051
4	0.046
5	0.042
6	0.038
7	0.034
8	0.031
9	0.028
10	0.025
11	0.023
12	0.021
13	0.0198**

Continuing

* Estimated using equation in Table D-3 and a flow of 450 cfs.

** Based on a steady supply of 15 mg/L of suspended sediments
from the Savannah River and re-equilibration with streambed

FIGURE D-4. Cesium-137 at SC 5 * Flow

TABLE D-5

Data Table and Equation Estimation for Hot Water Desorption
of Cesium-137 from Steel Creek Sediments

Date	Days (X)	Concentration Cs-137 pCi/L*	Background Cs-137 pCi/L(Y)	Calculated** Value, Cs-137 pCi/L
May 10		13		
17		4		
24		13		
June 1		14		
7		12		
<hr/>				
11 ±4 Background Cesium-137 Concentration				
June 14	0	42	31	41
21	7	47	36	34
28	14	59	39	28
July 6	22	27	16	23
12	28	26	15	20
19	35	31	20	16
26		-	-	-
Aug. 2	49	25	14	11
9		15	(4)†	-
16	63	20	9	8
23	70	17	6	6
30	77	18	7	5
Sept. 7	85	18	7	4
13	91	13	2	4
20	98	16	5	3
27	105	14	3	2
Oct. 4	112	12	1	2

* Removal of 11 pCi/L from data in Column 1.

** Data fitted with $y = ae^{-bx}$

Estimated Coefficients $a = 41.31 \pm 1.21$
 $b = 0.026563 \pm 0.0028$
 Correlation Coefficient $cc = 0.93$

† Deleted from fitting equation

The estimated transport in the first year would be about 1.7 Ci/yr (Figure D-5 and Table D-6) due to cesium-137 being desorbed from the sediments.

I.6. Transport of Cesium-137 in Biota

Only about 0.4 Ci of cesium-137 is in the biota on the Steel Creek flood plain. The hot water would be expected to kill this biota in the first year of operation of L Reactor and cause it to be transported offsite.

I.7. Summary of Cesium-137 Transport

The total amount of cesium-137 that is anticipated to be transported from Steel Creek during the first year of L-Reactor operation is about 9.8 Ci and this is expected to decrease to about 7.2 Ci in the second year, Table 5.1-21. The 2.6 Ci decrease the second year is due to the assumptions that hot water will no longer desorb cesium-137 from the sediments, there is no more cesium-137 to be contributed from vegetation, and that the initial flush of loose sediments is over.

The delivery of this cesium-137 to the Savannah River will depend on the river stage. At river stages greater than 91 feet (15,500 cfs), the swamp or river wetlands are flooded. During flooding, SRP streams travel in the swamp, across Creek Plantation Swamp, and then into the Savannah River at Little Hell Landing at river mile 134. Based on past experience, cesium-137 is deposited in the swamp during these flooded conditions, therefore reducing the amount of cesium-137 transported to the river.³ The Savannah River floods an average of 23% of the time.

I.8. Cesium-137 Concentration in the Savannah River

The cesium-137 concentrations in the Savannah River may increase a factor of 90 and a factor of more than two in Steel Creek, Table 5.1-22. The cesium-137 concentration estimates for the Savannah River were calculated for an expected minimum flow of 6100 cfs. This flow of 6100 cfs is likely for one year during the time that Richard B. Russel reservoir is filling (beginning 6/83). This flow is about 4,000 cfs less than the average flow of 10,200 cfs. However, these anticipated cesium-137 concentrations in the river (1.8 pCi/L highest) do not exceed previous cesium-137 concentrations of about 2.7 pCi/L measured in the mid 1960's (Table D-14). Using an assumed 20% annual decrease in cesium-137 transport from Steel Creek, a year beginning in FY-1986, the

FIGURE D-5. Transport of Cesium-137 from Hot Water Desorption of Cesium-137 from Steel Creek Sediment.

TABLE D-6

Estimated Releases Due to Cesium-137 Desorption from
Steel Creek Sediments

<u>Months*</u>	<u>Amount Released</u> <u>Ci/month</u>
1	0.949
2	0.423
3	0.188
4	0.839
5	0.0374
6	0.0167
7	0.0074
8	0.0033
9	0.0015
10	0.0007
11	0.0003
12	<u>0.0001</u>
Total	1.71 Ci

* 30.44 days/month (365.25/12)

cesium-137 concentration in the river would decrease to about 0.2 pCi/L in FY-1993 (Figure D-6 and Table 5.1-24). If cesium-137 transport decreases more rapidly than assumed, then the cesium-137 concentration in the river will decrease proportionally. Information is not available to accurately estimate reduction in releases at the present time. The expected cesium-137 concentration in the river would decrease about 23% if the Creek Plantation swamp was flooded annually based on the historic annual flooding frequency of 23%.

FIGURE D-6. Expected Cesium-137 Concentration in the Savannah River, pCi/L

6100 cfs - 9.8 Ci, 1984
7.2 Ci, 1985

PART II

II. CESIUM-137 DOSE ESTIMATES

II.1 Methods and Results

The estimated doses and supporting information for all cesium-137 cases given in Table 5.1-22 are contained in Tables D-7 through D-13. The maximum individual whole body dose* from SRP operations would increase from 1.8 mrem/yr to 10.7 mrem/yr [(principally from the consumption of fish (Table 5.1-23))]. The cesium-137 maximum adult individual whole body dose addition from L-Reactor startup will be greater than that from current operations for the first seven years of operation.

These doses were computed using the Nuclear Regulatory Commission dose code, LADTAP II, for assessing effects of commercial nuclear power reactors,¹² and data necessary for the calculation are given in Tables 5.1-21 and D-13.

A concentration ratio factor (cesium-137 concentration of fish/cesium-137 concentration of water) of 3000 was used to estimate the cesium-137 concentration in fish. The factor was obtained using SRP Health Protection Monitoring Data on water and fish measurements. The data from 1965 to 1971 were chosen for evaluation of the concentration factor. This period had easily measurable levels of cesium-137 in both fish and water (Table D-14). Prior to 1965, there were inconsistencies in measurement and after 1971, cesium-137 concentrations were near or below detection. Both the geometric mean and a linear regression technique were used to compute the average concentration factor. The geometric mean was calculated to minimize the effect of large and small outlying values (Table D-14). The linear regressed computation was made to minimize the yearly variations.

* Whole body dose was used instead of individual organ doses because health and genetic effects are usually estimated from whole body doses. The discussion will use only this term, but individual organ doses, doses to teenagers and infants are included in Tables D-8 through D-11.

TABLE D-7

Liquid Releases Dose Summary

LADTAP II
New DOSE FACTOR LIBRARY

L Restart

9.8 Ci Cs-137

First Year - No deposition

on Creek Plantation

	ORGAN DOSE COMMITMENT							
	Skin	Bone	Liver	Body	Thyroid	Kidney	Lung	G.I.-LLI
Max. Individual, mrem								
adult	1.11E-2	9.14E 0	1.25E 1	8.19E 0	9.60E-3	4.25E 0	1.42E 0	2.51E-1
teen	3.72E-2	9.80E 0	1.30E 1	4.56E 0	3.20E-3	4.45E 0	1.75E 0	2.17E-1
child	2.78E-3	1.25E 1	1.19E 1	1.77E 0	6.74E-3	3.90E 0	1.41E 0	8.15E-2
infant	—	3.10E-1	3.62E-1	2.57E-2	0.0	9.73E-2	3.94E-2	1.13E-3
Population, man-rem								
Port Wentworth	—	1.55E 0	2.11E 0	1.38E 0	0	7.18E-1	2.39E-1	4.09E-2
Beaufort-Jasper	—	2.98E 0	3.54E 0	1.60E 0	0	1.18E 0	4.10E-1	5.08E-2
Fish-sport	—	4.98E 1	6.25E 1	3.24E 1	0	2.11E 1	7.25E 0	1.01E 0
Fish-commercial	—	1.77E 0	2.22E 0	1.15E 0	0	7.49E-1	2.58E-1	3.59E-2
Salt Water Invert	—	7.29E-4	9.12E-4	4.70E-4	0	3.07E-4	1.06E-4	1.47E-5
Recreation	1.11E-1	—	—	9.60E-2	9.60E-2	—	—	—
Total	1.11E-1	5.61E 1	7.04E 1	3.65E 1	9.60E-2	2.37E 1	8.16E 0	1.14E 0

Year: 1990-2020

50-Mile-Radius population: 781,000

Beaufort-Jasper Population: 40,333

Port Wentworth Population: 29,167

River Flow Rate: 6100 cfs

Pathway	Adult-Total Body, mrem/yr
Fish	8.09
Drinking Water	0.094
Shoreline	0.0095
Swimming	0.000018
Boating	0.000054

TABLE D-8

Liquid Releases Dose Summary

LADTAP II
New DOSE FACTOR LIBRARY

1980 Releases Ci

Current

H²O 27000.0
⁶⁰Co 0.002
⁹⁰Sr 0.4
¹²⁹I 0.02
¹³⁷Cs 0.19
²³⁸U 0.19
²³⁹Pu 0.006

SRP - 1980 Releases

ORGAN DOSE COMMITMENT

	<u>Skin</u>	<u>Bone</u>	<u>Liver</u>	<u>Body</u>	<u>Thyroid</u>	<u>Kidney</u>	<u>Lung</u>	<u>G.I.-LLI</u>
<u>Max. Individual, mrem</u>								
adult	2.32E-4	5.82E-1	6.32E-1	6.52E-1(1)	4.17E-1	4.77E-1	4.17E-1	4.18E-1
teen	7.78E-4	5.36E-1	5.28E-1	4.52E-1	2.89E-1	3.66E-1	3.09E-1	2.98E-1
child	1.63E-4	8.97E-1	7.51E-1	7.16E-1	5.32E-1	5.04E-1	5.46E-1	5.34E-1
infant	—	3.16E-1	5.10E-1	5.89E-1	5.20E-1	5.16E-1	5.04E-1	5.10E-1
<u>Population, man-rem</u>								
Port Wentworth	—	3.37E-0	5.65E-0	6.47E-0	5.90E-0	5.69E-0	5.61E-0	5.80E-0
Beaufort-Jasper	—	5.71E-0	8.19E-0	9.54E-0	8.46E-0	8.26E-0	8.13E-0	8.37E-0
Fish-sport	—	1.86E-0	1.26E-0	9.12E-1	7.86E-2	4.55E-1	1.85E-1	1.08E-1
Fish-commercial	—	6.62E-2	4.47E-2	3.24E-2	2.80E-3	1.62E-2	6.60E-3	3.86E-3
Salt Water Invert	—	1.13E-3	1.02E-4	3.73E-4	2.77E-4	1.02E-4	8.33E-5	1.39E-4
Recreation	2.32E-4	—	—	1.97E-3	1.97E-3	—	—	—
Total	2.32E-4	1.10E 1	1.51E 1	1.70E 1	1.44E 1	1.44E 1	1.39E 1	1.42E 1

Year: 1990-2020

50-Mile-Radius population: 781,000

Beaufort-Jasper Population: 40,333

Port Wentworth Population: 29,167

River Flow Rate: cfs, 6100

Concentration Factor Water to Fish ¹³⁷Cs = 3,000

* Isotope Contribution %

Fish ¹³⁷Cs - 73.2%; ⁹⁰Sr-22.2%; H²O-4.59%Drinking Water H²O -86.7%; ⁹⁰Sr-12.6%; ¹³⁷Cs-0.42%

(1) Pathway	Adult-Total Body, mrem/yr
Fish*	0.214
Drinking Water*	0.438
Shoreline	0.000197
Swimming	0.000000376
Boating	0.00000417
Total	0.652

TABLE D-9

Liquid Releases Dose Summary

LADTAP II
New DOSE FACTOR LIBRARY

L-Restart

7.6 Ci Cs-137

First Year with Cs-137

Deposition on Creek Plantation

	ORGAN DOSE COMMITMENT							
	<u>Skin</u>	<u>Bone</u>	<u>Liver</u>	<u>Body</u>	<u>Thyroid</u>	<u>Kidney</u>	<u>Lung</u>	<u>G.I.-I.I.</u>
<u>Max. Individual, mrem</u>								
adult	8.62E-3	7.09E-0	9.69E-0	6.35E-0 ⁽¹⁾	7.44E-0	3.29E-0	1.10E-0	1.95E-1
teen	2.98E-2	7.60E-0	1.01E1	3.53E-0	2.48E-2	3.45E-0	1.36E-0	1.68E-1
child	6.03E-3	9.67E-0	9.26E-0	1.37E-0	5.23E-3	3.02E-0	1.09E-0	6.32E-2
infant	—	2.40E-1	2.81E-1	1.99E-2	0	7.54E-2	3.05E-2	8.79E-4
<u>Population, man-rem</u>								
Port Wentworth	—	1.20E-0	1.64E-0	1.07E-0	0	5.57E-1	1.85E-1	3.17E-2
Beaufort-Jasper	—	2.31E-0	2.74E-0	1.24E-0	0	9.18E-1	3.18E-1	3.94E-2
Fish-sport	—	3.86E 1	4.85E 1	2.51E 1	0	1.63E 1	5.62E-0	7.82E-1
Fish-commercial	—	1.37E-0	1.73E-0	8.93E-1	0	5.81E-1	2.00E-1	2.78E-2
Salt Water Invert	—	5.65E-4	7.07E-4	3.65E-4	0	2.38E-4	8.20E-5	1.14E-5
Recreation	8.62E-2	—	—	7.45E-2	7.45E-2	—	—	—
Total		4.35E 1	5.46E 1	2.83E 1	7.45E-2	1.84E 1	6.32E-0	8.81E-1

Year: 1990-2020

50-Mile-Radius population: 781,000

Beaufort-Jasper Population: 40,333

Port Wentworth Population: 29,167

River Flow Rate: cfs, 6100

Cs-137 Concentration Factor for Fish = 3,000

(1) <u>Pathway</u>	<u>Adult-Total Body mrem/yr</u>
Fish	6.27
Drinking Water	0.073
Shoreline	0.0074
Swimming	0.0000139
Boating	0.0000418
Total	6.35

TABLE D-10

Liquid Releases Dose Summary

LADTAP II
New DOSE FACTOR LIBRARY

L Restart

7.2 Ci Cs-137

Second Year - No Cs-137

Deposition in Creek Plantation

	ORGAN DOSE COMMITMENT							
	<u>Skin</u>	<u>Bone</u>	<u>Liver</u>	<u>Body</u>	<u>Thyroid</u>	<u>Kidney</u>	<u>Lung</u>	<u>G.I.-ILL</u>
<u>Max. Individual, mrem</u>								
adult	8.17E-3	6.71E 0	9.18E 0	6.02E 0 ⁽¹⁾	7.05E-3	3.12E 0	1.04E 0	1.85E-1
teen	2.74E-2	7.20E 0	9.57E 0	3.35E 0	2.35E-2	3.27E 0	1.29E 0	1.59E-1
child	5.72E-3	9.16E 0	8.77E 0	1.30E 0	4.95E-3	2.86E 0	1.03E 0	5.99E-2
infant	—	2.27E-1	2.66E-1	1.89E-2	0	7.15E-2	2.89E-2	8.32E-4
<u>Population, man-rem</u>								
Port Wentworth	—	1.14E 0	1.55E 0	1.02E 0	0	5.27E-1	1.75E-1	3.01E-2
Beaufort-Jasper	—	2.19E 0	2.60E 0	1.18E 0	0	8.70E-1	3.01E-1	3.73E-2
Fish-sport	—	3.66E 1	4.59E 1	2.38E 1	0	1.55E1	5.32E 0	7.41E-1
Fish-commercial	—	1.30E 0	1.63E 0	8.46E-1	0	5.50E-1	1.89E-1	2.64E-2
Salt Water Invert	—	5.35E-4	6.70E-4	3.45E-4	0	2.26E-4	7.75E-5	1.08E-5
Recreation	8.17E-2	—	—	7.05E-2	7.05E-2	—	—	—
Total	8.17E-2	4.12E1	5.14E1	26.9E 2	7.05E-2	1.74E1	5.99	8.35E-1

Year: 1990-2020

50-Mile-Radius population: 781,000

Beaufort-Jasper Population: 40,333

Port Wentworth Population: 29,167

River Flow Rate: 6100 cfs

Concentration Factor Water to Fish ¹³⁷Cs = 3,000

(1) <u>Pathway</u>	<u>Adult-Total Body,</u> <u>mrem/yr</u>
Fish	5.94
Drinking Water	0.069
Shoreline	0.007
Swimming	0.000013
Boating	0.000040
Total	6.02

TABLE D-11

Liquid Releases Dose Summary

LADTAP II
New DOSE FACTOR LIBRARY

L Restart

5.5 Ci Cs-137

Second Year - With Cs-137

Deposition on Creek Plantation

	ORGAN DOSE COMMITMENT							
	Skin	Bone	Liver	Body	Thyroid	Kidney	Lung	G.I.-LLI
<u>Max. Individual, mrem</u>								
adult	6.24E-3	5.13E-0	7.01E-0	4.60E-0 ⁽¹⁾	5.39E-3	2.38E-0	7.96E-1	1.41E-1
teen	2.09E-2	5.50E-0	7.31E-0	2.56E-0	1.80E-2	2.50E-0	9.82E-1	1.22E-1
child	4.37E-3	7.00E-0	6.70E-0	9.92E-1	3.78E-3	2.19E-0	7.89E-1	9.57E-2
infant	—	1.74E-1	2.03E-1	1.44E-2	0	5.46E-2	2.21E-2	6.36E-4
<u>Population, man-rem</u>								
Port Wentworth	—	8.68E-1	1.19E-0	7.77E-1	0	4.03E-1	1.34E-1	2.30E-2
Beaufort-Jasper	—	1.67E-0	1.99E-0	9.00E-1	0	6.65E-1	2.30E-1	2.85E-2
Fish-sport	—	2.80E-1	3.51E-1	1.82E-1	0	1.83E-1	4.07E-0	5.66E-1
Fish-commercial	—	9.95E-1	1.25E-0	6.47E-1	0	4.20E-1	1.45E-1	2.01E-2
Salt Water Invert	—	4.09E-4	5.12E-4	2.64E-4	0	1.72E-4	5.93E-5	8.22E-6
Recreation	6.24E-2	—	—	5.39E-2	5.39E-2	—	—	—
Total	6.24E-2	3.15E-1	3.95E-1	2.06E-1	5.39E-2	1.32E-1	4.58E-0	6.38E-1

Year: 1990-2020

50-Mile-Radius population: 781,000

Beaufort-Jasper Population: 40,333

Port Wentworth Population: 26,167

River Flow Rate: cfs, 6100

Concentration Factor Water to Fish = 3000

(1) Pathway	Adult-Total Body, mrem/yr
Fish	4.54
Drinking Water	0.053
Shoreline	0.0054
Swimming	0.0000101
Boating	0.0000303
	4.60

TABLE D-12

Liquid Releases Dose Summary

LADTAP II
New DOSE FACTOR LIBRARY

Current - 1980

0.19 Ci Cs-137

	ORGAN DOSE COMMITMENT							
	Skin	Bone	Liver	Body	Thyroid	Kidney	Lung	G.I.-LLI
<u>Max. Individual, mrem</u>								
adult	2.15E-4	1.77E-1	2.42E-1	1.59E-1 ⁽¹⁾	1.86E-4	8.42E-2	2.75E-2	4.87E-3
teen	7.22E-4	1.90E-1	2.53E-1	8.84E-2	5.20E-4	8.63E-2	3.39E-2	4.20E-3
child	1.51E-4	2.42E-1	2.31E-1	3.43E-2	1.31E-4	7.55E-2	2.73E-2	1.58E-3
infant	—	6.00E-3	7.03E-3	4.98E-4	0	1.89E-3	7.64E-4	2.20E-5
<u>Population, man-rem</u>								
Port Wentworth	—	3.00E-2	4.10E-2	2.68E-2	0	1.39E-2	4.63E-2	7.93E-4
Beaufort-Jasper	—	5.78E-2	6.86E-2	3.11E-2	0	2.30E-2	7.95E-3	9.86E-4
Fish-sport	—	9.66E-1	1.21E-0	6.28E-1	0	4.08E-1	1.41E-1	1.96E-2
Fish-commercial	—	3.44E-2	4.31E-2	2.32E-2	0	1.45E-2	5.00E-3	6.96E-4
Salt Water Invert	—	1.41E-5	1.77E-5	9.12E-6	0	5.96E-6	2.05E-6	2.84E-7
Recreation	2.15E-3	—	—	1.86E-3	1.86E-3	—	—	—
Total	2.15E-3	1.09E-0	1.36E 0	7.09E-1	1.86E 3	4.59E-1	2.00E-1	2.21E-2

Year: 1990-2020

50-Mile-Radius population: 781,000

Beaufort-Jasper Population: 40,333

Port Wentworth Population: 29,167

River Flow Rate: cfs, 6100

Concentration Factor Water to Fish = 3000

(1) Pathway	Adult-Total Body, mrem/yr
Fish	0.157
Drinking Water	0.00182
Shoreline	0.000185
Swimming	0.000000349
Boating	0.00000105

TABLE D-13

Site Parameters Used in Dose Calculations

River flow rate, average cfs	6,100
River dilution in estuary	3
Transit time, L-Area to river, hr	24
Transit time, SRP to water treatment plants, hr	72
Water treatment time, hr	24
Aquatic food harvest, kg/yr	
Fish -- sport	90,700
Fish -- commercial	31,800
Invertebrates - salt water	299,000
Irrigation	None
Shore width factor	0.2
Population average (1990-2020)	
Beaufort-Jasper water consumers	40,300
Port Wentworth water consumers	29,200
50-mile radius population	781,000
Age distribution of population, %	Child Teen Adult
Beaufort-Jasper	21 10 69
Port Wentworth	- - 100
50-mile radius population	21 11 68
Drinking water consumption	
Maximum individual L/yr	730
Fish consumption	
Maximum individual kg/yr	21

TABLE D-14

Comparison of Calculated and Measured Annual Mean Values of Cesium-137
Concentration in Savannah River Water and Fish

Water, pCi/L			Fish, pCi/g		Bioaccumulation Factor	
Year	Measured	Calculated*	Measured	Calculated*	Measured	Calculated
1965	2.05	2.45	8	5.68	3902	2300
1966	2.7	2.12	3	5.07	1111	2400
1967	2.05	1.75	3.5	4.46	1707	2500
1968	1.15	1.40	2.5	3.86	2174	2700
1969	0.55	1.05	4	3.25	7273	3000
1970	1.2	0.75	1.5	2.64	1250	3500
1971	0.2	0.40	2.7	2.04	13500	5100
Geometric Mean					2956	
Arithmetic Mean						3071

* Calculated concentration based on linear regression model fit of the measured concentration data.

PART III

III. HOT WATER DESORPTION

III.1. Hot Water Desorption of Cesium-137 from Steel Creek Sediments

Hot water desorption of cesium-137 from the sediments will occur following L-Reactor startup. Beginning in early June 1976 and until the end of that month, about 40,000 gpm of hot water, approximately 70°C, was diverted to Steel Creek from P Area. Cesium-137 concentrations and cesium-137 transport increased at SC 5 about eight miles downstream, during the diversion (Figure D-4). Diversion of similar amounts of ambient temperature water in 1978 and 1980 did not show this increase in cesium-137 from the sediments.

Laboratory experiments showed that higher water temperatures extract more cesium-137 than ambient temperatures (2.5%:70°C versus 0.1%:22°C). Samples of Steel Creek sediment obtained 1/4-mile below L-Reactor outfall were contacted with Savannah River water over the temperature range of 22 to 70°C (70°C L-reactor water discharge temperature) for a period of five to twelve days. An 0.8 micron filter was used to separate the desorbed (dissolved) phase from the sediment, and centrifugation was required prior to filtration. Processing required the sample to be at room temperature about two hours before final filtration was completed. Therefore, the amount remaining after cooling would remain in solution and be subject to transport offsite. The suspended solids left in the supernate after centrifugation were analyzed to determine the contribution from this small fraction that would remain suspended.

A definite temperature effect is evident in the dissolved fraction, and the amount of cesium-137 extracted increased with temperature, whereas the amount left in the suspended particles after centrifugation was about the same (Table D-15). The water of filtration from the higher temperature was colored (tan or brown) indicating a possibility of importance of organics or bio-organics on the fate of cesium-137. The ambient temperature results show a smaller fraction desorbed than reported previously in other literature values (0.1% versus 6% others) but this probably reflects more of a sample processing difference than difference in sediment types. The other sampling procedures either used a much coarser filter or centrifugation that did not remove as many of the fine sediment sizes as our filtration technique.

Considering both the desorbed (dissolved) and suspended solids left after centrifugation as part of the temperature effect, 3.2 to 5% is removed due to hot water.

TABLE D-15

Cesium-137 Extraction from Steel Creek Sediments Using Hot Water

Temperature °C	Dissolved Cs-137, pCi/L	Left in Suspension after Centrifugation, pCi/L	Dissolved %	Suspended %	Total %
70	226 ±29	227 ±25	2.5	2.5	5
52	88.6 ±17	200 ±35	1.0	2.2	3.2
43	64.2 ±15	321 ±46	0.7	3.6	4.3
22	12.0 ±4.8	302 ±12	0.1	3.4	3.5

PART IV

IV. CREEK PLANTATION SWAMP — BACKGROUND RADIATION

IV.1. Creek Plantation Swamp — External Background Relationship

In the mid-1970's (1974 through 1977) special efforts were made by SRP Environmental Monitoring Group to monitor both the external radiation field and cesium-137 concentrations in the sediment on Creek Plantation Swamp.¹³ These measurements were changed to a five-year cycle in 1977 because little differences could be found in the data over this four-year period. The cesium-137 concentrations in the sediment were measured over a 0 to 6 or 8 cm sediment depth interval. Thermoluminescent dosimeters, commonly referred to as TLD's, were used to measure the external radiation field and respond to natural, man-made, and cosmic radiation sources. These dosimeters are used routinely around SRP to measure the external radiation field.

A good correspondence was found between TLD dosimeter response and cesium-137 sediment concentration on Creek Plantation Swamp. The TLD - cesium-137 data were evaluated using a simple linear model, $y = mx + b$, and correlation coefficients between 0.65 to 0.91 were calculated for four yearly data sets, Table D-16. The intercept coefficient (b) gives the background dose. A background of about 0.25 mrem/day (92 mrem/yr) is greater than that at the SRP plant perimeter (0.17 mrem/day or 62 mrem/yr).¹³ The higher background radiation field in the Creek Plantation may be the result of:

- The accumulation of heavy minerals with their attendant natural radionuclides as compared to the upland sandy soils and/or
- Some remnant ⁶⁰Co may still be contributing to the external radiation field.

To estimate the cesium-137 contribution to the external radiation field, all TLD dosimeter values less than 0.28 mrem/day were removed from the data set. An upper limit of 0.28 mrem/day was used because individual dosimeter readings were subject to a precision error of ± 0.03 mrem/day,¹³ hence $0.25 + 0.03 = 0.28$. The remaining dosimeter values by year were averaged, that year's background intercept removed and the resulting external radiation field average was divided by the amount of cesium-137 estimated to be present in the Creek Plantation Swamp. The results show a remarkable uniformity in dose rate per Ci deposited on swamp relationship,

$$4.60 \pm 0.77 \frac{\text{mrem}}{\text{Ci-yr}}, \text{ Table D-16.}$$

TABLE D-16

Estimate of the Cesium-137 — External Radiation Field
Relationship for Creek Plantation Swamp

<u>Year</u>	<u>Slope mrem/day, pCi/gm</u>	<u>Intercept, mrem/day</u>	<u>Correlation Coefficient</u>	<u>Estimated Cs-137 Dose Rate per Ci Deposited</u>
1974	2.25E-3	2.62E-1	0.78	4.76
1975	2.99E-3	2.34E-1	0.65	3.73
1976	4.52E-3	2.41E-1	0.91	4.36
1977	4.46E-3	<u>2.76E-1</u>	0.88	<u>4.57</u>
0.2532 ± 0.016 mrem/day				4.60 ± 0.77 mrem/yr-Ci
9.25 ± 5.8 mrem/yr				

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APPENDIX E

THERMAL PLUME IN THE SAVANNAH RIVER BELOW THE MOUTH OF STEEL CREEK

Part I. Thermal Plume Modeling

Part II. Predicted Plumes with Low River Flow

PART I. THERMAL PLUME MODELING

1.0 Model Description

Computations were performed with the aid of a finite-element computer code DISPER1.¹ The code solves the time dependent or steady state dispersion problem for a single constituent, either some contaminant or water temperature. The finite element structure of the code using quadratic triangular elements also facilitates the use of arbitrary and curved domains with complex topography. The equation solved in DISPER1 is:

$$\rho \frac{\partial \theta}{\partial t} + V_i \frac{\partial \theta}{\partial x_i} = \rho p + \rho \frac{\partial}{\partial x_i} D_i \frac{\partial \theta}{\partial x_i} \quad (1)$$

where: θ = the substance being transported and advected
 t = time
 ρ = mass per unit volume of the substance
 x = direction of motion
 p = the distributed input rate per unit mass
 D = the dispersion coefficient
 V = the transport velocity
 i = indices for multidimensionality

when temperature distributions are required, equations similar to the above can be developed for thermal dispersion.

$$\rho \frac{\partial \theta}{\partial t} + V_i \frac{\partial \theta}{\partial x_i} = \rho p + \rho c \frac{\partial}{\partial x_i} D_i \frac{\partial \theta}{\partial x_i} \quad (2)$$

where: c = the specific heat

If the specific heat is set to unity, Equations 1 and 2 are identical. Finally, for well mixed problems, Equation 2 is integrated vertically over the water depth producing the following two-dimensional advection and dispersion equation.

$$\rho c h \frac{\partial \theta}{\partial t} + V_i \frac{\partial \theta}{\partial x_i} = F - \alpha h \theta - \sum_j Q_j \Delta_j + \rho c \frac{\partial}{\partial x_i} h D_i \frac{\partial \theta}{\partial x_i} \quad (3)$$

where: h = depth
 α = a decay coefficient
 F = a distributed sink
 $\sum_j Q_j \Delta_j$ = a summation of point sources

By applying the Galerkin method, the above equation is transformed to a variational equation, which is integrated to provide the system of equations pertaining to specified domains.

The code may, therefore, be described as a two-dimensional code with the third dimension simulated by allowing depth to be specified at each node. This is equivalent to assuming complete mixing in the vertical plane. It is seen in Figures E-1 and E-2 that this is a valid assumption for points beyond a few hundred yards from the mouths of the effluent streams.

2.0 Stream Modeling

The computational procedure requires several sequential steps before an adequate simulation model is obtained.

1. Designing the computational grid.
2. Specifying stream function boundary conditions.
3. Solving for velocities at each node point.
4. Specifying temperature boundary conditions.
5. Solving for temperatures at each node point with assumed dispersion coefficients.
6. Adjusting input parameters until good agreement with measurements are obtained.

2.1 Computational Grid

The computational grid for this simulation is shown in Figure E-3 and includes a reach of about 1.5 miles below the mouth of Steel Creek. The grid has 549 triangles, 1220 node points, and 233 boundary points which must be specified to obtain a stream function and velocity solution. This grid design is a compromise between trying to obtain as much detail as practical while covering an extended domain and operating within computer limitations.

2.2 Stream Function Boundary Conditions

Velocities over the domain of interest are computed using potential flow theory and the relationship between velocity and stream function.

$$u = \frac{1}{h} \frac{\partial \chi}{\partial y}, \quad v = -\frac{1}{h} \frac{\partial \chi}{\partial x} \quad (4)$$

where: u = velocity component in the x direction
 v = velocity component in the y direction
 χ = the stream function values
 h = river depth

Since it is impractical to specify the river depth at each node point over such an extended domain, h in the above equation is assigned a value of unity which implies a uniform depth of the river everywhere. Stream function gradients on the boundary of

FIGURE E-1. Savannah River Profiles (Temperature and Velocity^a)

FIGURE E-2. Savannah River Profiles (Temperature and Velocity^a)

FIGURE E-3. Computational Grid

the domain represent flow into or out of the domain. Boundary condition stream function values are obtained from velocity profiles such as provided in Figures E-4 and E-5, if it is assumed that the measured velocities are parallel to the river banks. A stream function value χ_i for node i is determined simply as:

$$\chi_i = \chi_{i-1} + u_i h_i d_i \quad (5)$$

where d_i is the incremental distance over which u_i is valid. It is necessary to have a positive increase in χ in going from the Georgia side of the river to the South Carolina side. For the river width and velocities shown in Figure E-1, the $\Delta\chi$ across the river is determined to be 590 ft³/s, which corresponds to a flow of 4510 cfs into the domain. The $\Delta\chi$ across Steel Creek (taken positive in the downstream direction) is proportional to its flow and can be simply determined by:

$$\Delta\chi_c = \Delta\chi_R \frac{F_c}{F_R} \quad (6)$$

where subscripts c and R denote Steel Creek and Savannah River respectively, and F denotes flow in cfs. The flow from Steel Creek into the river at this time was 969 cfs yielding a $\Delta\chi$ of 127. If the stream function value on the Georgia side of the river is arbitrarily chosen as zero, the boundary χ values are now sufficiently determined to obtain a velocity solution over the total domain using the DISPER1 code.

2.3 Temperature Boundary Conditions

Temperatures are specified within the domain by node number and are held at that value to solve for domain temperatures. To model the results of Figures E-1, E-2, E-4, and E-5, the temperature profiles of Figures E-4 and E-5 were used as boundary conditions. Temperatures everywhere else were obtained as a solution of a steady state condition using the velocities obtained previously.

Table E-1 shows the results of varying the transverse dispersion coefficient for several temperature solutions obtained from the same velocity solution. These data show that the simulation agrees well with measurement when the dispersion coefficient is slightly below 3.0 ft²/s. A plot of these data, Figure E-6, shows that the coefficient indicated at 0.7 and 1.4 miles below the mouth of Steel Creek is about the same. This good agreement is taken as an indication that the coefficient of 2.8 is the proper value to characterize dispersion in the reach considered. This value is also well within the range (0.05 to 8.6 ft²/s) of measured coefficients quoted in available literature.^{2,3}

FIGURE E-4. Steel Creek Profiles (Temperature and Velocity^a)

FIGURE E-5. Savannah River Profiles (Temperature and Velocity^a)

TABLE E-1

Computed Temperature Distributions Versus
Lateral Dispersion Coefficients Compared to Measurements*

Dispersion Coefficient, ft^2/s	0.7 Miles Downstream		1.4 Miles Downstream	
	Computed ΔT^{**}	Measured ΔT	Computed ΔT	Measured ΔT
10.0	0.7	2.7	0.1	1.7
5.0	1.7	2.7	0.7	1.7
3.0	2.6	2.7	1.5	1.7
1.0	4.3	2.7	3.3	1.7

* Obtained from Reference 1.

** ΔT computed and measured from Georgia shore to
South Carolina shore.

FIGURE E-6. Computed Temperature Distributions Versus Transverse Dispersion Coefficients

There is a systematic error in the resulting model of about 9% based on flow balance and computed heat content of the river. These data are shown in Table E-2, where the average temperature rise in the river is determined at 1.5 miles downstream from Steel Creek where temperature gradients are relatively small to minimize error in computing the average. The computed average rise is larger than the average based on flow and heat input for each of the cases with the error about the same in each case. The source of the error may be due to large temperature gradients at the mouth of Steel Creek or possibly a failure to maintain mass consistency in the computer model. However, since it represents a small conservatism, no arbitrary adjustments in the computational model seem necessary. The model is considered to be adequate for considering other flow rates in the Savannah River and/or Steel Creek with varying temperature conditions.

TABLE E-2

Heat Balance Computation at 1.5 Miles Below Steel Creek

Temperature Difference Between Creek and River, °F	Flow, cfs		Average,* °F		Error, %
	River	Creek	Based on Flow Rates	Computer Model	
15	6,200	969	2.03	2.21	8.9
20	6,200	969	2.70	2.95	9.2
25	6,200	969	3.38	3.68	8.9

* Temperature rise above ambient river temperature.

PART II. PREDICTED PLUMES WITH LOW RIVER FLOW

1.0 Introduction

Under certain unavoidable circumstances, minimum flows in the Savannah River may be lower at times than 6100 cfs, which has been a target minimum of the U.S. Corp of Engineers. These circumstances are dominated by reservoir construction and maintenance, the lack of commercial traffic on the Savannah River, and rainfall conditions. In 1983, L Area is scheduled to return to operating status. This will increase demand for cooling water from the Savannah River and will increase significantly thermal discharges to the river if operations are similar to methods prevailing previously. In the past, thermal effluents from both K and L Area discharged to the river via Steel Creek. It is probable that some flow from C Area discharges is also included. Computer simulations have been made of thermal discharges from Steel Creek under unusually low Savannah River flows of 4500 and 5300 cfs and the expected low flow of 6100 cfs to assess temperature distributions.

2.0 Model Results

Temperature distributions were obtained using a computer code DISPER1 over a domain including about 1.5 miles of the Savannah River (Figure E-3). The mouth of Steel Creek is near the upstream end of this domain.

South Carolina regulations⁴ regarding thermal effluents are concerned with temperatures inside established and proposed mixing zones and total surface area affected. The criteria pertain to 25% of the cross-sectional area of the river at any point downstream and 33% of the total surface area within any length increment downstream. Outside these zones the temperature is allowed to be a maximum of 5°F above ambient river temperature. The time over which temperature measurements are averaged for comparison with criteria is not specified.

Computations were made for two flow rates on Steel Creek, 550 cfs and 969 cfs. The two flow rates roughly correspond to nominally expected flow rates with only K or L Area operating and with K and L Areas operating simultaneously. Computations were made for three flow rates on the Savannah River, 4500, 5300, and 6200 cfs. All computations were made with a 10°C difference between the Steel Creek discharge temperature and ambient river temperature. Due to the physics that is modeled in DISPER1 the computed temperature distributions are linear with respect to Δt between creek and river; therefore, these results may be extrapolated linearly to obtain estimates at other Δt 's. Historically, extremes of Δt between Steel Creek and the river are occasionally in the range of 25°F.

Figures E-7a and E-7b show results with a river flow of 6200 cfs where the upper curve pertains to the 25% cross-sectional area boundary and the lower curve pertains to the 33% surface area boundary. Figure E-7a is for a Steel Creek discharge of 969 cfs, Figure E-7b is for a creek discharge of 550 cfs. Figures E-8a, E-8b, E-9a, and E-9b use the same format for river flows of 5300 and 4500 cfs. Isotherm contours are shown in Figures E-10a, b, c, and E-11, a, b, and c. These data show a peak temperature for the 25% cross-sectional area boundary at about 0.35 miles downstream from the creek mouth. The 33% surface area boundary peak temperature occurs at about 1.2 miles downstream. These peak temperatures are plotted in Figures E-12 and E-13 for creek flows of 969 and 550 cfs as a function of river flow.

In Figures E-7 through E-9, it is indicated that the 25% cross-sectional area criteria is limiting since this peak is highest on each graph. The graphs of Figures E-14 and E-15 were therefore generated using these data to indicate the prevailing conditions that could exist to produce a boundary temperature increase of 5°F or greater. Figure E-14, based on steady state conditions with a creek flow of 550 cfs, indicates that it takes about a 20°F Δt to approach a 5°F increase within the mixing zone for a river flow of 4500. Sustained Δt 's of 20°F and above under present conditions are very rare. However, as shown in Figure E-15, if the creek flow is increased to 969 cfs it takes only about 12.5°F to reach a 5°F increase within the mixing zone boundary. At a river flow of 6100 cfs a Δt of about 16°F results in an increase of 5°F in the mixing zone. A Δt of 16°F is the maximum 30-day average temperature observed during previous L-Reactor operation.

There is a systematic error in the model of about 9% based on flow balance and computed heat content of the river. The source of the error may be due to large temperature gradients at the mouth of Steel Creek or possibly to a failure to maintain mass consistency in the computer model. However, since it represents a small conservatism, no arbitrary adjustments in the computational model seem necessary.

FIGURE E-7a. River Temperature Increase Due to Steel Creek Discharge

FIGURE E-7b. River Temperature Increase Due to Steel Creek Discharge

FIGURE E-8a. River Temperature Increase Due to Steel Creek Discharge

FIGURE E-8b. River Temperature Increase Due to Steel Creek Discharge

FIGURE E-9a... River Temperature Increase Due to Steel Creek Discharge

FIGURE E-9b. River Temperature Increase Due to Steel Creek Discharge

Legend

- Δ 1 DEG F
- $\times$ 2 DEG F
- $\square$ 3 DEG F
- $\boxtimes$ 4 DEG F
- $\boxtimes$ 5 DEG F

FIGURE E-10a. Isotherms from Steel Creek Effluent

FIGURE E-10b. Isotherms from Steel Creek Effluent

FIGURE E-10c. Isotherms from Steel Creek Effluent

FIGURE E-11a. Isotherms from Steel Creek Effluent

Legend

- Δ 1 DEG F
- $\times$ 2 DEG F
- $\square$ 3 DEG F
- $\boxtimes$ 4 DEG F
- $\boxtimes$ 5 DEG F

FIGURE E-11b. Isotherms from Steel Creek Effluent

FIGURE E-11c. Isotherms from Steel Creek Effluent

FIGURE E-12. Maximum Temperature Increase at the 25% Mixing Zone Boundary

FIGURE E-13. Maximum Temperature Increase at the 33% Mixing Zone Boundary

FIGURE E-14. Minimum Delta - T Required for 5 Deg F at Mixing Zone Boundary

FIGURE E-15. Minimum Delta - T Required for 5 Deg F at Mixing Zone Boundary

REFERENCES

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APPENDIX F

L-Area Outfalls*

Part I: Details Individual L-Area Outfalls

Part II: Analytical Data for Comparative L-Area Outfalls

- Outfall C-4 used for L-7
- Outfall K-1 used for L-10
- Outfall K-3 used for L-3
- Outfall K-8 used for L-8

* "Savannah River Plant NPDES Permit Application." Compiled for the Department of Energy by E. I. du Pont de Nemours & Co., Savannah River Plant, Aiken, SC (1981).

PART I

DETAILS OF INDIVIDUAL L-AREA OUTFALLS

OUTFALL L-1 , Normally dry storm water outfall to an unnamed tributary of Steel Creek which empties into the Savannah River.

EFFLUENT SOURCES:

<u>BUILDING</u>	<u>FUNCTION</u>	<u>INTERNAL SEWERS</u>	<u>EXTERNAL RUNOFF</u>
No buildings			

POLLUTANTS WHICH MAY BE DISCHARGED:

FREQUENTLY: _____

INFREQUENTLY: _____

EFFLUENT SOURCES:

INTERNAL SEWERS

EXTERNAL
RUNOFF

No buildings

FREQUENTLY:

INFREQUENTLY:

OUTFALL L-3 : Normally dry storm water sewer which may receive domestic water system overflow before discharging into Steel Creek which empties into the Savannah River (on standby).

EFFLUENT SOURCES:

BUILDING	FUNCTION	INTERNAL SEWERS	EXTERNAL RUNOFF
105-L	Reactor building		✓
151-2L	Substation	✓	✓
183-2L	Filter & softener plant	✓	✓
183-4L	Clarification plant		✓

POLLUTANTS WHICH MAY BE DISCHARGED:

FREQUENTLY: _____

INFREQUENTLY: Al, Cl, CO₂, caustic soda, Fe, K, Mg, Na, NO₂, oil and grease, PO₄, SO₂, SO₄, Zn

EFFLUENT SOURCES:

[illegible]

FREQUENTLY: _____

II-189

OUTFALL L-5 Process sewer outfall to low level radioactivity seepage basin. This basin does not have an overflow (on standby).

EFFLUENT SOURCES:

BUILDING	FUNCTION	INTERNAL SEWERS	EXTERNAL RUNOFF
383-1G	Contaminated storage area	✓	
707-G	Change house for contaminated equipment work shop	✓	
712-G	Air compressor shelter	✓	
717-G	Contaminated equipment work shop	✓	
804-83G	Basin	✓	

POLLUTANTS WHICH MAY BE DISCHARGED:

FREQUENTLY: _____

INFREQUENTLY: _____

EFFLUENT SOURCES:

POLLUTANTS WHICH MAY BE DISCHARGED:

INFREQUENTLY: Al, Cl, CO₃, Fe, K, Mg, Na, NO₃, oil and grease, PO₄, SO₃, SO₄, Zn

OUTFALL L-7 : Reactor cooling wastewater/process sewer outfall to Steel Creek
which empties into the Savannah River (on standby).

EFFLUENT SOURCES:

<u>BUILDING</u>	<u>FUNCTION</u>	<u>INTERNAL SEWERS</u>	<u>EXTERNAL RUNOFF</u>
105-L	Reactor building	✓	
106-L	Process water storage tank	✓	
107-L	Cooling water effluent sump	✓	
183-2L	Filter & softener plant	✓	
136-L	Cooling water reservoir	✓	
607-16L	Sanitary treatment plant (sanitary)	✓	

POLLUTANTS WHICH MAY BE DISCHARGED:

FREQUENTLY:

INFREQUENTLY: Al, caustic soda, Cl, CO₂, Fe, K, Mg, Na, NO₃, oil and grease, org. N,
org. P, PO₄, SO₃, SO₄, surfactants, Zn

11-191

OUTFALL L-8 : Nonprocess cooling water outfall to an unnamed tributary of Steel Creek which empties into the Savannah River (on standby).

EFFLUENT SOURCES:

BUILDING	FUNCTION	INTERNAL SEWERS	EXTERNAL RUNOFF
105-L	Reactor building	✓	✓
106-L	Process water storage tanks		✓
108-1L	Engine house	✓	✓
108-2L	Engine house	✓	✓
109-L	Purge water storage basin		✓
110-L	Helium storage tank	✓	
152-1L	Substation		✓
183-2L	Filter & softener plant		✓
190-L	Cooling water pumphouse	✓	✓
904-1L	Process sewer manhole		✓

POLLUTANTS WHICH MAY BE DISCHARGED:

FREQUENTLY:

INFREQUENTLY: Al, Cl, Fe, Mg, NO₃, oil and grease, PO₄, SO₃, SO₄, Zn

OUTFALL L-9 : Normally dry storm water outfall to an unnamed tributary of Steel Creek which empites into the Savannah River.

EFFLUENT SOURCES:

<u>BUILDING</u>	<u>FUNCTION</u>	<u>INTERNAL SEWERS</u>	<u>EXTERNAL RUNOFF</u>
110-L	Helium storage tank		✓
152-L	Substation		✓
701-2L	Gatehouse		✓

POLLUTANTS WHICH MAY BE DISCHARGED:

FREQUENTLY: _____

INFREQUENTLY: _____

OUTFALL L-10 : Storm water outfall which receives some cooling water before discharging into an unnamed tributary of Steel Creek, which empties into the Savannah River (on standby).

EFFLUENT SOURCES:

BUILDING	FUNCTION	INTERNAL SEWERS	EXTERNAL RUNOFF
151-1L	Substation	✓	✓
190-L	Cooling water pumphouse		✓
501-L	Fence & road lighting		✓
701-1L	Area gatehouse & Patrol headquarters	✓	✓
704-L	Offices	✓	✓
704-3L	Offices	✓	✓

POLLUTANTS WHICH MAY BE DISCHARGED:

FREQUENTLY: _____

INFREQUENTLY: Oil and grease

<u>BUILDING</u>	<u>FUNCTION</u>	<u>INTERNAL SEWERS</u>	<u>EXTERNAL RUNOFF</u>
105-L	Reactor building	✓	

POLLUTANTS WHICH MAY BE DISCHARGED:

FREQUENTLY:

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OUTFALL L-13 : Normally dry storm water outfall to an unnamed tributary of Pen Branch which empties into the Savannah River.

EFFLUENT SOURCES:

<u>BUILDING</u>	<u>FUNCTION</u>	<u>INTERNAL SEWERS</u>	<u>EXTERNAL RUNOFF</u>
136-L	Cooling water reservoir		✓
701-1L	Area gatehouse & Patrol headquarters		✓
704-L	Offices		✓
711-L	Maintenance material storage building		✓
901-G	Water lines		✓
Cooling tower		✓	✓
Gas station			✓

POLLUTANTS WHICH MAY BE DISCHARGED:

FREQUENTLY:

INFREQUENTLY: Cl, oil and grease

[illegible]

FREQUENTLY: _____

[illegible]

EFFLUENT SOURCES:

POLLUTANTS WHICH MAY BE DISCHARGED:

FREQUENTLY:

INFREQUENTLY: 21

F-16

EFFLUENT SOURCES:

[illegible]

FREQUENTLY: _____

INFREQUENTLY: C1

EFFLUENT SOURCES:

[illegible]

FREQUENTLY:

INFREQUENTLY. C1

PART II

ANALYTICAL DATA FOR COMPARATIVE

L-AREA OUTFALLS

OUTFALL C-4 USED FOR L-7

PLEASE PRINT OR TYPE IN THE UNSHADED AREAS ONLY. You may report some or all of this information on separate sheets (use the same format) instead of completing these pages. SEE INSTRUCTIONS.

EPA I.D. NUMBER (copy from Item 1 of Form 1)

SC1890008989

Form Approved OMB No. 158-R0173

V. INTAKE AND EFFLUENT CHARACTERISTICS (continued from page 3 of Form 2-C)												OUTFALL NO.		
												C-4 b		
PART A - You must provide the results of at least one analysis for every pollutant in this table. Complete one table for each outfall. See instructions for additional details.														
1. POLLUTANT	2. EFFLUENT				3. UNITS (specify if blank)				4. INTAKE (optional)					
	a. MAXIMUM DAILY VALUE		b. MAXIMUM 30 DAY VALUE (if available)		c. LONG TERM AVG. VALUE (if available)		d. NO. OF ANALYSES	e. UNITS		f. LONG TERM AVERAGE VALUE		h. NO. OF ANALYSES		
	(1) CONCENTRATION	(2) MASS	(1) CONCENTRATION	(2) MASS	(1) CONCENTRATION	(2) MASS		g. CONCENTRATION	h. MASS	(1) CONCENTRATION	(2) MASS			
a. Biochemical Oxygen Demand (BOD)	5	4.7					1	mg/l	T/d	<3		2		
b. Chemical Oxygen Demand (COD)	32	30					1	mg/l	T/d	16.8		2		
c. Total Organic Carbon (TOC)	6	5.6					1	mg/l	T/d	4.5		2		
d. Total Suspended Solids (TSS)	12	11					1	mg/l	T/d	19.5		2		
e. Ammonia (as N)	<1.0	<940					1	mg/l	kg/d	<0.6		2		
f. Flow	VALUE 651,000		VALUE		VALUE		1	l/min		VALUE				
g. Temperature (winter)	VALUE 59.6		VALUE		VALUE		1	°C		VALUE				
h. Temperature (summer)	VALUE		VALUE		VALUE			°C		VALUE				
i. pH	MINIMUM 6.4	MAXIMUM 7.1	MINIMUM	MAXIMUM			1	STANDARD UNITS						
PART B - Mark "X" in column 2-a for each pollutant you know or have reason to believe is present. Mark "X" in column 2-b for each pollutant you believe to be absent. If you mark column 2-a for any pollutant, you must provide the results of at least one analysis for that pollutant. Complete one table for each outfall. See the instructions for additional details and requirements.														
1. POLLUTANT AND CAS NO. (if available)	2. MARK "X"		3. EFFLUENT				4. UNITS				5. INTAKE (optional)			
	a. RECEIVED FROM TREAT	b. EXISTING AS-SENT	a. MAXIMUM DAILY VALUE		b. MAXIMUM 30 DAY VALUE (if available)		c. LONG TERM AVG. VALUE (if available)		d. NO. OF ANALYSES	e. UNITS		f. LONG TERM AVERAGE VALUE		h. NO. OF ANALYSES
			(1) CONCENTRATION	(2) MASS	(1) CONCENTRATION	(2) MASS	(1) CONCENTRATION	(2) MASS		g. CONCENTRATION	h. MASS	(1) CONCENTRATION	(2) MASS	
a. Bromide (24959-67-9)		X	<2	<1.9					1	mg/l	T/d	<2.0		2
b. Chlorine, Total Residual	X		0.2	190					1	mg/l	kg/d			
c. Color	X		18						1	Pt-Co Units		32		1
d. Fecal Coliform		X	0						1	No./100 ml				
e. Fluoride (16984-48-8)		X	<0.10	94					1	mg/l	kg/d	<0.1		2
f. Nitrate-Nitrite (as N)	X		0.26	240					1	mg/l	kg/d	0.19		2

ITEM V-B CONTINUED FROM FRONT

1. POLLUTANT AND CAS NO. (if available)	2. MAXIMUM DAILY VALUE		3. EFFLUENT						4. UNITS		5. INTAKE (optional)		
	A. NO. OF ANALYSES	B. NO. OF ANALYSES	A. MAXIMUM DAILY VALUE		B. MAXIMUM DAILY VALUE		C. LONG TERM AVERAGE VALUE (if available)		A. CONCENTRATION	B. MASS	A. LONG TERM AVERAGE VALUE		B. NO. OF ANALYSES
			(1) CONCENTRATION	(2) MASS	(1) CONCENTRATION	(2) MASS	(1) CONCENTRATION	(2) MASS			(1) CONCENTRATION	(2) MASS	
g. Nitrogen, Total Organic (as N)		X	<1.0	<940					1	mg/l	kg/d	<1.2	2
h. Oil and Grease		X	<10	<9.4					1	mg/l	T/d	<8	2
i. Phosphorus (as P), Total (7723-14-0)		X	0.01	9.4					1	mg/l	kg/d	0.04	2
j. Radioactivity													
(1) Alpha, Total		X	1.56 ± 0.84	1.5 ± 0.8					1	pCi/d	mCi/d	<1.21	1
(2) Beta, Total		X	2.6 ± 1.5	2.4 ± 1.4					1	pCi/d	mCi/d	1.3 ± 1.1	1
(3) Radium, Total		X	<0.18	<0.17					1	pCi/d	mCi/d	<0.43	1
(4) Radium 226, Total		X	0.43 ± 0.23	0.40 ± 0.22					1	pCi/d	mCi/d	0.23 ± 0.16	1
k. Sulfate (as SO ₄) (14808-79-8)		X	5	4.7					1	mg/l	T/d	<4	2
l. Sulfide (as S)		X	<1	<940					1	mg/l	kg/d	<0.65	2
m. Sulfite (as SO ₃) (14268-45-3)		X	<2	<1.9					1	mg/l	T/d	<1.5	2
n. Surfactants		X	0.036	34					1	mg/l	kg/d	<0.028	2
o. Aluminum, Total (7429-90-5)		X	<0.1	<94					1	mg/l	kg/d	1.1	2
p. Barium, Total (7440-39-3)		X	<0.08	<75					1	mg/l	kg/d	<0.3	2
q. Boron, Total (7440-42-8)		X	<0.1	<94					1	mg/l	kg/d	<0.045	2
r. Cobalt, Total (7440-48-4)		X	<0.001	<0.94					1	mg/l	kg/d	<0.002	2
s. Iron, Total (7439-89-6)		X	0.41	380					1	mg/l	kg/d	2.0	2
t. Magnesium, Total (7439-95-4)		X	1.1	100					1	mg/l	kg/d	1.6	2
u. Molybdenum, Total (7439-98-7)		X	0.010	9.4					1	mg/l	kg/d	<0.002	2
v. Manganese, Total (7439-96-5)		X	0.049	46					1	mg/l	kg/d	0.14	2
w. Tin, Total (7440-31-5)		X	<0.008	<7.5					1	mg/l	kg/d	<0.008	2
x. Titanium, Total (7440-32-6)		X	<0.02	<19					1	mg/l	kg/d	<0.026	2

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SC1890008989	C-4

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PART C - If you are a primary industry and this outfall contains process wastewater, refer to Table 2c-2 in the instructions to determine which of the GC/MS fractions you must test for. Mark "X" in column 2-a for all such GC/MS fractions that apply to your industry and for ALL toxic metals, cyanides, and total phenols. If you are not required to mark column 2-a (*secondary industries, non-process wastewater outfalls, and non-required GC/MS fractions*), mark "X" in column 2-b for each pollutant you know or have reason to believe is present. Mark "X" in column 2-c for each pollutant you believe to be absent. If you mark either columns 2-a or 2-b for any pollutant, you must provide the results of at least one analysis for that pollutant. Note that there are seven pages to this part; please review each carefully. Complete one table (*full seven pages*) for each outfall. See instructions for additional details and requirements.

1. POLLUTANT AND CAS NUMBER (if available)	2. MARK "X"			3. EFFLUENT						4. UNITS	5. INTAKE (optional)				
	a. ANAL. YES	b. ANAL. NO	c. ANAL. NO	a. MAXIMUM DAILY VALUE		b. MAXIMUM 30 DAY VALUE (if available)		c. LONG TERM AVG. VALUE (if available)			a. CONCENTRATION	b. MASS	b. LONG TERM AVERAGE VALUE		b. NO. OF ANAL. YES
				(i) CONCENTRATION	(i) MASS	(i) CONCENTRATION	(i) MASS	(i) CONCENTRATION	(i) MASS				(i) CONCENTRATION	(i) MASS	
METALS, CYANIDE, AND TOTAL PHENOLS															
1M. Antimony, Total (7440-36-0)			X	<0.001	<0.94						1	mg/l	kg/d	<0.003	2
2M. Arsenic, Total (7440-38-2)			X	<0.001	<0.94						1	mg/l	kg/d	<0.002	2
3M. Beryllium, Total (7440-41-7)			X	<0.004	<3.7						1	mg/l	kg/d	<0.003	2
4M. Cadmium, Total (7440-43-9)			X	<0.003	<2.8						1	mg/l	kg/d	0.013	2
5M. Chromium, Total (7440-47-3)			X	<0.04	<37						1	mg/l	kg/d	<0.002	2
6M. Copper, Total (7550-50-8)			X	<0.01	<9.4						1	mg/l	kg/d	<0.012	2
7M. Lead, Total (7439-97-6)			X	0.001	0.94						1	mg/l	kg/d	<0.003	2
8M. Mercury, Total (7439-97-6)			X	0.0003	0.28						1	mg/l	kg/d	<0.002	2
9M. Nickel, Total (7440-02-0)			X	<0.03	<28						1	mg/l	kg/d	<0.003	2
10M. Selenium, Total (7782-49-2)			X	0.004	3.7						1	mg/l	kg/d	<0.002	2
11M. Silver, Total (7440-22-4)			X	0.0004	0.37						1	mg/l	kg/d	<0.0007	2
12M. Thallium, Total (7440-28-0)			X	<0.003	<2.8						1	mg/l	kg/d	<0.003	2
13M. Zinc, Total (7440-66-6)		X		0.070	66						1	mg/l	kg/d	<0.027	2
14M. Cyanide, Total (67-12-6)			X	<0.02	<19						1	mg/l	kg/d	<0.015	2
15M. Phenols, Total			X	<0.002	<1.9						1	mg/l	kg/d	<0.004	2
DIOXIN															
2,3,7,8-Tetra-chlorodibenzo-P-Dioxin (1764-01-6)			X	DESCRIBE RESULTS No peak was detected on the GC-MS scan.											

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CONTINUE ON REVERSE

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CONTINUED FROM THE FRONT															
1. POLLUTANT AND CAS NUMBER (if available)	2. MARK "X"			3. EFFLUENT						4. UNITS		5. INTAKE (optional)			
	A. TEST METHOD	B. ANALYST	C. DATE	D. MAXIMUM DAILY VALUE		E. MAXIMUM 30 DAY VALUE (if available)		F. LONG TERM AVG. VALUE (if available)		G. NO. OF ANALYSES	H. CONCENTRATION	I. MASS	J. LONG TERM AVERAGE VALUE		K. NO. OF ANALYSES
				(1) CONCENTRATION	(2) MASS	(1) CONCENTRATION	(2) MASS	(1) CONCENTRATION	(2) MASS				(1) CONCENTRATION	(2) MASS	
GC/MS FRACTION – VOLATILE COMPOUNDS															
1V. Acrolein (107-02-8)			X	ND						1				ND	2
2V. Acrylonitrile (107-13-1)			X	ND						1				ND	2
3V. Benzene (71-43-2)			X	<1 ^a	<0.94					1	µg/l	kg/d		<1 ^a	2
4V. Bis (Chloromethyl) Ether (542-88-1)			X	ND						1				ND	2
5V. Bromoform (75-25-2)			X	ND						1				ND	2
6V. Carbon Tetrachloride (56-23-6)			X	ND						1				ND	2
7V. Chlorobenzene (106-90-7)			X	ND						1				ND	2
8V. Chlorodibromomethane (124-48-1)			X	ND						1				ND	2
9V. Chloroethane (75-00-3)			X	ND						1				ND	2
10V. 2-Chloroethylvinyl Ether (110-75-8)			X	ND						1				ND	2
11V. Chloroform (67-66-3)			X	<1	<0.94					1	µg/l	kg/d		<1	2
12V. Dichlorobromomethane (75-27-4)			X	ND						1				ND	2
13V. Dichlorodifluoromethane (75-71-8)			X	ND						1				ND	2
14V. 1,1-Dichloroethane (75-34-3)			X	ND						1				ND	2
15V. 1,2-Dichloroethane (107-06-2)			X	ND						1				ND	2
16V. 1,1-Dichloroethylene (75-35-4)			X	ND						1				ND	2
17V. 1,2-Dichloropropane (78-07-6)			X	ND						1				ND	2
18V. 1,2-Dichloropropylene (542-75-6)			X	ND						1				ND	2
19V. Ethylbenzene (100-41-4)			X	<1 ^a	<0.94					1	µg/l	kg/d		<1 ^a	2
20V. Methyl Bromide (74-83-9)			X	ND						1				ND	2
21V. Methyl Chloride (74-87-3)			X	ND						1				ND	2

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ND = Not detected

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 EPA I.D. NUMBER (copy from Item 1 of Form 1) SC1890008989
 OUTFALL NUMBER G-4

Form Approved OMB No. 158-R0173

1. POLLUTANT AND CAS NUMBER (if available)	2. MARK 'X'			3. EFFLUENT						4. UNITS		5. INTAKE (optional)		
	A. TYPE OF ANALYSIS	B. NO. OF ANALYSES	C. NO. OF ANALYSES	A. MAXIMUM DAILY VALUE		B. MAXIMUM 30 DAY VALUE (if available)		C. LONG TERM AVERAGE VALUE (if available)		D. CONCENTRATION	E. MASS	F. LONG TERM AVERAGE VALUE		G. NO. OF ANALYSES
				(1) CONCENTRATION	(2) MASS	(1) CONCENTRATION	(2) MASS	(1) CONCENTRATION	(2) MASS			(1) CONCENTRATION	(2) MASS	
GC/MS FRACTION - VOLATILE COMPOUNDS (continued)														
22V. Methylene Chloride (75-09-2)			X	<1 ^a	<0.94					1	µg/l	kg/d	<1 ^a	2
23V. 1,1,2,2-Tetrachloroethane (79-34-6)			X	ND						1			ND	2
24V. Tetrachloroethylene (127-18-4)			X	ND						1			<1 ^a	2
25V. Toluene (108-88-3)			X	1 ^a	0.94					1	µg/l	kg/d	<6 ^a	2
26V. 1,2-Dichloroethylene (156-60-5)			X	ND						1			ND	2
27V. 1,1,1-Trichloroethane (71-55-6)			X	<1 ^a	<0.94					1	µg/l	kg/d	<1 ^a	2
28V. 1,1,2-Trichloroethane (79-00-5)			X	ND						1			ND	2
29V. Trichloroethylene (79-01-8)			X	ND						1			ND	2
30V. Trichlorofluoromethane (75-69-4)			X	ND						1			ND	2
31V. Vinyl Chloride (75-01-4)			X	ND						1			ND	2
GC/MS FRACTION - ACID COMPOUNDS														
1A. 2-Chlorophenol (95-57-8)			X	ND						1			ND	2
2A. 2,4-Dichlorophenol (120-83-2)			X	ND						1			ND	2
3A. 2,4-Dimethylphenol (106-67-9)			X	ND						1			ND	2
4A. 4,6-Dinitro-O-Cresol (534-52-1)			X	ND						1			ND	2
5A. 2,4-Dinitrophenol (81-28-5)			X	ND						1			ND	2
6A. 2-Nitrophenol (88-76-5)			X	ND						1			ND	2
7A. 4-Nitrophenol (100-02-7)			X	ND						1			ND	2
8A. p-Chloro-M-Cresol (69-60-7)			X	ND						1			ND	2
9A. Pentachlorophenol (87-86-8)			X	ND						1			ND	2
10A. Phenol (108-95-2)			X	<1	<0.94					1	µg/l	kg/d	<1 ^a	2
11A. 2,4,6-Trichlorophenol (88-06-2)			X	ND						1			ND	2

EPA Form 3510-2C (8-80)

ND = Not detected

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1. POLLUTANT AND CAS NUMBER (if available)	2. MARK 'X'			3. EFFLUENT				4. UNITS			5. INTAKE (optional)			
	TYPE OF ANAL. VES.	NO. OF ANAL. VES.	CONC. OF ANAL. VES.	D. MAXIMUM DAILY VALUE		E. MAXIMUM 30 DAY VALUE (if available)		F. LONG TERM AVG. VALUE (if available)		A. CONCENTRATION	B. MASS	C. LONG TERM AVERAGE VALUE		D. NO. OF ANAL. VES.
				(1) CONCENTRATION	(2) MASS	(1) CONCENTRATION	(2) MASS	(1) CONCENTRATION	(2) MASS			(1) CONCENTRATION	(2) MASS	
GC/MS FRACTION - BASE/NEUTRAL COMPOUNDS														
10. Acenaphthene (83-32-9)			X	ND						1			ND	2
20. Acenaphthylene (200-98-8)			X	ND						1			ND	2
30. Anthracene (120-12-7)			X	<1	<0.94					1	µg/L	kg/d	ND	2
40. Benzidine (92-87-5)			X	ND						1			ND	2
50. Benzo (a) Anthracene (56-55-3)			X	ND						1			ND	2
60. Benzo (a) Pyrene (50-32-8)			X	ND						1			ND	2
70. 3,4-Benzo-fluoranthene (205-99-2)			X	ND						1			ND	2
80. Benzo (ghi) Perylene (191-24-2)			X	ND						1			ND	2
90. Benzo (h) Fluoranthene (207-08-9)			X	ND						1			ND	2
100. Bis (2-Chloro-ethoxy) Methane (111-91-1)			X	ND						1			ND	2
110. Bis (2-Chloro-ethyl) Ether (111-44-4)			X	ND						1			ND	2
120. Bis (2-Chloro-propoxy) Ether (39638-32-9)			X	2	1.9					1	µg/L	kg/d	<6 ^a	2
130. Bis (2-Ethyl-hexyl) Phthalate (117-81-7)			X	ND						1			ND	2
140. 4-Bromo-phenyl Phenyl Ether (101-65-3)			X	ND						1			ND	2
150. Butyl Benzyl Phthalate (85-68-7)			X	ND						1			ND	2
160. 2-Chloro-naphthalene (91-58-7)			X	ND						1			ND	2
170. 4-Chloro-phenyl Phenyl Ether (7005-72-3)			X	ND						1			ND	2
180. Chrysene (218-01-9)			X	ND						1			ND	2
190. Dibenzo (a,h) Anthracene (53-70-3)			X	ND						1			ND	2
200. 1,2-Dichloro-benzene (95-50-1)			X	ND						1			ND	2
210. 1,3-Dichloro-benzene (541-73-1)			X	ND						1			ND	2

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ND = Not detected

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EPA I.D. NUMBER (copy from Item 1 of Form 1)

SC1890008989

OUTFALL NUMBER

C-4

Form Approved OMB No. 158-R0173

CONTINUED FROM PAGE V-6																
1. POLLUTANT AND CAS NUMBER (if available)	2. MARK 'X'			3. EFFLUENT								4. UNITS		5. INTAKE (optional)		
	EPA ID NO.	USE PAT. NO.	CAS NO.	6. MAXIMUM DAILY VALUE		7. MAXIMUM 30 DAY VALUE (if available)		8. LONG TERM AVERAGE VALUE (if available)		LIMITING ANAL. VSFS	A. CONCENTRATION	B. MASS	9. LONG TERM AVERAGE VALUE		10. NO. OF ANAL. VSFS	
				(1) CONCENTRATION	(2) MASS	(1) CONCENTRATION	(2) MASS	(1) CONCENTRATION	(2) MASS				(1) CONCENTRATION	(2) MASS		
GC/MS FRACTION - BASE/NEUTRAL COMPOUNDS (continued)																
228. 1,4-Dichlorobenzene (106-46-7)			X	ND						1				ND	2	
238. 3,3'-Dichlorobenzidine (91-94-1)			X	ND						1				ND	2	
248. Diethyl Phthalate (84-66-2)			X	1 ^a	0.94					1	µg/l	kg/d		<1 ^a	2	
258. Dimethyl Phthalate (131-11-3)			X	ND						1				ND	2	
268. Di-N-Butyl Phthalate (84-74-2)			X	<1 ^a	<0.34					1	µg/l	kg/d		<1 ^a	2	
278. 2,4-Dinitrotoluene (121-14-2)			X	ND						1				ND	2	
288. 2,6-Dinitrotoluene (506-20-2)			X	ND						1				ND	2	
298. Di-N-Octyl Phthalate (117-84-0)			X	ND						1				ND	2	
308. 1,2-Diphenylhydrazine (as Azobenzene) (122-66-7)			X	ND						1				ND	2	
318. Fluoranthene (206-44-0)			X	ND						1				ND	2	
328. Fluorene (88-73-7)			X	ND						1				ND	2	
338. Hexachlorobenzene (118-71-1)			X	ND						1				ND	2	
348. Hexachlorobutadiene (87-68-3)			X	ND						1				ND	2	
358. Hexachlorocyclopentadiene (77-47-4)			X	ND						1				ND	2	
368. Hexachloroethane (67-72-1)			X	ND						1				ND	2	
378. Indeno (1,2,3-cd) Pyrene (193-39-5)			X	ND						1				ND	2	
388. Isophorone (78-59-1)			X	ND						1				ND	2	
398. Naphthalene (91-20-3)			X	ND						1				ND	2	
408. Nitrobenzene (98-95-3)			X	ND						1				ND	2	
418. N-Nitrosodimethylamine (62-75-9)			X	ND						1				ND	2	
428. N-Nitrosodi-N-Propylamine (621-64-7)			X	ND						1				ND	2	

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ND = Not detected

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CONTINUE ON REVER:

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1. POLLUTANT AND CAS NUMBER (if available)				2. MARK 'X'			3. EFFLUENT						4. UNITS		5. INTAKE (optional)		
	a. TEST NO.	b. eq. NO.	c. eq. NO.	a. MAXIMUM DAILY VALUE		b. MAXIMUM 30 DAY VALUE (if available)		c. LONG TERM AVG. VALUE (if available)		d. NO. OF ANAL. YSES	e. CONCENTRATION	f. MASS	g. LONG TERM AVERAGE VALUE		h. NO. OF ANAL. YSES		
				(1) CONCENTRATION	(2) MASS	(1) CONCENTRATION	(2) MASS	(1) CONCENTRATION	(2) MASS				(1) CONCENTRATION	(2) MASS			
GC/MS FRACTION – BASE/NEUTRAL COMPOUNDS (continued)																	
43B. N-Nitro-sulphenylamine (86-30-6)			X	ND						1				ND		2	
44B. Phenanthrene (85-01-8)			X	ND						1				ND		2	
45B. Pyrene (129-00-0)			X	ND						1				ND		2	
46B. 1,2,4- Tri-chlorobenzene (120-82-1)			X	ND						1				ND		2	
GC/MS FRACTION – PESTICIDES																	
1P. Aldrin (309-00-2)			X	ND						1				ND		2	
2P. α -BHC (319-84-6)			X	ND						1				ND		2	
3P. β -BHC (319-85-7)			X	ND						1				ND		2	
4P. γ -BHC (58-89-9)			X	ND						1				ND		2	
5P. δ -BHC (319-86-8)			X	ND						1				ND		2	
6P. Chlordane (57-74-0)			X	ND						1				ND		2	
7P. 4,4'-DDT (50-29-3)			X	ND						1				ND		2	
8P. 4,4'-DDE (72-55-9)			X	ND						1				ND		2	
9P. 4,4'-DDD (72-54-8)			X	ND						1				ND		2	
10P. Dieldrin (60-57-1)			X	ND						1				ND		2	
11P. α -Endosulfan (115-29-7)			X	ND						1				ND		2	
12P. β -Endosulfan (115-29-7)			X	ND						1				ND		2	
13P. Endosulfan Sulfate (1031-07-8)			X	ND						1				ND		2	
14P. Endrin (72-20-8)			X	ND						1				ND		2	
15P. Endrin Aldelyde (7421-91-4)			X	ND						1				ND		2	
16P. Heptachlor (76-44-8)			X	ND						1				ND		2	

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ND = Not detected

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CONTINUED FROM PAGE V-8				EPA I.D. NUMBER (copy from Item 1 of Form 1) SC1890008989				OUTFALL NUMBER C-4				Form Approved OMB No. 158-R0173				
1. POLLUTANT AND CAS NUMBER (if available)	2. MARK 'X'			3. EFFLUENT								4. UNITS		5. INTAKE (optional)		
	A. ANAL. TECH. USED	B. ANAL. METHOD	C. ANAL. DATE	A. MAXIMUM DAILY VALUE		B. MAXIMUM 30 DAY VALUE (if available)		C. LONG TERM AVG. VALUE (if available)		D. NO. OF ANAL. YRS	E. CONCEN- TRATION	F. MASS	G. LONG TERM AVERAGE VALUE		H. NO. OF ANAL. YRS	
				(1) CONCENTRATION	(2) MASS	(1) CONCENTRATION	(2) MASS	(1) CONCENTRATION	(2) MASS				(1) CONCENTRATION	(2) MASS		
GC/MS FRACTION - PESTICIDES (continued)																
17P. Heptachlor Epoxide (1024-57-3)			X	ND						1			ND		2	
18P. PCB-1242 (63469-21-9)			X	ND						1			ND		2	
19P. PCB-1254 (111097-69-1)			X	ND						1			ND		2	
20P. PCB-1221 (111104-28-2)			X	ND						1			ND		2	
21P. PCB-1232 (111141-16-5)			X	ND						1			ND		2	
22P. PCB-1248 (12672-29-6)			X	ND						1			ND		2	
23P. PCB-1260 (111098-82-6)			X	ND						1			ND		2	
24P. PCB-1016 (12674-11-2)			X	ND						1			ND		2	
25P. Toxaphene (8001-35-2)			X	ND						1			ND		2	

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ND = Not detected

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Section V Notes:

- Also present in Laboratory blank.
- Outfall samples (Envirodyne) collected 13-14 January 1981; Savannah River samples collected 24-25 June 1980 (Enwright/Spectrix); and 23-24 September 1989 (Envirodyne).

OUTFALL K-1 USED FOR L-10

PLEASE PRINT OR TYPE IN THE UNSHADED AREAS ONLY. You may report some or all of this information on separate sheets (use the same format) instead of completing these pages. SEE INSTRUCTIONS.

EPA I.D. NUMBER (copy from Form 1 of Form 1)

SC1890008989

Form Approved OMB No. 158-R0173

V. INTAKE AND EFFLUENT CHARACTERISTICS (continued from page 3 of Form 2-C)												OUTFALL NO. K-1 ^b	
PART A - You must provide the results of at least one analysis for every pollutant in this table. Complete one table for each outfall. See instructions for additional details.													
1. POLLUTANT	2. EFFLUENT						3. UNITS (specify if blank)		4. INTAKE (optional)				
	B. MAXIMUM DAILY VALUE		D. MAXIMUM 30 DAY VALUE (if available)		C. LONG TERM AVG. VALUE (if available)		D. NO. OF ANALYSES	B. COEFFICIENT THAT UNIT	D. MASS	A. LONG TERM AVERAGE VALUE		D. NO. OF ANALYSES	
	(1) CONCENTRATION	(2) MASS	(1) CONCENTRATION	(2) MASS	(1) CONCENTRATION	(2) MASS				(1) CONCENTRATION	(2) MASS		
a. Biochemical Oxygen Demand (BOD)	4	0.41					1	mg/l	kg/d				
b. Chemical Oxygen Demand (COD)	5	0.51					1	mg/l	kg/d				
c. Total Organic Carbon (TOC)	3	0.30					1	mg/l	kg/d				
d. Total Suspended Solids (TSS)	<1	<0.10					1	mg/l	kg/d				
e. Ammonia (as N)	<1.0	<0.10					1	mg/l	kg/d				
f. Flow	VALUE	70	VALUE		VALUE		1	l/min		VALUE			
g. Temperature (winter)	VALUE	24.2	VALUE		VALUE	20.7	2	°C		VALUE			
h. Temperature (summer)	VALUE		VALUE		VALUE			°C		VALUE			
i. pH	MINIMUM	6.1	MAXIMUM	6.5			1	STANDARD UNITS					

PART B - Mark "X" in column 2-a for each pollutant you know or have reason to believe is present. Mark "X" in column 2-b for each pollutant you believe to be absent. If you mark column 2-a for any pollutant, you must provide the results of at least one analysis for that pollutant. Complete one table for each outfall. See the instructions for additional details and requirements.

1. POLLUTANT AND CAS NO. (if available)	2. MARK "X"		3. EFFLUENT						4. UNITS		5. INTAKE (optional)			
	a. PRESENT	b. ABSENT	B. MAXIMUM DAILY VALUE		D. MAXIMUM 30 DAY VALUE (if available)		C. LONG TERM AVG. VALUE (if available)		D. NO. OF ANALYSES	B. COEFFICIENT THAT UNIT	D. MASS	A. LONG TERM AVERAGE VALUE		D. NO. OF ANALYSES
			(1) CONCENTRATION	(2) MASS	(1) CONCENTRATION	(2) MASS	(1) CONCENTRATION	(2) MASS				(1) CONCENTRATION	(2) MASS	
a. Bromide (24969-67-9)		X	<2.0	<0.20					1	mg/l	kg/d			
b. Chlorine, Total Residual	X		1.7	0.17			1.1	0.11	2	mg/l	kg/d			
c. Color	X		9						1	Pt-Co Units				
d. Fecal Coliform		X	0						1	No/100 ml				
e. Fluoride (16984-48-8)		X	<0.10	<10					1	mg/l	g/d			
f. Nitrate-Nitrite (as N)		X	0.39	40					1	mg/l	g/d			

ITEM V-B CONTINUED FROM FRONT

ITEM V-11 CONTINUED FROM FRONT														
1. POLLUTANT AND CAS NO. (if available)	2. MARK "X"		3. EFFLUENT						4. UNITS		5. INTAKE (optional)			
	a. ANAL. TYPE	b. ANAL. YEAR	a. MAXIMUM DAILY VALUE		b. MAXIMUM 30 DAY VALUE (if available)		c. LONG TERM AVERAGE VALUE (if available)		d. NO. OF ANAL. YRS	e. CONCENTRATION	f. MASS	g. LONG TERM AVERAGE VALUE (if available)		h. NO. OF ANAL. YRS
			(1) CONCENTRATION	(2) MASS	(1) CONCENTRATION	(2) MASS	(1) CONCENTRATION	(2) MASS				(3) CONCENTRATION	(4) MASS	
p. Hydrogen, Total (organic (as N))		X	<1.0	<0.10					1	mg/ℓ	kg/d			
h. Oil and Grease		X	<10	<1.0					1	mg/ℓ	kg/d			
i. Phosphorus (as P), Total (7723-14-0)		X	0.03	3.0					1	mg/ℓ	g/d			
j. Radioactivity														
(1) Alpha, Total		X	<0.77	<78					1	pCi/ℓ	nCi/d			
(2) Beta, Total		X	2.9 ±	0.29 ±					1	pCi/ℓ	nCi/d			
(3) Radium, Total		X	1.0	0.10					1	pCi/ℓ	nCi/d			
(4) Radium 226, Total		X	<0.41	<42					1	pCi/ℓ	nCi/d			
k. Sulfate (as SO ₄) (14808-79-8)		X	<0.20	<20					1	pCi/ℓ	nCi/d			
l. Sulfide (as S)		X	58	5.9					1	mg/ℓ	kg/d			
m. Sulfide (as S)		X	<1	<0.10					1	mg/ℓ	kg/d			
n. Sulfide (as S)		X	<2	<0.20					1	mg/ℓ	kg/d			
o. Surfactants		X	0.041	4.2					1	mg/ℓ	g/d			
p. Aluminum, Total (7429-90-5)		X	0.4	41					1	mg/ℓ	g/d			
q. Bismuth, Total (7440-38-3)		X	<0.3	<30					1	mg/ℓ	g/d			
r. Boron, Total (7440-42-8)		X	<0.10	<10					1	mg/ℓ	g/d			
s. Cobalt, Total (7440-48-4)		X	0.001	0.10					1	mg/ℓ	g/d			
t. Iron, Total (7439-89-6)	X		0.16	16					1	mg/ℓ	g/d			
u. Magnesium, Total (7439-95-4)	X		1.0	0.10					1	mg/ℓ	kg/d			
v. Molybdenum, Total (7439-98-7)		X	0.002	0.20					1	mg/ℓ	g/d			
w. Manganese, Total (7439-96-5)		X	<0.010	<1.0					1	mg/ℓ	g/d			
x. Tin, Total (7440-31-5)		X	0.139	19					1	mg/ℓ	g/d			
y. Titanium, Total (7440-32-6)		X	<0.02	2.0					1	mg/ℓ	g/d			

EPA I.D. NUMBER (copy from Item 1 of Form 1)	OUTFALL NUMBER
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CONTINUED FROM PAGE 3 OF FORM 2-C

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PART C - If you are a primary industry and this outfall contains process wastewater, refer to Table 2c-2 in the instructions to determine which of the GC/MS fractions you must test for. Mark "X" in column 2-a for all such GC/MS fractions that apply to your industry and for ALL toxic metals, cyanides, and total phenols. If you are not required to mark column 2-a (*secondary industries, non-process wastewater outfalls, and non-required GC/MS fractions*), mark "X" in column 2-b for each pollutant you know or have reason to believe is present. Mark "X" in column 2-c for each pollutant you believe to be absent. If you mark either columns 2-a or 2-b for any pollutant, you must provide the results of at least one analysis for that pollutant. Note that there are seven pages to this part; please review each carefully. Complete one table (*a// seven pages*) for each outfall. See instructions for additional details and requirements.

1. POLLUTANT AND CAS NUMBER (if available)	2. MARK 'X'			3. EFFLUENT						d. NO. OF ANAL. YRS	4. UNITS		5. INTAKE (optional)			
	a. GC/MS FRACTION	b. TOXIC METALS	c. CYANIDES AND PHENOLS	a. MAXIMUM DAILY VALUE		b. MAXIMUM 30 DAY VALUE (if available)		c. LONG TERM AVG. VALUE (if available)			e. CONCENTRATION	f. MASS	g. LONG TERM AVERAGE VALUE		h. NO. OF ANAL. YRS	
				(i) CONCENTRATION	(j) MASS	(i) CONCENTRATION	(j) MASS	(i) CONCENTRATION	(j) MASS				(i) CONCENTRATION	(j) MASS		
METALS, CYANIDE, AND TOTAL PHENOLS																
1M. Antimony, Total (7440-36-0)			X	<0.003	<0.33							1	mg/l	g/d		
2M. Arsenic, Total (7440-38-2)			X	<0.001	<0.10							1	mg/l	g/d		
3M. Beryllium, Total (7440-41-7)			X	<0.001	<0.10							1	mg/l	g/d		
4M. Cadmium, Total (7440-43-9)			X	<0.001	<0.10							1	mg/l	g/d		
5M. Chromium, Total (7440-47-3)			X	0.002	0.20							1	mg/l	g/d		
6M. Copper, Total (7550-50-8)			X	0.010	1.0							1	mg/l	g/d		
7M. Lead, Total (7439-97-6)			X	0.002	0.20							1	mg/l	g/d		
8M. Mercury, Total (7439-97-6)			X	0.0003	30							1	mg/l	mg/d		
9M. Nickel, Total (7440-02-0)			X	<0.001	<0.10							1	mg/l	g/d		
10M. Selenium, Total (7782-49-2)			X	<0.002	<0.20							1	mg/l	g/d		
11M. Silver, Total (7440-22-4)			X	<0.001	<0.10							1	mg/l	g/d		
12M. Thallium, Total (7440-28-0)			X	<0.003	<0.30							1	mg/l	g/d		
13M. Zinc, Total (7440-66-6)		X		<0.005	<0.51							1	mg/l	g/d		
14M. Cyanide, Total (57-12-5)			X	<0.02	<2.0							1	mg/l	g/d		
15M. Phenols, Total			X	<0.002	<0.20							1	mg/l	g/d		
DIOXIN																
2,3,7,8 Tetra chlorodibenzo P. Dioxin (1764 01 6)			X	DESCRIBE RESULTS No peak was detected on the GC-MS scan.												

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CONTINUE ON REVERSE

CONTINUED FROM THE FRONT

1. POLLUTANT AND CAS NUMBER (if available)	2. MARK "X"			3. EFFLUENT						10. HAZARDOUS WASTE	4. UNITS		5. INTAKE (optional)			
	A. USE OF CHEMICAL	B. USE OF FERTILIZER	C. USE OF PESTICIDE	B. MAXIMUM DAILY VALUE		D. MAXIMUM 30 DAY VALUE (if available)		E. LONG TERM AVG. VALUE (if available)			A. CONCENTRATION	B. MASS	C. LONG TERM AVERAGE VALUE		D. NO. OF ANALYSES	
				(1) CONCENTRATION	(2) MASS	(3) CONCENTRATION	(4) MASS	(5) CONCENTRATION	(6) MASS				(1) CONCENTRATION	(2) MASS		
GC/MS FRACTION - VOLATILE COMPOUNDS																
1V. Acrolein (107-02-8)			X	ND							1					
2V. Acrylonitrile (107-13-1)			X	ND							1					
3V. Benzene (71-43-2)			X	<1	<0.10						1	µg/l	g/d			
4V. Bis (Chloromethyl) Ether (542-88-1)			X	ND							1					
5V. Bromoform (75-25-2)			X	ND							1					
6V. Carbon Tetrachloride (56-23-5)			X	ND							1					
7V. Chlorobenzene (108-90-7)			X	ND							1					
8V. Chlorodibromomethane (124-48-1)			X	ND							1					
9V. Chloroethane (75-00-3)			X	ND							1					
10V. 2 Chloroethylvinyl Ether (110-75-8)			X	ND							1					
11V. Chloroform (67-66-3)		X		26	2.6						1	µg/l	g/d			
12V. Dichlorobromomethane (75-27-4)			X	2	0.20						1	µg/l	g/d			
13V. Dichlorodifluoromethane (75-71-8)			X	ND							1					
14V. 1,1-Dichloroethane (75-34-3)			X	ND							1					
15V. 1,2-Dichloroethane (107-06-2)			X	ND							1					
16V. 1,1-Dichloroethylene (75-35-4)			X	ND							1					
17V. 1,2-Dichloropropane (78-87-5)			X	ND							1					
18V. 1,2-Dichloropropylene (542-75-6)			X	ND							1					
19V. Ethylbenzene (100-41-4)			X	ND							1					
20V. Methyl Bromide (74-83-9)			X	ND							1					
21V. Methyl Chloride (74-87-3)			X	ND							1					

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EPA I.D. NUMBER (copy from Item 1 of Form 1) SC1890008989

OUTFALL NUMBER K-1

Form Approved OMB No. 158-R0173

1. POLLUTANT AND CAS NUMBER (if available)	2. MAIN 'X'			3. EFFLUENT				4. UNITS	5. INTAKE (optional)			
	A. ANALYST	B. DATE	C. CORRECTION	6. MAXIMUM DAILY VALUE		7. MAXIMUM 30 DAY VALUE			8. LONG TERM AVG. VALUE		9. LONG TERM AVERAGE VALUE	10. NO. OF ANALYSES
				(1) CONCENTRATION	(2) MASS	(1) CONCENTRATION	(2) MASS		(1) CONCENTRATION	(2) MASS		
GC/MS FRACTION - VOLATILE COMPOUNDS (continued)												
22V. Methylene Chloride (75-09-2)		X		10 ^a	1.0				1	µg/l	g/d	
23V. 1,1,2,2-Tetrachloroethane (79-34-5)			X	ND					1			
24V. Tetrachloroethylene (127-18-4)			X	1 ^a	0.10				1	µg/l	g/d	
25V. Toluene (108-88-3)			X	1 ^a	0.10				1	µg/l	g/d	
26V. 1,2-Trans-Dichloroethylene (156-60-5)			X	ND					1			
27V. 1,1,1-Trichloroethane (71-55-6)			X	ND					1			
28V. 1,1,2-Trichloroethane (79-00-5)			X	ND					1			
29V. Trichloroethylene (79-01-6)			X	ND					1			
30V. Trichlorofluoromethane (75-69-4)			X	ND					1			
31V. Vinyl Chloride (75-01-4)			X	ND					1			
GC/MS FRACTION - ACID COMPOUNDS												
1A. 2-Chlorophenol (95-57-8)			X	ND					1			
2A. 2,4-Dichlorophenol (120-83-2)			X	ND					1			
3A. 2,4-Dimethylphenol (105-67-9)			X	ND					1			
4A. 4,6-Dinitro-O-Cresol (534-52-1)			X	ND					1			
5A. 2,4-Dinitrophenol (51-28-5)			X	ND					1			
6A. 2-Nitrophenol (88-75-5)			X	ND					1			
7A. 4-Nitrophenol (100-02-7)			X	ND					1			
8A. P-Chloro M-Cresol (59-50-7)			X	ND					1			
9A. Pentachlorophenol (87-86-5)			X	ND					1			
10A. Phenol (108-95-2)			X	ND					1			
11A. 2,4,6-Trichlorophenol (88-06-2)			X	ND					1			

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ND = Not detected

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CONTINUED FROM THE FRONT

1. POLLUTANT AND CAS NUMBER (if available)				2. MARK 'X'			3. EFFLUENT						4. UNITS		5. INTAKE (optional)		
				A. MAXIMUM DAILY VALUE		B. MAXIMUM 30 DAY VALUE (if available)		C. LONG TERM AVG. VALUE (if available)		D. NO. OF ANAL. YRS.	A. CONCENTRATION	B. MASS	E. LONG TERM AVERAGE VALUE		F. NO. OF ANAL. YRS.		
				(1) CONCENTRATION	(2) MASS	(1) CONCENTRATION	(2) MASS	(1) CONCENTRATION	(2) MASS				(1) CONCENTRATION	(2) MASS			
GC/MS FRACTION - BASE/NEUTRAL COMPOUNDS																	
10. Acenaphthene (83-32-9)			X	ND						1							
20. Acenaphthylene (208-96-8)			X	ND						1							
30. Anthracene (120-12-7)			X	ND						1							
40. Benzidine (92-87-5)			X	ND						1							
50. Benzo (a) Anthracene (56-55-3)			X	ND						1							
60. Benzo (a) Pyrene (50-32-8)			X	ND						1							
70. 3,4-Benzofluoranthene (205-99-2)			X	ND						1							
80. Benzo (ghi) Perylene (191-24-2)			X	ND						1							
90. Benzo (k) Fluoranthene (207-00-9)			X	ND						1							
100. Bis (2-Chloroethoxy) Methane (111-91-1)			X	ND						1							
110. Bis (2-Chloroethyl) Ether (111-44-4)			X	ND						1							
120. Bis (2-Chloroisopropyl) Ether (39638-32-9)			X	ND						1							
130. Bis (2-Ethylhexyl) Phthalate (117-81-7)			X	<1	<0.10					1	ug/l	g/d					
140. 4-Bromophenyl Phenyl Ether (101-55-3)			X	ND						1							
150. Butyl Benzyl Phthalate (85-68-7)			X	ND						1							
160. 2-Chloronaphthalene (91-50-7)			X	ND						1							
170. 4-Chlorophenyl Phenyl Ether (7005-72-3)			X	ND						1							
180. Chrysene (218-01-9)			X	ND						1							
190. Dihenzo (a,h) Anthracene (53-70-3)			X	ND						1							
200. 1,2-Dichlorobenzene (95-50-1)			X	ND						1							
210. 1,3-Dichlorobenzene (541-73-1)			X	ND						1							

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ND = Not detected

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EPA I.D. NUMBER (copy from Item 1 of Form 1)

SC1890008989

OUTFALL NUMBER

K-1

EPA Approved OMB No. 158-R0173

1. POLLUTANT AND CAS NUMBER (if available)	2. MATRIX			3. EFFLUENT						11. HAZARDOUS WASTE CODE	4. UNITS		5. INTAKE (optional)		
	TYPE OF WASTE	ID NO.	ANALYST'S SIGNATURE	A. MAXIMUM DAILY VALUE		B. MAXIMUM 30 DAY VALUE (if available)		C. LONG TERM AVG. VALUE (if available)			A. CONCENTRATION	B. MASS	A. LONG TERM AVG. VALUE		B. NO. OF ANAL YSES
				(1) CONCENTRATION	(2) MASS	(1) CONCENTRATION	(2) MASS	(1) CONCENTRATION	(2) MASS				(1) CONCENTRATION	(2) MASS	
GC/MS FRACTION - BASE/NEUTRAL COMPOUNDS (continued)															
22B. 1,4-Dichlorobenzene (106-46-7)			X	ND							1				
23B. 3,3'-Dichlorobenzidine (91-94-1)			X	ND							1				
24B. Diethyl Phthalate (84-66-2)			X	<1 ^a	<0.10						1	µg/L	g/d		
25B. Dimethyl Phthalate (131-11-3)			X	ND							1				
26B. Di-N-Butyl Phthalate (84-74-2)			X	<1 ^a	<0.10						1	µg/L	g/d		
27B. 2,4-Dinitrotoluene (121-14-2)			X	ND							1				
28B. 2,6-Dinitrotoluene (806-20-2)			X	ND							1				
29B. Di-N-Octyl Phthalate (117-84-0)			X	ND							1				
30B. 1,2-Diphenylhydrazine (as Azobenzene) (122-66-7)			X	ND							1				
31B. Fluoranthene (206-44-0)			X	ND							1				
32B. Fluorene (86-73-7)			X	ND							1				
33B. Hexachlorobenzene (118-71-1)			X	ND							1				
34B. Hexachlorobutadiene (87-68-3)			X	ND							1				
35B. Hexachlorocyclopentadiene (77-47-4)			X	ND							1				
36B. Hexachloroethane (67-72-1)			X	ND							1				
37B. Indeno (1,2,3-cd) Pyrene (193-39-5)			X	ND							1				
38B. Isophorone (78-59-1)			X	ND							1				
39B. Naphthalene (91-20-3)			X	ND							1				
40B. Nitrobenzene (98-95-3)			X	ND							1				
41B. N-Nitrosodimethylamine (62-75-9)			X	ND							1				
42B. N-Nitrosodi-N-Propylamine (621-64-7)			X	ND							1				

EPA F 510-2C (6-80)

ND = Not detected

GE V-268

CONTINUED ON REVERSE

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CONTINUED FROM THE FRONT																		
1. POLLUTANT AND CAS NUMBER (if available)	2. MATRIX			3. EFFLUENT								4. UNITS		5. INTAKE (optional)				
	a. effluent type	b. effluent flow rate	c. effluent concentration	a. MAXIMUM DAILY VALUE		b. MAXIMUM 30 DAY VALUE (if available)		c. LONG TERM AVERAGE VALUE (if available)		a. CONCENTRATION	b. MASS	c. LONG TERM AVERAGE VALUE		d. FREQUENCY ANAL. YRS				
				(1) CONCENTRATION	(2) MASS	(1) CONCENTRATION	(2) MASS	(1) CONCENTRATION	(2) MASS			(1) CONCENTRATION	(2) MASS					
GC/MS FRACTION - BASE/NEUTRAL COMPOUNDS (continued)																		
43B. N-Nitrosodiphenylamine (86-30-6)			X	ND											1			
44B. Phenanthrene (85-01-0)			X	ND											1			
45B. Pyrene (129-00-0)			X	ND											1			
46B. 1,2,4-Trichlorobenzene (120-02-1)			X	ND											1			
GC/MS FRACTION - PESTICIDES																		
1P. Aldrin (309-00-2)			X	ND											1			
2P. α -BHC (319-84-6)			X	ND											1			
3P. β -BHC (319-05-7)			X	ND											1			
4P. γ -BHC (58-09-9)			X	ND											1			
5P. δ -BHC (319-06-8)			X	ND											1			
6P. Chlordane (57-74-9)			X	ND											1			
7P. 4,4'-DDT (50-79-3)			X	ND											1			
8P. 4,4'-DDE (72-55-9)			X	ND											1			
9P. 4,4'-DDD (72-54-8)			X	ND											1			
10P. Dieldrin (60-57-1)			X	ND											1			
11P. α -Endosulfan (115-29-7)			X	ND											1			
12P. β -Endosulfan (115-29-7)			X	ND											1			
13P. Endosulfan Sulfate (1031-07-8)			X	ND											1			
14P. Endrin (72-20-0)			X	ND											1			
15P. Endrin Aldehyde (7471-93-4)			X	ND											1			
16P. Heptachlor (76-44-0)			X	ND											1			

EPA Form 3510-2C (6-00)

ND = Not detected

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1. POLLUTANT AND CAS NUMBER (if available)		2. MARCH 'A'			3. EFFLUENT				4. UNITS		5. INTAKE (optional)	
		TEST DATE	INSTRUMENT	LAB. NO.	A. MAXIMUM DAILY VALUE		B. MAXIMUM 30 DAY VALUE (if available)		C. LONG TERM AVG. VALUE (if available)		D. CONC. VS.	E. CONC. VS.
					(1) CONCENTRATION	(2) MASS	(1) CONCENTRATION	(2) MASS	(1) CONCENTRATION	(2) MASS		
GC/MS FRACTION - PESTICIDES (continued)												
17P. Heptachlor Epoxide (1024-57-3)				X	ND						1	
18P. PCB-1242 (53469-21-9)				X	ND						1	
19P. PCB-1254 (11097-69-1)				X	ND						1	
20P. PCB-1221 (11104-28-2)				X	ND						1	
21P. PCB-1232 (11141-16-5)				X	ND						1	
22P. PCB-1248 (12672-29-8)				X	ND						1	
23P. PCB-1260 (11096-82-5)				X	ND						1	
24P. PCB-1016 (12674-11-2)				X	ND						1	
25P. Toxaphene (8001-35-2)				X	ND						1	

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ND = Not detected

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Section V Notes:

- a) Also present in laboratory blank.
b) Samples collected 21-22 October 1980.

OUTFALL K-3 USED FOR L-3

PLEASE PRINT OR TYPE IN THE UNSHADED AREAS ONLY. You may report some or all of this information on separate sheets (use the same format) instead of completing these pages. SEE INSTRUCTIONS.

EPA I.D. NUMBER (copy from Item 1 of Form 1)

SC1890008989

Form Approved OMB No. 158-R0173

V. INTAKE AND EFFLUENT CHARACTERISTICS (continued from page 3 of Form 2-C)

OUTFALL NO.

K-3^b

PART A - You must provide the results of at least one analysis for every pollutant in this table. Complete one table for each outfall. See instructions for additional details.

1. POLLUTANT	2. EFFLUENT						4. NO. OF ANALYSES	4. UNITS (if blank)		5. INTAKE (optional)		6. NO. OF ANALYSES
	a. MAXIMUM DAILY VALUE		b. MAXIMUM 30 DAY VALUE (if available)		c. LONG TERM AVG. VALUE (if available)			a. CONCENTRATION	b. MASS	a. LONG TERM AVERAGE VALUE		
	(1) CONCENTRATION	(2) MASS	(1) CONCENTRATION	(2) MASS	(1) CONCENTRATION	(2) MASS				(1) CONCENTRATION	(2) MASS	
a. Biochemical Oxygen Demand (BOD)	5	12.4					1	mg/l	kg/d			
b. Chemical Oxygen Demand (COD)	8	19.8					1	mg/l	kg/d			
c. Total Organic Carbon (TOC)	4	9.9					1	mg/l	kg/d			
d. Total Suspended Solids (TSS)	4	9.9					1	mg/l	kg/d			
e. Ammonia (as N)	<1.0	<2.5					1	mg/l	kg/d			
f. Flow	VALUE 1720		VALUE		VALUE		1	l/min		VALUE		
g. Temperature (winter)	VALUE 24.2		VALUE		VALUE 18.4		2	°C		VALUE		
h. Temperature (summer)	VALUE		VALUE		VALUE			°C		VALUE		
i. pH	MINIMUM 6.0	MAXIMUM 7.8	MINIMUM	MAXIMUM			1	STANDARD UNITS				

PART B - Mark "X" in column 2-a for each pollutant you know or have reason to believe is present. Mark "X" in column 2-b for each pollutant you believe to be absent. If you mark column 2-a for any pollutant, you must provide the results of at least one analysis for that pollutant. Complete one table for each outfall. See the instructions for additional details and requirements.

1. POLLUTANT AND CAS NO. (if available)	2. MARK "X"		3. EFFLUENT						4. NO. OF ANALYSES	4. UNITS		5. INTAKE (optional)		6. NO. OF ANALYSES
	a. PRESENT	b. ABSENT	a. MAXIMUM DAILY VALUE		b. MAXIMUM 30 DAY VALUE (if available)		c. LONG TERM AVG. VALUE (if available)			a. CONCENTRATION	b. MASS	a. LONG TERM AVERAGE VALUE		
			(1) CONCENTRATION	(2) MASS	(1) CONCENTRATION	(2) MASS	(1) CONCENTRATION	(2) MASS				(1) CONCENTRATION	(2) MASS	
a. Bromide (24959-67-9)		X	<2.0	<4.9					1	mg/l	kg/d			
b. Chlorine, Total Residual	X		1.6	4.0			1.4	3.4	2	mg/l	kg/d			
c. Color	X		16						1	Pt-Co Units				
d. Fecal Coliform		X	0						1	No/100 ml				
e. Fluoride (16984-48-8)		X	<0.10	<0.25					1	mg/l	kg/d			
f. Nitrate-Nitrite (as N)		X	0.43	1.07					1	mg/l	kg/d			

ITEM V-B CONTINUED FROM FRONT

1. POLLUTANT AND CAS NO. (If available)	2. MARK 'X'		3. EFFLUENT								4. UNITS		5. INTAKE (optional)		
	A. RE- LISHED PER SENT	B. RE- LISHED PER SENT	B. MAXIMUM DAILY VALUE		D. MAXIMUM 30 DAY VALUE (If available)		E. LONG TERM AVERAGE VALUE (If available)		H. NO. OF ANAL- YSES	I. CONCENT- RATION	J. MASS	G. LONG TERM AVERAGE VALUE		K. NO. OF ANAL- YSES	
			(1) CONCENTRATION	(1) MASS	(1) CONCENTRATION	(1) MASS	(1) CONCENTRATION	(1) MASS				(1) CONCENTRATION	(1) MASS		
g. Nitrogen, Total Organic (as N)		X	<1.0	<2.5					1	mg/l	kg/d				
h. Oil and Grease		X	<10	<24.7					1	mg/l	kg/d				
i. Phosphorus (as P), Total (7723-14-0)		X	0.03	74					1	mg/l	g/d				
j. Radioactivity															
(1) Alpha, Total		X	<0.78	<1.9					1	pCi/l	µCi/d				
(2) Beta, Total		X	3.0 ± 1.0	7.4 ± 2.5					1	pCi/l	µCi/d				
(3) Radium, Total		X	<0.38	<0.94					1	pCi/l	µCi/d				
(4) Radium 226, Total		X	0.25 ± 0.14	0.62 ± 0.35					1	pCi/l	µCi/d				
k. Sulfate (as SO ₄) (14800-79-8)		X	28	69.3					1	mg/l	kg/d				
l. Sulfide (as S)		X	<1	<2.5					1	mg/l	kg/d				
m. Sulfite (as SO ₃) (14266-45-3)		X	<2	<4.9					1	mg/l	kg/d				
n. Surfactants		X	<0.025	<62					1	mg/l	g/d				
o. Aluminum, Total (7429-90-5)		X	0.5	1.2					1	mg/l	kg/d				
p. Barium, Total (7440-39-3)		X	<0.3	<0.74					1	mg/l	kg/d				
q. Boron, Total (7440-42-8)		X	0.10	0.25					1	mg/l	kg/d				
r. Cobalt, Total (7440-48-4)		X	0.033	82					1	mg/l	g/d				
s. Iron, Total (7439-89-6)	X		<0.04	<99					1	mg/l	g/d				
t. Magnesium, Total (7439-95-4)	X		1.0	2.5					1	mg/l	kg/d				
u. Molybdenum, Total (7439-98-7)		X	<0.001	<2.5					1	mg/l	g/d				
v. Manganese, Total (7439-96-5)		X	<0.010	<25					1	mg/l	g/d				
w. Tin, Total (7440-31-5)		X	0.039	96					1	mg/l	g/d				
x. Titanium, Total (7440-32-6)		X	<0.02	<50					1	mg/l	g/d				

EPA I.D. NUMBER (copy from Item 1 of Form 1)	OUTFALL NUMBER
SC1890008989	K-3

CONTINUED FROM PAGE 3 OF FORM 2-C

Form Approved OMB No. 150-R0173

PART C - If you are a primary industry and this outfall contains process wastewater, refer to Table 2c-2 in the instructions to determine which of the GC/MS fractions you must test for. Mark "X" in column 2-a for all such GC/MS fractions that apply to your industry and for ALL toxic metals, cyanides, and total phenols. If you are not required to mark column 2-a (secondary industries, non-process wastewater outfalls, and non-required GC/MS fractions), mark "X" in column 2-b for each pollutant you know or have reason to believe is present. Mark "X" in column 2-c for each pollutant you believe to be absent. If you mark either columns 2-a or 2-b for any pollutant, you must provide the results of at least one analysis for that pollutant. Note that there are seven pages to this part; please review each carefully. Complete one table (all seven pages) for each outfall. See instructions for additional details and requirements.

1. POLLUTANT AND CAS NUMBER (if available)	2. MARK 'X'			3. EFFLUENT						4. UNITS	5. INTAKE (optional)				
	Direct Discharge	Process Wastewater	Cyanide	6. MAXIMUM DAILY VALUE		7. MAXIMUM 30 DAY VALUE (if available)		8. LONG TERM AVERAGE VALUE (if available)			9. CONCENTRATION	10. MASS	11. LONG TERM AVERAGE VALUE		12. NO. OF ANALYSES
				(1) CONCENTRATION	(2) MASS	(1) CONCENTRATION	(2) MASS	(1) CONCENTRATION	(2) MASS				(1) CONCENTRATION	(2) MASS	
METALS, CYANIDE, AND TOTAL PHENOLS															
1M. Antimony, Total (7440-36-0)			X	<0.003	<7.4										
2M. Arsenic, Total (7440-38-2)			X	<0.001	<2.5										
3M. Beryllium, Total (7440-41-7)			X	<0.001	<2.5										
4M. Cadmium, Total (7440-43-9)			X	<0.001	<2.5										
5M. Chromium, Total (7440-47-3)			X	<0.001	<2.5										
6M. Copper, Total (7550-50-8)			X	<0.010	<25										
7M. Lead, Total (7439-97-6)			X	0.002	4.9										
8M. Mercury, Total (7439-97-8)			X	<0.0002	<0.49										
9M. Nickel, Total (7440-02-0)			X	<0.001	<2.5										
10M. Selenium, Total (7782-49-2)			X	<0.002	<4.9										
11M. Silver, Total (7440-22-4)			X	<0.001	<2.5										
12M. Thallium, Total (7440-28-0)			X	<0.003	<7.4										
13M. Zinc, Total (7440-66-6)		X		0.009	22										
14M. Cyanide, Total (57-12-5)			X	<0.02	<49										
15M. Phenols, Total			X	0.002	4.9										
DIOXIN															
2,3,7,8-Tetrachlorodibenzo-P-Dioxin (1764-01-6)			X	DESCRIBE RESULTS No peak was detected on the GC-MS scan.											

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1. POLLUTANT AND CAS NUMBER (if available)	2. MARK 'X'			3. EFFLUENT						NO. OF ANAL. YSES	4. UNITS		5. INTAKE (optional)			
	ANAL. YSES	CONCENTRATION	D. MASS	B. MAXIMUM DAILY VALUE		C. MAXIMUM 30 DAY VALUE (if available)		E. LONG TERM AVERAGE VALUE (if available)			CONCENTRATION	D. MASS	F. LONG TERM AVERAGE VALUE		NO. OF ANAL. YSES	
				(1) CONCENTRATION	(2) MASS	(1) CONCENTRATION	(2) MASS	(1) CONCENTRATION	(2) MASS				(1) CONCENTRATION	(2) MASS		
GC/MS FRACTION - VOLATILE COMPOUNDS																
1V. Acrolein (107-02-8)				X	ND										1	
2V. Acrylonitrile (107-13-1)				X	ND										1	
3V. Benzene (71-43-2)				X	ND										1	
4V. Bis (Chloromethyl) Ether (542-88-1)				X	ND										1	
5V. Bromoform (75-25-2)				X	ND										1	
6V. Carbon Tetrachloride (56-23-5)				X	ND										1	
7V. Chlorobenzene (108-90-7)				X	ND										1	
8V. Chlorodibromomethane (124-48-1)				X	ND										1	
9V. Chloroethane (75-00-3)				X	ND										1	
10V. 2-Chloroethylvinyl Ether (110-75-8)				X	ND										1	
11V. Chloroform (67-66-3)				X	35	87									1	µg/l g/d
12V. Dichlorobromomethane (75-27-4)				X	<1	<2.5									1	µg/l g/d
13V. Dichlorodifluoromethane (75-71-8)				X	ND										1	
14V. 1,1-Dichloroethane (75-34-3)				X	ND										1	
15V. 1,2-Dichloroethane (107-06-2)				X	ND										1	
16V. 1,1-Dichloroethylene (75-35-4)				X	ND										1	
17V. 1,2-Dichloropropene (78-87-5)				X	ND										1	
18V. 1,2-Dichloropropylene (542-75-6)				X	ND										1	
19V. Ethylbenzene (100-41-4)				X	ND										1	
20V. Methyl Bromide (74-83-9)				X	ND										1	
21V. Methyl Chloride (74-87-3)				X	ND										1	

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ND = Not detected

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EPA I.D. NUMBER (copy from Item 1 of Form 1)
SC1890008989OUTFALL NUMBER
K-3

Form Approved OMB No. 158-R0173

1. POLLUTANT AND CAS NUMBER (If available)	2. MARK 'X'			3. EFFLUENT						4. UNITS	5. INTAKE (optional)				
	A. TEST METHOD	B. DETECTION LIMIT	C. CONC. UNIT	A. MAXIMUM DAILY VALUE		B. MAXIMUM 15 DAY VALUE (If available)		C. LONG TERM AVG. VALUE (If available)			D. CONCENTRATION	E. MASS	F. LONG TERM AVERAGE VALUE		G. NO. OF ANAL. YES
				(i) CONCENTRATION	(ii) MASS	(i) CONCENTRATION	(ii) MASS	(i) CONCENTRATION	(ii) MASS				(i) CONCENTRATION	(ii) MASS	
GC/MS FRACTION - VOLATILE COMPOUNDS (continued)															
22V. Methylene Chloride (75-09-2)			X	<1 ^a	<2.5					1	µg/l	g/d			
23V. 1,1,2,2-Tetrachloroethane (79-34-5)			X	ND						1					
24V. Tetrachloroethylene (127-18-4)			X	ND						1					
25V. Toluene (108-88-3)			X	<1 ^a	<2.5					1	µg/l	g/d			
26V. 1,2-Dichloroethylene (166-60-5)			X	ND						1					
27V. 1,1,1-Trichloroethane (71-55-6)			X	ND						1					
28V. 1,1,2-Trichloroethane (79-00-6)			X	ND						1					
29V. Trichloroethylene (79-01-6)			X	ND						1					
30V. Trichlorofluoromethane (78-69-4)			X	ND						1					
31V. Vinyl Chloride (75-01-4)			X	ND						1					
GC/MS FRACTION - ACID COMPOUNDS															
1A. 2-Chlorophenol (98-57-8)			X	ND						1					
2A. 2,4-Dichlorophenol (120-83-2)			X	ND						1					
3A. 2,4-Dimethylphenol (105-67-9)			X	ND						1					
4A. 4,6-Dinitro-O-Cresol (634-62-1)			X	ND						1					
5A. 2,4-Dinitrophenol (51-28-5)			X	ND						1					
6A. 2-Nitrophenol (68-79-5)			X	ND						1					
7A. 4-Nitrophenol (100-02-7)			X	ND						1					
8A. P-Chloro-M-Cresol (59-60-7)			X	ND						1					
9A. Pentachlorophenol (87-86-5)			X	ND						1					
10A. Phenol (108-95-2)			X	ND						1					
11A. 2,4,6-Trichlorophenol (88-06-2)			X	ND						1					

EPA Form 3510-2C (8-80)

ND = Not detected

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1. POLLUTANT AND CAS NUMBER (if available)	2. MARK 'X'			3. EFFLUENT						4. UNITS		5. INTAKE (optional)		
	A. ANALYST'S SIGNATURE	B. ANALYST'S NAME	C. ANALYST'S TITLE	A. MAXIMUM DAILY VALUE		B. MAXIMUM 30 DAY VALUE (if available)		C. LONG TERM AVERAGE VALUE (if available)		A. CONCENTRATION	B. MASS	A. LONG TERM AVERAGE VALUE		B. NO. OF ANALYSES
				(1) CONCENTRATION	(2) MASS	(1) CONCENTRATION	(2) MASS	(1) CONCENTRATION	(2) MASS			(1) CONCENTRATION	(2) MASS	
GC/MS FRACTION - BASE/NEUTRAL COMPOUNDS														
10. Acenaphthene (83-32-9)			X	ND										1
20. Acenaphthylene (208-96-8)			X	ND										1
30. Anthracene (120-12-7)			X	ND										1
40. Benzidine (92-87-6)			X	ND										1
50. Benzo (a) Anthracene (56-55-3)			X	ND										1
60. Benzo (a) Pyrene (50-32-8)			X	ND										1
70. 3,4-Benzofluoranthene (205-99-2)			X	ND										1
80. Benzo (ghi) Perylene (191-24-2)			X	ND										1
90. Benzo (k) Fluoranthene (207-08-9)			X	ND										1
100. Bis (2-Chloroethyl) Methane (111-91-1)			X	ND										1
110. Bis (2-Chloroethyl) Ether (111-44-4)			X	ND										1
120. Bis (2-Chloroisopropyl) Ether (39638-32-9)			X	ND										1
130. Bis (2-Ethylhexyl) Phthalate (117-81-7)			X	ND										1
140. 4-Bromophenyl Phenyl Ether (101-55-3)			X	ND										1
150. Butyl Benzyl Phthalate (85-68-7)			X	ND										1
160. 7-Chloronaphthalene (91-58-7)			X	ND										1
170. 4-Chlorophenyl Phenyl Ether (7005-72-3)			X	ND										1
180. Chrysene (218-01-9)			X	ND										1
190. Dibenzo (a,h) Anthracene (53-70-3)			X	ND										1
200. 1,2-Dichlorobenzene (95-50-1)			X	ND										1
210. 1,3-Dichlorobenzene (541-73-1)			X	ND										1

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ND = Not detected

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EPA I.D. NUMBER (copy from Item 1 of Form 1) SC1890008989

OUTFALL NUMBER K-3

Form Approved OMB No. 158 R0173

1. POLLUTANT AND CAS NUMBER (if available)	2. MAIN USE			3. EFFLUENT				5. ANALYSIS	4. UNITS		5. INTAKE (optional)				
	A. CONCENTRATION	B. MASS	C. USE	3. MAXIMUM DAILY VALUE		3. MAXIMUM 30 DAY VALUE (if available)			3. LONG TERM AVG. VALUE (if available)		A. CONCENTRATION	B. MASS	5. INTAKE (optional)		
				(1) CONCENTRATION	(2) MASS	(1) CONCENTRATION	(2) MASS		(1) CONCENTRATION	(2) MASS			(1) CONCENTRATION	(2) MASS	
GC/MS FRACTION - BASE/NEUTRAL COMPOUNDS (continued)															
220. 1,4-Dichlorobenzene (106-46-7)			X	ND											
238. 3,3'-Dichlorobenzidine (91-94-1)			X	ND											
240. Diethyl Phthalate (84-66-2)			X	ND											
250. Dimethyl Phthalate (131-11-3)			X	ND											
260. Di-N-Butyl Phthalate (84-74-2)			X	ND											
278. 2,4-Dinitrotoluene (121-14-2)			X	ND											
288. 2,6-Dinitrotoluene (606-20-2)			X	ND											
290. Di-N-Octyl Phthalate (117-84-0)			X	ND											
300. 1,2-Diphenylhydrazine (as Arobenzene) (122-66-7)			X	ND											
318. Fluoranthene (206-44-0)			X	ND											
328. Fluorene (86-73-7)			X	ND											
330. Hexachlorobenzene (118-71-1)			X	ND											
348. Hexachlorobutadiene (87-68-3)			X	ND											
358. Hexachlorocyclopentadiene (77-47-4)			X	ND											
360. Hexachloroethane (67-72-1)			X	ND											
370. Indeno (1,2,3-cd) Pyrene (193-39-5)			X	ND											
380. Isophorone (78-59-1)			X	ND											
390. Naphthalene (91-20-3)			X	ND											
400. Nitrobenzene (98-95-3)			X	ND											
410. N Nitro sodiumethylamine (62-75-0)			X	ND											
420. N Nitrosodi-n-Propylamine (62-1-64-7)			X	ND											

EPA Form 3510-2C (6-EO)

ND = Not detected

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CONTINUE ON REVERSE

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CONTINUED FROM THE FRONT

1. POLLUTANT AND CAS NUMBER (if available)	2. MARK "X"			3. EFFLUENT						4. UNITS		5. INTAKE (optional)			
	A. TEST ING SP. OVR AM	B. TEST ING SP. OVR AM	C. TEST ING SP. OVR AM	6. MAXIMUM DAILY VALUE		D. MAXIMUM 30 DAY VALUE (if available)		E. LONG TERM AVERAGE VALUE (if available)		F. NO. OF ANALYSES	G. CONCENTRATION	H. MASS	I. LONG TERM AVERAGE VALUE		J. NO. OF ANALYSES
				(1) CONCENTRATION	(2) MASS	(1) CONCENTRATION	(2) MASS	(1) CONCENTRATION	(2) MASS				(1) CONCENTRATION	(2) MASS	
GC/MS FRACTION - BASE/NEUTRAL COMPOUNDS (continued)															
43B. N Nitro-sodiphenylamine (86-30-6)			X	ND						1					
44D. Phenanthrene (85-01-8)			X	ND						1					
45B. Pyrene (120-00-0)			X	ND						1					
46D. 1,2,4 - Tri-chlorobenzene (120-82-1)			X	ND						1					
GC/MS FRACTION - PESTICIDES															
1P. Aldrin (309-00-2)			X	ND						1					
2P. α -BHC (310-84-6)			X	ND						1					
3P. β -BHC (310-85-7)			X	ND						1					
4P. γ -BHC (58-89-9)			X	ND						1					
5P. δ -BHC (319-86-8)			X	ND						1					
6P. Chlordane (57-74-9)			X	ND						1					
7P. 4,4'-DDT (50-29-3)			X	ND						1					
8P. 4,4'-DDE (72-55-9)			X	ND						1					
9P. 4,4'-DDD (72-54-8)			X	ND						1					
10P. Dieldrin (60-57-1)			X	ND						1					
11P. α -Endosulfan (115-29-7)			X	ND						1					
12P. β -Endosulfan (115-29-7)			X	ND						1					
13P. Endosulfan Sulfate (1031-07-8)			X	ND						1					
14P. Endrin (72-20-8)			X	ND						1					
15P. Endrin Aldehyde (7421-93-4)			X	ND						1					
16P. Heptachlor (76-44-0)			X	ND						1					

EPA Form 3510-2C (6-80)

ND = Not detected

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CONTINUED FROM PAGE V-8				EPA I.D. NUMBER (copy from Item 1 of Form 1)		OUTFALL NUMBER		Form Approved OMB No. 158-R0173						
				SC1890008989		K-3								
1. POLLUTANT AND CAS NUMBER (if available)	2. MARK 'X'			3. EFFLUENT						4. UNITS	5. INTAKE (optional)			
	A. ANAL. NO.	B. DATE	C. ANAL. NO.	A. MAXIMUM DAILY VALUE		B. MAXIMUM 30 DAY VALUE (if available)		C. LONG TERM AVG. VALUE (if available)			D. NO. OF ANAL. YRS	E. LONG TERM AVERAGE VALUE		F. NO. OF ANAL. YRS
				(1) CONCENTRATION	(2) MASS	(1) CONCENTRATION	(2) MASS	(1) CONCENTRATION	(2) MASS			(1) CONCENTRATION	(2) MASS	
GC/MS FRACTION - PESTICIDES (continued)														
17P. Heptachlor Epoxide (1024-57-3)			X	ND							1			
18P. PCB-1242 (53469-21-9)			X	ND							1			
19P. PCB-1264 (11097-69-1)			X	ND							1			
20P. PCB-1221 (11104-28-2)			X	ND							1			
21P. PCB-1232 (11141-16-5)			X	ND							1			
22P. PCB-1248 (12672-29-6)			X	ND							1			
23P. PCB-1260 (11098-82-5)			X	ND							1			
24P. PCB-1018 (12674-11-2)			X	ND							1			
25P. Toxaphene (8001-35-2)			X	ND							1			

EPA Form 3510-2C (6-80)

ND = Not detected

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Section V Notes:

- a) Also present in laboratory blank.
 b) Samples collected 21-22 October 1980.

OUTFALL K-8 USED FOR L-8

PLEASE PRINT OR TYPE IN THE UNSHADED AREAS ONLY. You may report some or all of this information on separate sheets (use the same format) instead of completing these pages.
SEE INSTRUCTIONS.

EPA I.D. NUMBER (copy from Item 1 of Form 1)

SC1890008989

Form Approved OMB No. 158-00173

V. INTAKE AND EFFLUENT CHARACTERISTICS (continued from page 3 of Form 2-C)

OUTFALL NO.
K-8^b

PART A - You must provide the results of at least one analysis for every pollutant in this table. Complete one table for each outfall. See instructions for additional details.

1. POLLUTANT	2. EFFLUENT				3. LONG TERM AVG. VALUE (if available)		4. NO. OF ANALYSES	5. UNITS (if of block)		6. INTAKE (optional)		
	A. MAXIMUM DAILY VALUE		B. MAXIMUM 30 DAY VALUE (if available)		C. LONG TERM AVG. VALUE (if available)			A. CONCENTRATION	B. MASS	7. LONG TERM AVERAGE VALUE		B. NO. OF ANALYSES
	(1) CONCENTRATION	(2) MASS	(1) CONCENTRATION	(2) MASS	(1) CONCENTRATION	(2) MASS				(1) CONCENTRATION	(2) MASS	
a. Biochemical Oxygen Demand (BOD)	<2	<9.3					1	mg/l	kg/d			
b. Chemical Oxygen Demand (COD)	12	55.5					1	mg/l	kg/d			
c. Total Organic Carbon (TOC)	7	32.4					1	mg/l	kg/d			
d. Total Suspended Solids (TSS)	4	18.5					1	mg/l	kg/d			
e. Ammonia (as N)	<1.0	<4.6					1	mg/l	kg/d			
f. Flow	VALUE 3220		VALUE		VALUE		1	l/min		VALUE		
g. Temperature (winter)	VALUE 20.8		VALUE		VALUE 17.5		2	°C		VALUE		
h. Temperature (summer)	VALUE		VALUE		VALUE			°C		VALUE		
i. pH	MINIMUM 6.0	MAXIMUM 6.4	MINIMUM	MAXIMUM			1	STANDARD UNITS				

PART B - Mark "X" in column 2-a for each pollutant you know or have reason to believe is present. Mark "X" in column 2-b for each pollutant you believe to be absent. If you mark column 2-a for any pollutant, you must provide the results of at least one analysis for that pollutant. Complete one table for each outfall. See the instructions for additional details and requirements.

1. POLLUTANT AND CAS NO. (if available)	2. MARK "X"		3. EFFLUENT				4. NO. OF ANALYSES	5. UNITS		6. INTAKE (optional)			
	a. PRESENT	b. ABSENT	A. MAXIMUM DAILY VALUE		B. MAXIMUM 30 DAY VALUE (if available)			C. LONG TERM AVG. VALUE (if available)	A. CONCENTRATION	B. MASS	7. LONG TERM AVERAGE VALUE		B. NO. OF ANALYSES
			(1) CONCENTRATION	(2) MASS	(1) CONCENTRATION	(2) MASS					(1) CONCENTRATION	(2) MASS	
a. Bromide (24959-67-9)		X	<2.0	<9.3									
b. Chlorine, Total Residual	X		0.15	0.69				1	mg/l	kg/d			
c. Color	X		22					1	Pt-Co Units				
d. Fecal Coliform		X	2					1	No./100 ml				
e. Fluoride (16984-49-1)		X	<0.10	<0.46				1	mg/l	kg/d			
f. Nitrate-Nitrite (as N)	X		0.51	2.4				1	mg/l	kg/d			

ITEM V-B CONTINUED FROM FRONT

1. POLLUTANT AND CAS NO. (if available)	2. MARK 'X'		3. EFFLUENT						4. UNITS		5. INTAKE (optional)			
	a. ANALYST	b. DATE	a. MAXIMUM DAILY VALUE		b. MAXIMUM 30 DAY VALUE (if available)		c. LONG TERM AVERAGE VALUE (if available)		d. NO. OF ANALYSES	e. CONCENTRATION	f. MASS	g. LONG TERM AVERAGE VALUE (if available)		h. NO. OF ANALYSES
			(1) CONCENTRATION	(2) MASS	(3) CONCENTRATION	(4) MASS	(5) CONCENTRATION	(6) MASS				(7) CONCENTRATION	(8) MASS	
g. Nitrogen, Total Organic (as N)		X	<1.0	<4.6					1	mg/l	kg/d			
h. Oil and Grease	X		<10	<46					1	mg/l	kg/d			
i. Phosphorus (as P), Total (7723 14 0)	X		0.02	93					1	mg/l	g/d			
j. Radioactivity														
(1) Alpha, Total		X	<1.47	<6.8					1	pCi/l	µCi/d			
(2) Beta, Total		X	2.5 ± 1.1	11.6 ± 5.1					1	pCi/l	µCi/d			
(3) Radium, Total		X	<0.45	<2.1					1	pCi/l	µCi/d			
(4) Radium 226, Total		X	0.18 ± 0.14	0.83 ± 0.65					1	pCi/l	µCi/d			
k. Sulfate (as SO ₄) (14801 29 8)	X		7	32.4					1	mg/l	kg/d			
l. Sulfide (as S)		X	<1	<4.6					1	mg/l	kg/d			
m. Sulfite (as SO ₃) (14265 45 3)	X		<2	<9.3					1	mg/l	kg/d			
n. Surfactants		X	<0.025	<0.12					1	mg/l	kg/d			
o. Aluminum, Total (7429 90 5)		X	<0.3	<1.4					1	mg/l	kg/d			
p. Barium, Total (7440 39 3)		X	<0.3	<1.4					1	mg/l	kg/d			
q. Bismuth, Total (7440 42 8)		X	0.11	0.51					1	mg/l	kg/d			
r. Cobalt, Total (7440 48 4)		X	<0.001	<4.6					1	mg/l	g/d			
s. Iron, Total (7439 89 6)	X		0.42	1.9					1	mg/l	kg/d			
t. Magnesium, Total (7439 95 4)	X		1.1	5.1					1	mg/l	kg/d			
u. Molybdenum, Total (7439 98 7)		X	<0.010	<46					1	mg/l	g/d			
v. Manganese, Total (7439 98 5)		X	0.045	0.21					1	mg/l	kg/d			
w. Tin, Total (7440 31 5)		X	<0.02	<93					1	mg/l	g/d			
x. Titanium, Total (7440 32 6)		X	<0.02	<93					1	mg/l	g/d			

EPA I.D. NUMBER (copy from Item 1 of Form 1)	OUTFALL NUMBER
SC1890008989	K-8

CONTINUED FROM PAGE 3 OF FORM 2-C

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PART C - If you are a primary industry and this outfall contains process wastewater, refer to Table 2c-2 in the instructions to determine which of the GC/MS fractions you must test for. Mark "X" in column 2-a for all such GC/MS fractions that apply to your industry and for ALL toxic metals, cyanides, and total phenols. If you are not required to mark column 2-a (secondary industries, non-process wastewater outfalls, and non-required GC/MS fractions), mark "X" in column 2-b for each pollutant you know or have reason to believe is present. Mark "X" in column 2-c for each pollutant you believe to be absent. If you mark either columns 2-a or 2-b for any pollutant, you must provide the results of at least one analysis for that pollutant. Note that there are seven pages to this part; please review each carefully. Complete one table (all seven pages) for each outfall. See instructions for additional details and requirements.

1. POLLUTANT AND CAS NUMBER (if available)	2. MARK 'X'			3. EFFLUENT						4. UNITS		5. INTAKE (optional)			
	A. TEST METHOD	B. SP. ANAL. UNIT	C. SP. ANAL. UNIT	D. MAXIMUM DAILY VALUE		E. MAXIMUM 30 DAY VALUE (if available)		F. LONG TERM AVG. VALUE (if available)		G. NO. OF ANAL. YRS	H. CONCENTRATION	I. MASS	J. LONG TERM AVERAGE VALUE		K. NO. OF ANAL. YRS
				(1) CONCENTRATION	(2) MASS	(1) CONCENTRATION	(2) MASS	(1) CONCENTRATION	(2) MASS				(1) CONCENTRATION	(2) MASS	
METALS, CYANIDE, AND TOTAL PHENOLS															
1M. Antimony, Total (7440-36-0)			X	<0.003	<14					1	mg/l	g/d			
2M. Arsenic, Total (7440-38-2)			X	<0.001	<4.6					1	mg/l	g/d			
3M. Beryllium, Total (7440-41-7)			X	0.012	56					1	mg/l	g/d			
4M. Cadmium, Total (7440-43-9)			X	<0.003	<14					1	mg/l	g/d			
5M. Chromium, Total (7440-47-3)			X	0.010	46					1	mg/l	g/d			
6M. Copper, Total (7550-50-8)			X	0.013	60					1	mg/l	g/d			
7M. Lead, Total (7439-97-6)			X	0.001	4.6					1	mg/l	g/d			
8M. Mercury, Total (7439-97-6)			X	<0.0002	<0.93					1	mg/l	g/d			
9M. Nickel, Total (7440-02-0)			X	0.007	32					1	mg/l	g/d			
10M. Selenium, Total (7782-49-2)			X	<0.002	<9.3					1	mg/l	g/d			
11M. Silver, Total (7440-22-4)			X	<0.0003	<1.4					1	mg/l	g/d			
12M. Thallium, Total (7440-28-0)			X	<0.003	<14					1	mg/l	g/d			
13M. Zinc, Total (7440-66-6)		X		0.010	46					1	mg/l	g/d			
14M. Cyanide, Total (57-12-5)			X	<0.02	<93					1	mg/l	g/d			
15M. Phenols, Total			X	<0.002	<9.3					1	mg/l	g/d			
DIOXIN															
2,3,7,8-Tetrachlorodibenzo-P-Dioxin (1764-01-6)			X	DESCRIBE RESULTS No peak detected on the GC-MS scan.											

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CONTINUED FROM THE FRONT																
1. POLLUTANT AND CAS NUMBER (if available)	2. MEDIA "X"			3. EFFLUENT						4. UNITS		5. INTAKE (optional)				
	A. TYPE OF MEDIA AD	B. NO. OF SAMPLES SENT	C. NO. OF ANALYSES SENT	6. MAXIMUM DAILY VALUE		D. MAXIMUM 30 DAY VALUE (if available)		E. LONG TERM AVG. VALUE (if available)		F. NO. OF ANALYSES	G. CONCENTRATION	H. MASS	I. LONG TERM AVERAGE VALUE		J. NO. OF ANALYSES	
				(1) CONCENTRATION	(2) MASS	(1) CONCENTRATION	(2) MASS	(1) CONCENTRATION	(2) MASS				(1) CONCENTRATION	(2) MASS		
GC/MS FRACTION - VOLATILE COMPOUNDS																
1V. Acrolein (107-02-8)			X	ND						1						
2V. Acrylonitrile (107-13-1)			X	ND						1						
3V. Benzene (71-43-2)			X	<1 ^a	<4.6					1	µg/l	g/d				
4V. Bis (Chloromethyl) Ether (542-88-1)			X	ND						1						
5V. Bromoform (75-26-2)			X	ND						1						
6V. Carbon Tetrachloride (56-23-5)			X	ND						1						
7V. Chlorobenzene (108-90-7)			X	ND						1						
8V. Chlorodibromomethane (124-48-1)			X	ND						1						
9V. Chloroethane (75-00-3)			X	ND						1						
10V. 2-Chloroethylvinyl Ether (110-76-8)			X	ND						1						
11V. Chloroform (67-66-3)			X	ND						1						
12V. Dichlorobromomethane (75-27-4)			X	ND						1						
13V. Dichlorodifluoromethane (75-71-8)			X	ND						1						
14V. 1,1-Dichloroethane (75-34-3)			X	ND						1						
15V. 1,2-Dichloroethane (107-06-2)			X	ND						1						
16V. 1,1-Dichloroethylene (75-35-4)			X	ND						1						
17V. 1,2-Dichloropropane (78-87-5)			X	ND						1						
18V. 1,2-Dichloropropylene (542-75-6)			X	ND						1						
19V. Ethylbenzene (100-41-4)			X	ND						1						
20V. Methyl Bromide (74-83-9)			X	ND						1						
21V. Methyl Chloride (74-87-3)			X	ND						1						

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 EPA I.D. NUMBER (copy from Item 1 of Form 1) SC1890008989
 OUTFALL NUMBER K-8

Form Approved OMB No. 158-R0173

1. POLLUTANT AND CAS NUMBER (if available)	2. MARK "X"			3. EFFLUENT								4. UNITS		5. INTAKE (optional)		
	A. ANAL. BY GC/MS	B. ANAL. BY HPLC	C. ANAL. BY OTHER	A. MAXIMUM DAILY VALUE		B. MAXIMUM 30 DAY VALUE (if available)		C. LONG TERM AVERAGE VALUE (if available)		D. NO. OF ANAL. YRS	a. CONCEN- TRATION	b. MASS	a. LONG TERM AVERAGE VALUE		b. NO. OF ANAL. YRS	
				(i) CONCENTRATION	(ii) MASS	(i) CONCENTRATION	(ii) MASS	(i) CONCENTRATION	(ii) MASS				(i) CONCENTRATION	(ii) MASS		
GC/MS FRACTION - VOLATILE COMPOUNDS (continued)																
22V. Methylene Chloride (75-09-2)			X	<1 ^a	<4.6					1	µg/l	g/d				
23V. 1,1,2,2-Tetra- chloroethane (79-34-6)			X	ND						1						
24V. Tetrachloro- ethylene (127-18-4)			X	2	9.3					1	µg/l	g/d				
25V. Toluene (108-88-3)			X	1 ^a	4.6					1	µg/l	g/d				
26V. 1,2-Trans- Dichloroethylene (156-60-5)			X	ND						1						
27V. 1,1,1-Trichloroethane (71-65-0)			X	ND						1						
28V. 1,1,2-Trichloroethane (79-00-5)			X	ND						1						
29V. Trichloro- ethylene (79-01-6)			X	ND						1						
30V. Trichloro- fluoromethane (75-69-4)			X	ND						1						
31V. Vinyl Chloride (75-01-4)			X	ND						1						
GC/MS FRACTION - ACID COMPOUNDS																
1A. 2-Chloropheno (98-57-8)			X	ND						1						
2A. 2,4-Dichloro phenol (120-83-2)			X	ND						1						
3A. 2,4-Dimethyl- phenol (105-67-9)			X	ND						1						
4A. 4,6-Dinitro-O- Cresol (534-52-1)			X	ND						1						
5A. 2,4-Dinitro- phenol (51-28-6)			X	ND						1						
6A. 2-Nitrophenol (88-75-6)			X	ND						1						
7A. 4-Nitrophenol (100-02-7)			X	ND						1						
8A. P-Chloro-M- Cresol (59-50-7)			X	ND						1						
9A. Pentachloro- phenol (87-86-5)			X	ND						1						
10A. Phenol (108-95-2)			X	ND						1						
11A. 2,4,6-Trichlorophenol (88-06-2)			X	ND						1						

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ND = Not detected

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CONTINUE ON REVERSE

CONTINUED FROM THE FRONT

1. POLLUTANT AND CAS NUMBER (if available)	2. MARK "X"			3. EFFLUENT								4. UNITS		5. INTAKE (optional)		
	A. TEST DATE (if available)	B. OCCASIONAL ANALYSIS	C. CONTINUOUS ANALYSIS	a. MAXIMUM DAILY VALUE		b. MAXIMUM 30 DAY VALUE (if available)		c. LONG TERM AVERAGE VALUE (if available)		d. NO. OF ANALYSES	e. CONCENTRATION	f. MASS	g. LONG TERM AVERAGE VALUE		h. NO. OF ANALYSES	
				(i) CONCENTRATION	(ii) MASS	(i) CONCENTRATION	(ii) MASS	(i) CONCENTRATION	(ii) MASS				(i) CONCENTRATION	(ii) MASS		
GC/MS FRACTION - BASE/NEUTRAL COMPOUNDS																
18. Acenaphthene (83-32-9)			X	ND						1						
28. Acenaphthylene (208-98-8)			X	ND						1						
38. Anthracene (120-12-7)			X	ND						1						
48. Benzidine (92-87-6)			X	ND						1						
58. Benzo (a) Anthracene (56-55-3)			X	ND						1						
68. Benzo (a) Pyrene (50-32-8)			X	ND						1						
78. 3,4-Benzo-fluoranthene (205-99-2)			X	ND						1						
88. Benzo (ghi) Perylene (191-24-2)			X	ND						1						
98. Benzo (h) Fluoranthene (207-08-9)			X	ND						1						
108. Bis (2-Chloro-ethoxy) Methane (111-91-1)			X	ND						1						
118. Bis (2-Chloro-ethyl) Ether (111-44-8)			X	ND						1						
128. Bis (2-Chloro-isopropyl) Ether (39838-32-9)			X	ND						1						
138. Bis (2-Ethyl-hexyl) Phthalate (117-81-7)			X	ND						1						
148. 4-Bromo-phenyl Phenyl Ether (101-65-3)			X	ND						1						
158. Butyl Benzyl Phthalate (86-68-7)			X	ND						1						
168. 2-Chloro-naphthalene (91-58-7)			X	ND						1						
178. 4-Chloro-phenyl Phenyl Ether (7005-72-3)			X	ND						1						
188. Chrysene (218-01-9)			X	ND						1						
198. Dibenzo (a,h) Anthracene (53-70-3)			X	ND						1						
208. 1,2-Dichloro-benzene (95-50-1)			X	ND						1						
218. 1,3-Dichloro-benzene (641-73-1)			X	ND						1						

EPA Form 3510-2C (6-80)

ND = Not detected

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EPA I.D. NUMBER (copy from Item 1 of Form 1) SC1890008989

OUTFALL NUMBER K-8

Form Approved OMB No. 150-R0173

1. POLLUTANT AND CAS NUMBER (if available)	2. ANALYSIS				3. EFFLUENT				4. CONC. OF ANAL. YES	4. UNITS		5. INTAKE (optional)				6. NO. OF ANAL. YES		
	111.111 RI QUIN LO	111.111 RI QUIN LO	111.111 RI QUIN LO	111.111 RI QUIN LO	A. MAXIMUM DAILY VALUE		B. MAXIMUM 30 DAY VALUE (if available)			C. LONG TERM AVERAGE VALUE (if available)		A. CONC. THATION	B. MASS	3. LONG TERM AVERAGE VALUE			B. CONC. THATION	B. MASS
					(1)	(2) MASS	(1)	(2) MASS		(1)	(2) MASS			(1) CONC. THATION	(2) MASS			
GC/MS FRACTION - BASE/NEUTRAL COMPOUNDS (continued)																		
220. 1,1-Dichlorobenzene (106-46-7)				X	ND													
230. 1,3-Dichlorobenzene (91-94-1)				X	ND													
240. Diethyl Phthalate (84-66-2)				X	ND													
250. Dimethyl Phthalate (131-11-3)				X	ND													
260. Di-N-Butyl Phthalate (84-74-2)				X	ND													
270. 2,4-Dinitrotoluene (121-14-2)				X	ND													
280. 2,6-Dinitrotoluene (606-20-2)				X	ND													
290. Di-N-Octyl Phthalate (117-84-0)				X	ND													
300. 1,2-Diphenylhydrazine (or Azobenzene) (122-66-7)				X	ND													
310. Fluoranthene (206-44-0)				X	ND													
320. Fluorene (86-73-7)				X	ND													
330. Hexachlorobenzene (118-71-1)				X	ND													
340. Hexachlorobutadiene (87-68-3)				X	ND													
350. Hexachlorocyclopentadiene (77-47-4)				X	ND													
360. Hexachloroethane (67-72-1)				X	ND													
370. Indeno (1,2,3-cd) Pyrene (193-39-5)				X	ND													
380. Isophorone (78-59-1)				X	ND													
390. Naphthalene (91-20-3)				X	ND													
400. Nitrobenzene (98-95-3)				X	ND													
410. N-Nitrosodimethylamine (62-75-9)				X	ND													
420. N-Nitrosodimethylpropylamine (621-64-7)				X	ND													

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ND = Not detected

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CONTINUE ON REVERSE

CONTINUED FROM THE FRONT

CONTINUED FROM THE FRONT															
1. POLLUTANT AND CAS NUMBER (if available)	2. MARK 'X'			3. EFFLUENT						4. UNITS		5. INTAKE (optional)			
	a. USE INC. RE. QUIN. A.U.	b. NO. OF ANAL. YES	c. NO. OF ANAL. YES	a. MAXIMUM DAILY VALUE		b. MAXIMUM 30 DAY VALUE (if available)		c. LONG TERM AVG. VALUE (if available)		d. NO. OF ANAL. YES	a. CONCENTRATION	b. MASS	a. LONG TERM AVERAGE VALUE		b. NO. OF ANAL. YES
				(1) CONCENTRATION	(2) MASS	(1) CONCENTRATION	(2) MASS	(1) CONCENTRATION	(2) MASS				(1) CONCENTRATION	(2) MASS	
GC/MS FRACTION – BASE/NEUTRAL COMPOUNDS (continued)															
43B. N-Nitro-toluenylamine (86-30-6)			X	ND						1					
44B. Phenanthrene (85-01-8)			X	ND						1					
45B. Pyrene (129-00-0)			X	ND						1					
46D. 1,2,4-Tri-chlorobenzene (120-82-1)			X	ND						1					
GC/MS FRACTION – PESTICIDES															
1P. Aldrin (309-00-2)			X	ND						1					
2P. α -BHC (319-84-6)			X	0.018	83					1	$\mu\text{g}/\text{l}$	mg/d			
3P. β -BHC (319-85-7)			X	ND						1					
4P. γ -BHC (58-89-9)			X	0.011	51					1	$\mu\text{g}/\text{l}$	mg/d			
5P. δ -BHC (319-86-8)			X	ND						1					
6P. Chlordane (57-74-9)			X	ND						1					
7P. 4,4'-DDT (50-29-3)			X	ND						1					
8P. 4,4'-DDE (72-55-9)			X	ND						1					
9P. 4,4'-DDD (72-64-8)			X	ND						1					
10P. Dieldrin (60-57-1)			X	ND						1					
11P. α -Endosulfan (115-29-7)			X	ND						1					
12P. β -Endosulfan (115-29-7)			X	ND						1					
13P. Endosulfan Sulfate (1031-07-8)			X	ND						1					
14P. Endrin (72-20-8)			X	ND						1					
15P. Endrin Aldehyde (7421-93-4)			X	ND						1					
16P. Heptachlor (76-44-8)			X	0.007	32					1	$\mu\text{g}/\text{l}$	mg/d			

CONTINUED FROM PAGE V-8

 EPA I.D. NUMBER (copy from Item 1 of Form 1)
 SC1890008989
OUTFALL NUMBER
K-8

Form Approved OMB No. 158-R0173

1. POLLUTANT AND CAS NUMBER (if available)	2. MARK 'X'			3. EFFLUENT						4. UNITS		5. INTAKE (optional)				
	A. ANAL. METHOD (if available)	B. PREP. METHOD (if available)	C. PREP. METHOD (if available)	a. MAXIMUM DAILY VALUE		b. MAXIMUM 30 DAY VALUE (if available)		c. LONG TERM AVERAGE VALUE (if available)		d. NO. OF ANAL. YRS.	a. CONCENTRATION	b. MASS	e. LONG TERM AVERAGE VALUE		f. NO. OF ANAL. YRS.	
				(1) CONCENTRATION	(2) MASS	(1) CONCENTRATION	(2) MASS	(1) CONCENTRATION	(2) MASS				(1) CONCENTRATION	(2) MASS		
GC/MS FRACTION - PESTICIDES (continued)																
17P. Heptachlor Epoxide (1024-57-3)			X	ND							1					
18P. PCB-1242 (53469-21-9)			X	ND							1					
18P. PCB-1254 (11097-69-1)			X	ND							1					
20P. PCB-1221 (11104-28-2)			X	ND							1					
21P. PCB-1232 (11141-15-5)			X	ND							1					
22P. PCB-1248 (12672-29-6)			X	ND							1					
23P. PCB-1260 (11098-82-5)			X	ND							1					
24P. PCB-1018 (12674-11-2)			X	ND							1					
25P. Toxaphene (8001-35-2)			X	ND							1					

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ND = Not detected

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Section V Notes:

- a) Also present in Laboratory blank.
 b) Samples collected 28-29 October 1980.

Distribution

Copy
No.

1. F. H. Allhoff, DOE-SR	48. J. P. Church
2. E. S. Goldberg	49. J. E. McAllister
3. M. J. Sires	50. J. B. Price
4-13. J. M. Gaver	51. J. R. Taylor
14. G. A. Smithwick	52. J. C. Corey
15. R. E. Erickson	53. D. W. Hayes
16. J. C. Tseng	54. R. A. Matthews
17-27. W. E. Wisenbaker	55. R. E. Cooper
	56. T. V. Crawford
28-32. F. E. Kruesi, Wilm.	57-62. H. E. Mackey
33. J. E. Conaway	63. E. J. Christensen
	64. E. K. Dukes
34. J. T. Granaghan-T. Hendrick, SRP	65. W. L. Marter
35. J. W. Joseph, 704-L	66. R. A. Moyer
36. D. R. Muhlbaier, 704-L	67. W. L. Pillinger
37. H. E. Landrum, 704-L	68. J. T. Prendergast, Jr.
38. J. L. Womack, 703-A	69. O. A. Towler
39. L. H. Meyer, 703-A	70. D. Chavis
40. E. B. Sheldon, 703-A	71-87. TIS
41. W. C. Reinig, 703-A	88. Record Copy
42. S. Mirshak, SRL	89-98. NUS - B. Marcy
43. J. R. Hilley	Savannah River Center
44. J. R. Crandall	NUS Corporation
45. J. D. Spencer	37 Varden Drive
46. D. A. Ward	Aiken, SC 29801
47. H. P. Olson	
	99-100. TIC